IMPACT OF TRAFFIC INCIDENT DURATION AND ROAD CHARACTERISTICS ON TRAFFIC FLOW PERFORMANCE

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Abstract

Non-recurrent events that occur in any part of the highway such as accident, vehicle breakdown, fire, scattering of substances like load, fuel oil etc. on the road which disrupt the traffic flow are defined as traffic incidents. Traffic Incident Management is the planned and coordinated utilization of all human and institutional resources in order to reduce the negative effects of these incidents and to ensure the safety of the drivers, pedestrians, all other victims and response teams. Incidents generally causes congestion and yields in increased travel time which imposes costs to road users, either economic loss or reduced quality of life and mobility. This thesis presents the recent literature review on the traffic incident management theory and practice along with the traffic incident simulation models.

The thesis study is comprised of two parts; a data collection and analysis and a simulation experiment phase. Firstly, Traffic incident data from Istanbul Metropolitan Area is collected and analyzed. Secondly, a microscopic traffic simulation model was developed to simulate different types of incidents and traffic demand and also various geometric characteristics of highway. The analyses are performed taking total travel time, queue length and the speed as performance measures. Lastly, to evaluate and compare the performance of the cases, statistical tests are applied.

The results show that there is a linear relationship between the incident duration and the average flow speed. The increase in incident duration causes the decrease in average speed up to 11.8% for overall traffic flow and up to 29.6% for the traffic flow of the post-incident process. The longest average queue length is observed in incidents in the middle lane. The shortest average queue length is observed in incidents in the right lane. In incidents in the middle lane, queue length increases up to 34.6% compared to the incidents in the right lane for overall traffic flow. In cases where the number of vehicles per lane is the same, the increase in the number of lanes causes a decrease in average speed up to 6.4% for the traffic flow of the post-incident process. According to the results of the applied statistical tests, when overall simulation periods are analyzed, statistically different results are seen only in incident duration, vehicle input, and lane width changes. When post-incident processes are analyzed, statistically different results are seen only in incident duration and lane width changes.

The results of this thesis could be used by the traffic control authorities to reduce incident duration, congestion, secondary incidents, and the associated human and economic losses.

Keywords: Traffic Incident Management, Traffic Simulation Modeling, VISSIM

TRAFİK OLAY SÜRESİ VE YOL ÖZELLİKLERİNİN TRAFİK AKIM PERFORMANSINA ETKİSİ

Özet

Karayolunun herhangi bir kesiminde meydana gelen kaza, araç arızası, yangın, yük, akaryakıt vb. maddelerin yola saçılması gibi trafik akımını bozan tekrarsız durumlar trafik olayları olarak tanımlanır. Trafik Olay Yönetimi, bu olayların olumsuz etkilerini azaltmak; sürücülerin, yayaların, diğer tüm mağdurların ve müdahale ekiplerinin can güvenliğini sağlamak için insani ve kurumsal bütün kaynakların planlı ve koordineli bir biçimde kullanılmasıdır. Olaylar genellikle yol kullanıcılarına, ekonomik kayıp veya düşük yaşam kalitesi ve hareket kabiliyeti gibi maliyetler getiren seyahat süresinde artışa neden olan tıkanıklığa sebep olurlar. Bu tez, trafik olayı simülasyon modelleri ile birlikte trafik olay yönetimi teorisi ve uygulaması hakkındaki güncel literatür incelemesini sunmaktadır.

Tez çalışması; veri toplama ve analizi ile simülasyon deney aşaması olmak üzere iki bölümden oluşmaktadır. İlk olarak, İstanbul Büyükşehir Belediyesi sınırları içinden trafik olayı verileri toplanmış ve analiz edilmiştir. İkinci olarak, farklı olay türlerini ve trafik talebini ve ayrıca karayolunun çeşitli geometrik özelliklerini simüle etmek için mikroskobik bir trafik simülasyon modeli geliştirilmiştir. Analizler performans ölçütü olarak toplam seyahat süresi, kuyruk uzunluğu ve hız dikkate alınarak yapılmıştır. Son olarak, bu durumların performansını değerlendirmek ve karşılaştırmak için istatistiksel testler uygulanmıştır.

Tez sonuçları göstermektedir ki olay süresi ile ortalama akım hızı arasında lineer bir ilişki vardır. Olay süresindeki artış ortalama hızda genel trafik akımı için %11.8'e varan, olay sonrası sürecin trafik akımı içinse %29.6'ya varan azalmaya sebep olmaktadır. En uzun ortalama kuyruk boyu orta şeritte meydana gelen olaylarda gözlemlenmektedir. En kısa ortalama kuyruk boyu sağ şeritte meydana gelen olaylarda gözlemlenmektedir. Genel trafik akımı için orta şeritte meydana gelen olaylarda sağ şeritte meydana gelen olaylara kıyasla kuyruk boyu %34.6'ya kadar artmaktadır. Şerit başına düşen araç sayısının aynı olduğu durumlarda, şerit sayısındaki artış, olay sonrası sürecin trafik akımı için ortalama hızda

%6.4'e varan bir azalmaya neden olmaktadır. Uygulanan istatistiksel testlerin sonuçlarına göre, genel simülasyon periyotları incelendiğinde, istatistiksel olarak farklı sonuçlar sadece olay süresi, araç girdisi ve şerit genişliği değişikliklerinde görülmüştür. Kaza sonrası süreçler incelendiğinde ise, sadece olay süresi ve şerit genişliği değişimlerinde istatistiksel olarak farklı sonuçlar görülmüştür.

Bu tezin sonuçları trafik kontrol yetkilileri tarafından olay süresini, tıkanıklığı, ikincil olayları ve ilgili insani ve ekonomik kayıpları azaltmak için kullanılabilir.

Anahtar kelimeler: Trafik Olay Yönetimi, Trafik Simülasyonu Modellemesi, VISSIM

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*To my mom Firdevs whose prayers are always with me,
to my dad Bekir who is my first teacher and
commander, and to my lovely sister Semina...*

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List of Abbreviations

AIMSUN	**A**dvanced **I**nteractive **M**icroscopic **S**imulator for **U**rban and **N**on-Urban **N**etworks
CEDR	**C**onference of **E**uropean **D**irectors of **R**oad
CORSIM	**COR**ridor **SIM**ulation
DSS	**D**ecision **S**upport **S**ystem
EENA	**E**uropean **E**mergency **N**umber **A**ssociation
EU	**E**uropean **U**nion
EXP	**E**xperiment
FHWA	**F**ederal **H**ighways **A**dministration
GIF	**G**raphics **I**nterchange **F**ormat
GIS	**G**eographic **I**nformation **S**ystems
HCM	**H**ighway **C**apacity **M**anual
HeERO	**H**armonised **e**Call **E**uropean **P**ilot
HGV	**H**eavy **G**oods **V**ehicle
INC. DUR.	**I**ncident **D**uration
INC. POS.	**I**ncident **P**osition
INP.	**I**nput
ISO	**I**nternational **O**rganization for **S**tandardization
ITS	**I**ntelligent **T**ransportation **S**ystems
İBB	**İ**stanbul **M**etropolitan **M**unicipality
JEMUS	**G**endarmerie **I**ntegrated **C**ommunication and **I**nformation **S**ystem
LW	**L**ane **W**idth

M	**M**eter
MIN	**M**inute
N.	**N**umber
NRA	**N**ational **R**oad **A**dministration
NTIMC	**N**ational **T**raffic **I**ncident **M**anagement **C**oalition
NUG	**N**ational **U**nified **G**oal
QLEN	**Q**ueue **L**ength
SPEEDAVGHARM(ALL)	**H**armonic **A**verage of **S**peed
STEMS	**S**mart **T**raffic **E**vacuation **M**anagement **S**ystem
SVR	**S**upport **V**ector **R**egression
TIM	**T**raffic **I**ncident **M**anagement
TIMH	**T**raffic **I**ncident **M**anagement **H**andbook
TRAVTM(ALL)	**T**ravel **T**ime
UK	**U**nited **K**ingdom
USA	**U**nited **S**tates of **A**merica
VEH	**V**ehicle
VEHS(ALL)	**N**umber of **V**ehicle
VISSIM	**V**erkehr **I**n **S**tädten - **SIM**ulationsmodell
WTH.	**W**idth
WZTMP	**W**ork **Z**one **T**raffic **M**anagement **P**lan

Chapter 1

Introduction

Traffic incidents are non-recurrent events that includes accidents, vehicle breakdowns and fires, roadway maintenance and construction, and special events that significantly affect roadway operations. They can cause a significant capacity reduction of roadways. Traffic incidents have been defined as a significant cause of increased congestion. In the USA, The National Traffic Incident Management Coalition (NTIMC) presumes that traffic incidents are the reason of approximately 25% of the congestion on US roadways, and that for every minute a freeway lane is blocked due to an incident, this causes in 4 minutes of travel delay time [1]. Traffic incident management (TIM) aims to offer the rapid recovery of traffic safety and capacity, and leads to many measurable benefits, such as decreases in fuel consumption, incident duration, secondary accidents, and traffic jams. Traffic incidents have also negative effect on people's social life and traffic system. According to World Health Organization traffic incidents (excluding roadway maintenance and construction) kill more than 1.35 million people each year around the world [2]. The situation is not different than the world in Turkey. Averagely 18 people deaths occur in 1 day by reason of traffic incidents in Turkey [3]. Many studies have been made for prediction and reducing the incident duration time. A general incident timeline is shown in Figure (1.1).

Many simulation models are also proposed to model queue formation due to traffic incidents. Wright et al. propose an incident-based jam growth model [5]. Roberg

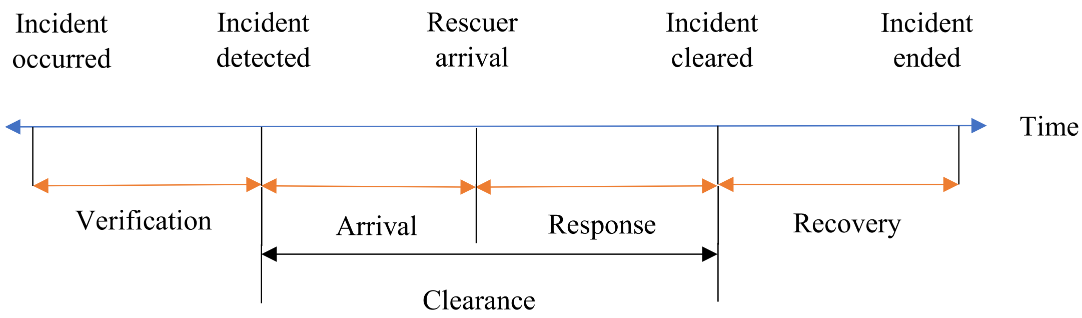

Figure 1.1: General incident timeline [4].

et al. develop several alternative strategies in to prevent gridlock of a network and dissipate traffic jams once they have been formed [6]. There are also many traditional traffic control methods for traffic incident management in highways, such as lane control, variable speed limit control, and ramp metering control and combination of these strategies. Barcelo et al. investigated the efficiency of traffic control strategies within the scope of incident management [7]. Ding and Gou simulated the effective highway capacity for traffic incident at different mainline traffic, road configuration and speed limits [8].

In TIM, it is vital to manage the incidents occurring in traffic effectively and accurately. At this point, the institutions responsible for the construction, maintenance and operation of the transportation network and other institutions such as emergency response teams and the police have great duties. Within the scope of incident management, in the extraction of cost-benefit analysis of the investments to be made by these institutions, it is of critical importance to determine the negative effects that will occur in the part of the incident affected area.

The purpose of this thesis study is to model the effects of traffic incidents via microscopic traffic simulation realistically, to determine the negative effects of traffic incidents on road operation performance indicators and to state their degree of effectiveness. In this thesis, the importance of incident management was evaluated by analyzing different scenarios. It is thought that the improvement of incident management will cause decrease in delay, fuel consumption and emissions of harmful gases, and increase in average speed. With the outcomes to be obtained as a result of the study, it is aimed for the institutions responsible for incident management to realize the economic benefits of TIM and to fulfill their responsibilities in the most efficient way.

Within the scope of these studies the traffic incident videos and the traffic flow parameters of the highway section from Istanbul, Turkey were analyzed to determine the queue formation. By using VISSIM, a microscopic traffic simulation model was developed to represent various types of lane closures and durations based on the queue formation model. Lastly, results of these simulations were discussed to understand the effects of these changes on TIM.

This thesis, which we are currently in Chapter 1, namely Introduction, consists of 5 chapters. In Chapter 2, namely Literature Review, Traffic Incident Characteristics are mentioned. In this context, information related to Traffic Incident Definition, Traffic Incident Classification and Traffic Incident Detection and Management is presented. Intelligent Transportation Systems Applications are touched on as a part of Traffic Incident Detection and Management. Then detailed information about International Management Systematics and National Management Systematics is presented. Finally, in the Traffic Incident Models section, the previous studies related to this issue are mentioned and these studies are presented in an additional table.

In Chapter 3, namely Incident Simulation Modeling Methodology, first the Incident Data Collection and Analysis process is explained. Afterwards, the Incident Simulation section is started. In this section, the types of traffic simulation models are briefly addressed under the heading Traffic Simulation Modeling. Under the heading of Incident Simulation Modeling, the features of the simulation software that we used, and what all the terms used in this software do are described in detail. Under the title of Scenarios, the design we made in the simulation software, our experimental setup table, the scenarios we applied, the parameters we considered when creating these scenarios, and which ones we analyzed after the simulation were mentioned.

In Chapter 4, namely Results and Discussion, firstly, performance evaluation criteria which we will use to evaluate these simulations that we dealt under the title of Analysis of Incident Scenarios before are mentioned. Secondly, we analyzed the simulation results of our scenario groups, which we determined according to the parameters we mentioned earlier, in a total of 135 simulations, with the help of some graphs, based on performance evaluation criteria. Thirdly, under the title of Detailed Analysis on Speed-Discharge Characteristics, for the same experimental groups, we focused on the changes of the speed in only incident period and immediately after incident period. We created some other graphs to see and comment discharge. Lastly, after plotting graphs, under the title of Statistical Tests, we applied some statistical tests for in depth analysis.

In Chapter 5, namely Conclusion and Further Studies, the results we have obtained are presented. The negative situations and deficiencies we encountered during the thesis studies are mentioned. Considering these, it is mentioned what can be done in further studies.

Chapter 2

Literature Review

2.1 Traffic Incident Characteristics

2.1.1 Traffic Incident Definition

The term traffic incident is expressed in the Traffic Incident Management Handbook (TIMH) as discontinuous situations that cause a decrease in road capacity or an abnormal increase in demand [9]. These incidents include traffic accidents, vehicle breakdowns, load spills, road repairs, reconstruction projects and so on. Similarly, in the Highway Capacity Manual (HCM), traffic incident is defined as occurrences such as accident, malfunction, and debris that decrease the highway capacity and lead to diversity in daily travel times along the highway [10]. Transport and emergency response agencies dealing directly or indirectly with traffic incidents have different definitions as to which situations will constitute the incident. The main reason for this is that transportation and emergency response agencies have different missions in many areas [11].

An incident is an occasional event. This event is determined by three factors. First, the features and the behavior of the road users affect the incident probability such as alcohol use or the age of the driver [12]. The second group of factors are the external factors, such as the road features or the weather conditions. Finally, the number of incidents depends on the number of road users. Incident

Management could be described as the process that covers the detection, verification, analysis, interference, and clearance of an incident. Incident Management could provide an increase in accident victims' survival ratio, decrease in delay time, improvement of duration of intervention, increase in air quality, decrease in secondary incidents and increase in the security of participants, accident victims, and other people. Incident Management could also provide qualitative benefits such as improvement of public perception about transactions which are done in institutions, decrease in drivers' disappointments, increase in the quality of life and increase in the coordination between intervention units.

The analysis of Shefer et al. proves that the number of incidents is increasing in the number of road users, but if congestion is extreme, the number of incidents will reduce and the seriousness of accidents is less [13]. One can imagine that in a gridlock situation there will be fewer incidents than when people are driving at higher speeds. Peirson et al. and Noland et al. investigate the relationship between incidents and traffic flow and find that the number of incidents is increasing in the number of road users [14, 15].

2.1.2 Traffic Incident Classification

It is very significant to reduce the effects of traffic incidents (accident, breakdown, etc.), to increase passenger safety and the efficiency of the transportation system. It is useful to examine the types of incidents to understand the ways to minimize the effects of incidents. In order to classify the incidents that occur on the highways, a compilation of the previous research results related to the subject was made by Cambridge Systematics in 1997 [16]. The classification shown in Figure (2.1) is taken from this report prepared by Cambridge Systematics and shows the distribution of incidents (excluding roadway maintenance and construction) occurring on highways according to the type, severity and duration of the incident. The majority of the incidents are due to vehicles that have failed in the emergency lane, and they have less impact on highway capacity than other incidents. The chart taken from the report prepared by Cambridge Systematics also shows the effects of different kinds of traffic events on mobility.

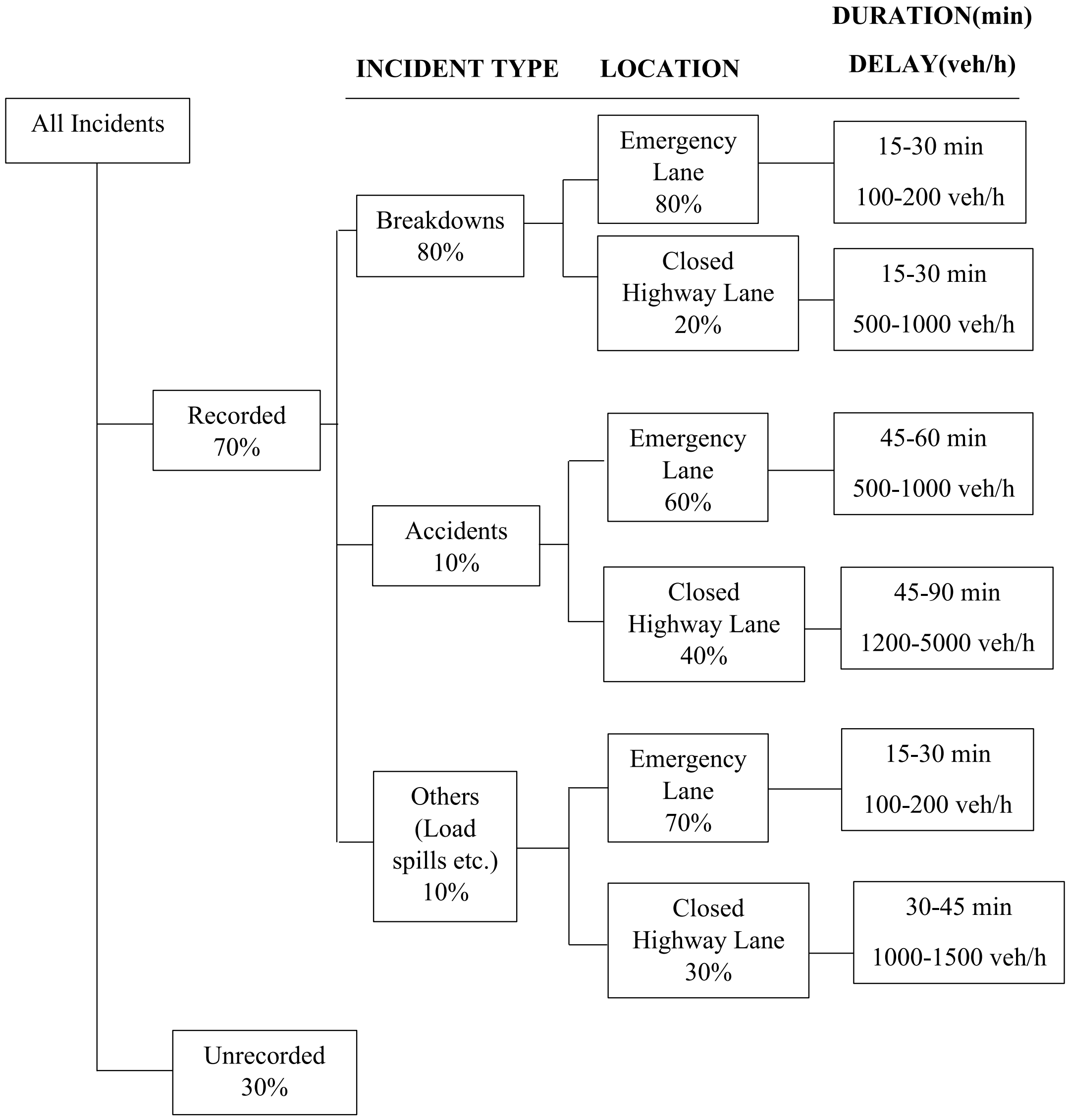

Figure 2.1: Incident Types and Their Effects [16].

2.1.3 Traffic Incident Detection and Management

Intelligent Transportation Systems Applications

Intelligent Transportation Systems (ITS) are described as the solutions for decrease in traffic congestion and highway transportation's negative effects on environment, and making roads safer by the help of various Technologies [17]. Information, communication, control, and perception technologies are used in ITS applications. The researches which were done on the purpose of increase in passenger protection, accident prevention, and minimization of injuries and deaths clearly indicate that ITS are promising systems [18]. Substructure of ITS is shown in Figure (2.2).

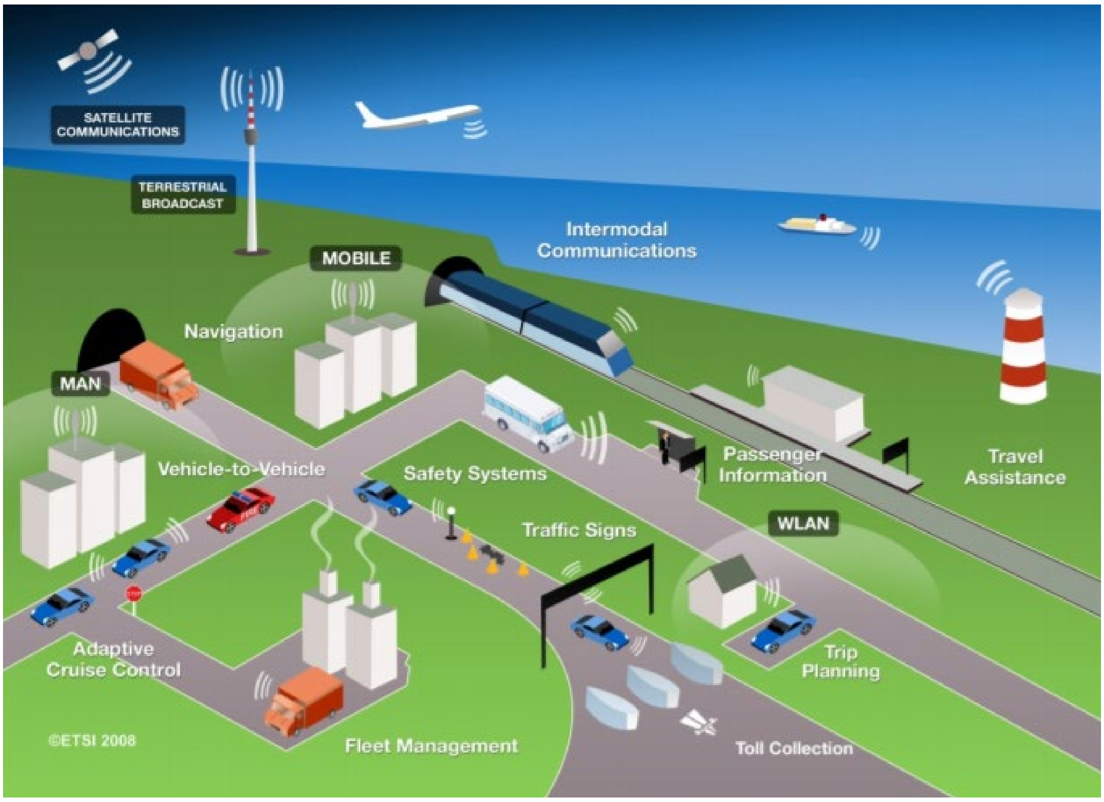

Figure 2.2: Substructure of ITS [19].

ITS applications need an architecture for having a strategic structure like all other complex systems. ITS architecture has a high level frame qualification for the actualization of projects which are made on the purpose of applications' integration. ITS architecture also contains technical information and legal issues. It is aimed to facilitate the integration process and to achieve desirable performance [20]. International Organization for Standardization (ISO) has identified an architecture which has the code ISO 14813. This architecture sets an example for other architectures [21]. ISO's ITS architecture reference model is shown in Figure (2.3).

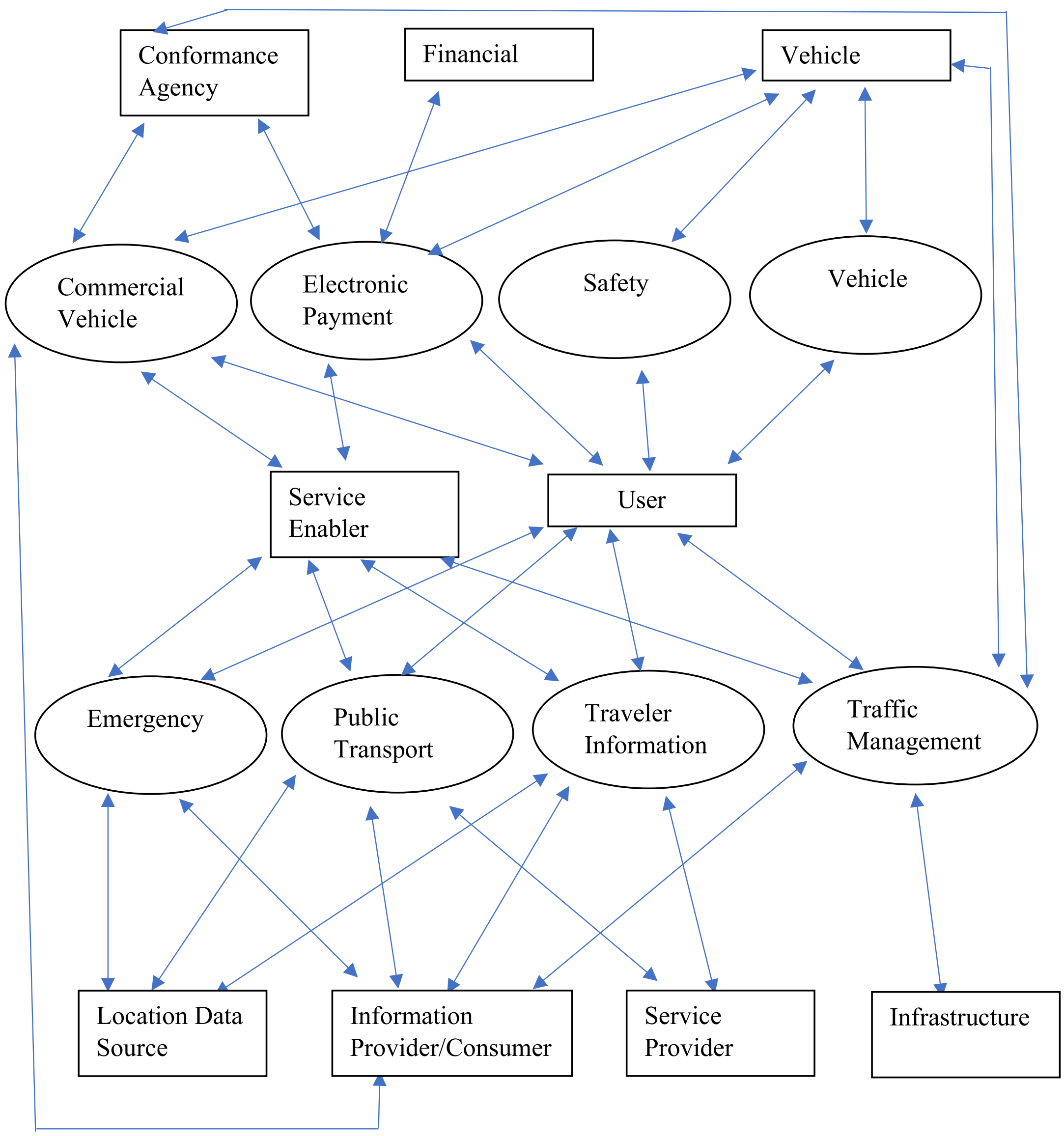

Figure 2.3: ISO's ITS architecture reference model [21].

Lots of developed countries around the world are carrying on studies about ITS architecture and the most known one is the USA's one. The USA's national ITS architecture scheme is shown in Figure (2.4). This architecture shows similarities with ISO's architecture on some issues such as data flow.

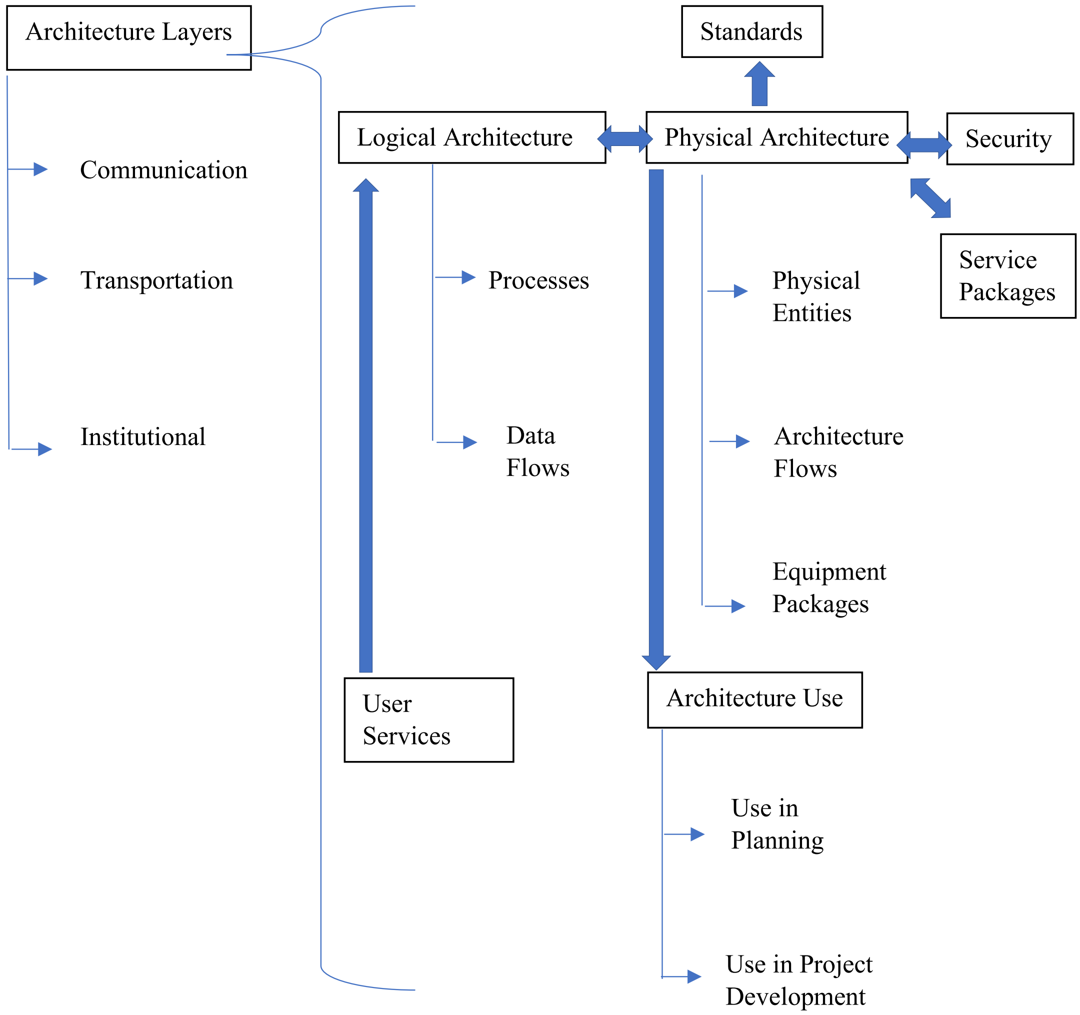

Figure 2.4: The USA's national ITS architecture scheme [20].

Turkey where serious progresses about transportation have been made is improving itself about ITS. There are some studies in Turkey for making intervention easier in an emergency situation especially traffic accident. Turkey has become a member of HeERO (Harmonised eCall European Pilot) project. This project enables the car to call emergency call center automatically in an accident [22]. There are also some observation cameras which relay information to traffic control center. These cameras may also be watched by the Disaster Coordination Center independently [23].

Traffic Information System (TIS) is a system which makes possible independents and stakeholder institutions' data to share with each other within limits and to use it for public welfare. TIS serves for inspection and control, and data collection and analysis.

Electronic Monitoring System and Sliding Message Boards are used in lots of countries for inspection and control purpose TIS. Red light violation accidents can be prevented by using Electronic Monitoring System. An example from Spain is shown in Figure (2.5).

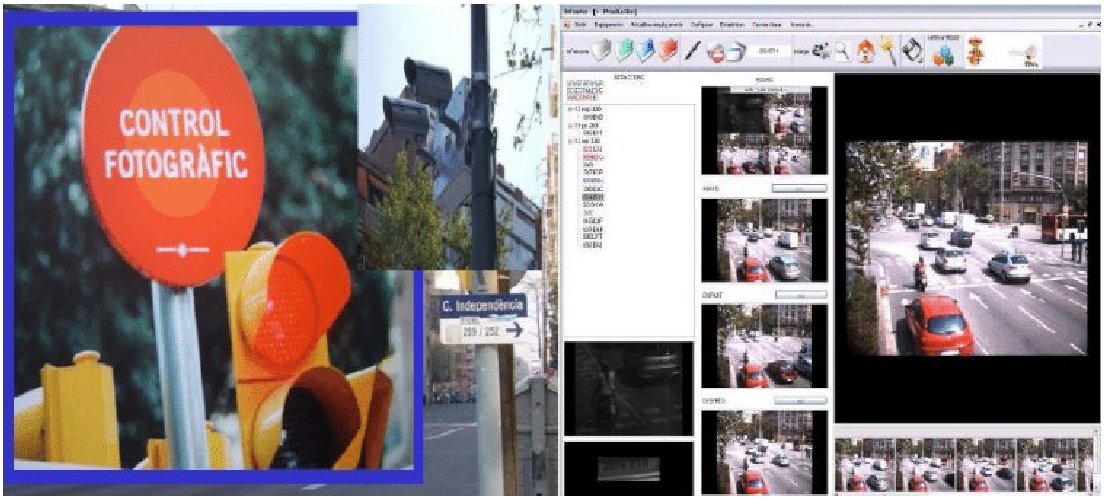

Figure 2.5: An example of an Electronic Monitoring System application from Spain [24].

Drivers are informed about traffic accident, traffic volume, weather and road conditions with Sliding Message Boards. Examples from Japan and the USA are shown in Figure (2.6).

Figure 2.6: Examples of Sliding Message Boards from Japan and the USA [24].

Every country has its own system for data collection and analysis purpose Traffic Information System. Examples are shown in Table (2.1).

COUNTRY	**TRAFFIC INFORMATION SYSTEM**
Bangladesh	Micro-Computer Accident Analysis Package (MAAP)
Cambodia	Road Crash and Victim Information System (RCVIS)
Indonesia	Accident Data System
Japan	An integrated database by ITARDA
Malaysia	Computerized Accident Recording Systems (CARS) and MIROS Road Accident Analysis and Database System (M-ROADS)
Pakistan	Road Safety Wing (RSW)
Philippines	Traffic Recording and Analysis System (TRAS)
Singapore	Traffic Accident Analysis Module (TAAM) and National Database TPRTA
Germany	Electronic Accident Type Card (EUSka)
Netherlands	Road Crash Database
USA	Accident Location Information System (ALIS)

Table 2.1: Traffic Information Systems of some countries [25].

There are three groups in Turkey which are interested in inspection and control purpose Traffic Information System: General Directorate of Security Affairs – Traffic Services Department, General Directorate of Highways and municipalities [26]. General Directorate of Security Affairs' traffic patrols may use mobile query with using GPRS technology by their tablet computers rapidly. In this way, people minimize their time loss. Another inspection and control purpose Traffic Information System is Gendarmerie Integrated Communication and Information System project (JEMUS). Any information may be obtained in anytime, anywhere, and any format by JEMUS as shown in Figure (2.7) [24].

The most distinct data collection and analysis purpose TIS in Turkey is Istanbul Metropolitan Municipality's system. Intervention to technic problems in minimum time, pursuance of traffic signs, determination of deficiencies, updating numerical map data, collection of numbering information, and creation of urban

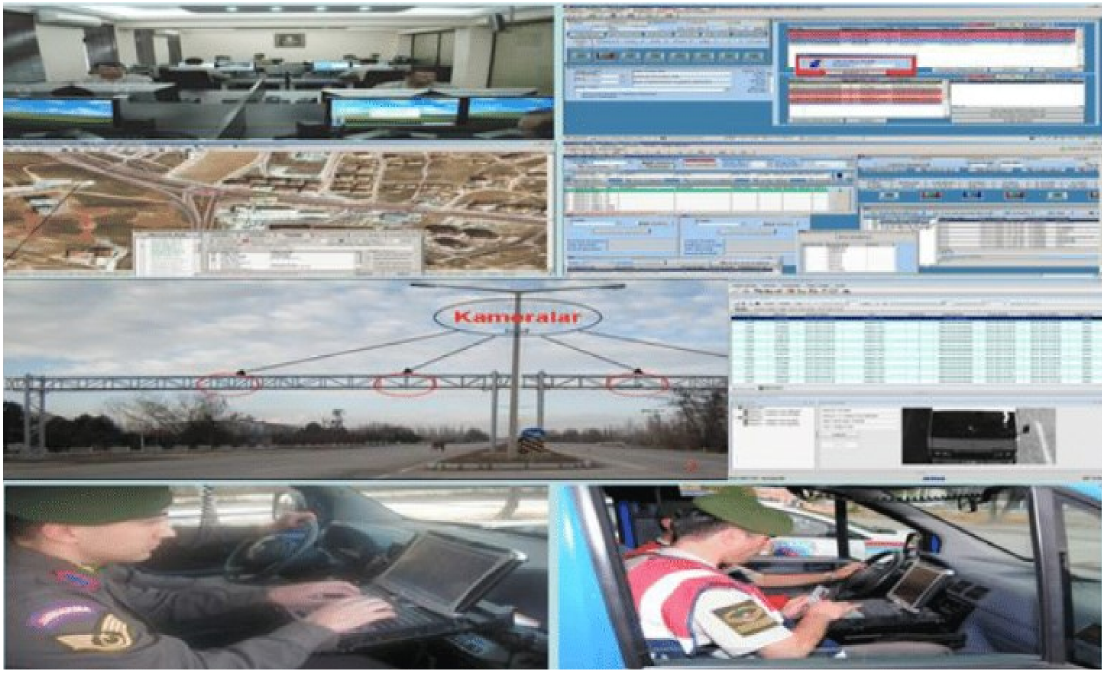

Figure 2.7: Applications of Gendarmerie Integrated Communication and Information System (JEMUS) project [24].

transportation information are executed by using Istanbul Metropolitan Municipality's system. Also Camera Traffic Analysis System, Image Processing, and Online Intersection Control System are available as shown in Figure (2.8). By using these applications money and time savings were carried out [27].

Figure 2.8: An example of Camera Traffic Analysis System [24].

2.1.3.1 International Management Systematics

Some countries' National Road Administrations (NRA) or representative organizations inside and outside Europe are shown in Table (2.2).

Country	**NRA or representative organization**
Austria	ASFiNAG
Belgium-Flanders	Agentschap Wegen en Verkeer
Denmark	Vejdirektoratet
England	English Highways Agency
Finland	FINNRA
Iceland	Vegagerdin
Italy	StradeANAS
The Netherlands	Rijkswaterstaat
Norway	Statens vegvesen
Slovenia	Slovenian Roads Agency (also in eCall)
Sweden	Trafikverket
Australia (State of Victoria)	VicRoads
Czech Republic	Road and Motorway Directorate
Estonia	Estonian Roads Administration
France	Ministère du Développement durable ...
Germany	BMVBS (Bundesministerium für Verkehr ...)
Latvia	Latvian Road Administration
Republic of Ireland	Road Safety Authority
Scotland	Transport Scotland
Switzerland	FEDRO

Table 2.2: Some countries' National Road Administrations (NRA) or representative organizations inside and outside Europe [28].

An NRA's area of responsibility is described by its institutional roles in government [28]. Jurisdiction and lines of coordination have to be determined where different government agencies are responsible for incident management. Conversely, technology (including ITS) has a tendency to overleap boundaries and generate new occasions for better working. For this reason, the rethinking of constitutional roles is substantially directed by technology. Roles can be divided into internal structures within NRAs, for instance between a policy division and traffic management centers, and between national and regional levels. An idea which works well in one country can not work in another country. So, this may be an obstacle to the transfer of specific elements of best practice between countries.

The police's first responsibility has a tendency to be for public safety and criminal investigation; quick clearance and the minimization of congestion tend to be reduced priorities [28]. Any adjustment of the role of the police can include critical negotiations due to their legal status. Relying on the web survey, NRAs from seven countries (Austria, Australia (Victoria State), Denmark, England, Netherlands, Norway, and Switzerland) either already have taken roles from the police, or stated that they would like to.

Some countries have specific organizational and procedural structures for dealing with major emergencies, for instance:

- In Austria, emergencies are treated at provincial level [28]. Though, important emergencies can be announced a national disaster by the district governor. A change in order structure is usually made during an emergency. Nonetheless it does not affect the roles of ASFINAG or its partners. Like with normal incidents, adequate cooperation and two-way communication are ensured with response forces such as police, fire department, rescue service.

- In Denmark, the police are responsible for constituting an emergency organization including the relevant institutions [28].

- Finland has specific procedures. Furthermore, follow-up workshops are organized after major emergencies to evaluate performance and determine any lessons learned [28].
- In Italy, COEM group which is based in National Coordination Center manages emergency situations [28].
- In Norway, if a major emergency takes place, the manager of the regional NRA office takes the decision to constitute an emergency organization with other responders to manage the incident [28]. Major emergency teams exist at all levels of NRA organization.
- The UK government's Cabinet Office publishes general guidelines on risks and preparedness, including ones for transport [29].
- The Netherlands has both specific procedures and management structures, Sweden has specific procedures but no specific command structure, and Latvia has neither specific procedures nor specific command structures.

TIM in the United States of America

Although many countries outside Europe have developed incident management applications, the USA draw attention for three reasons:

- the Federal Highways Administration (FHWA) has been very efficient in detailing and publishing best practice rules by uniting various partners [28];
- the FHWA consistently looks for data from different nations and has taken on 'SCAN' study tours of incident management and different practices in Europe [28];
- the federal states keep up a high level of self-sufficiency inside the bureaucratic structure, which implies that the FHWA works inside a system of governmentally received measures, general best practice counsel, and instances of state or other local practice [28].

For several years, the FHWA has worked with different associations to shape the National Traffic Incident Management Coalition (NTIMC) and build up a National Unified Goal (NUG) for TIM relying on three high level objectives [30]:

- responder safety
- safe rapid incident clearance
- prompt reliable and compatible communications

Roles and responsibilities

Responsibilities are characterized externally: explicitly by government, or implicitly assessing the established roles of other different responders, particularly the police. As shown in Figure (2.9), which is based on the CEDR TIM overview and consequent alterations, the police are more concerned with guiding incident management than any other responder across Europe.

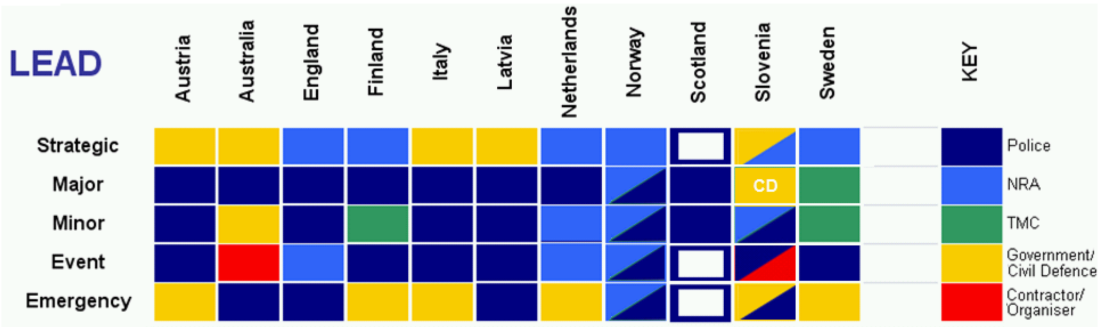

Figure 2.9: Established roles of different responders of some countries [28].

Roles and responsibilities in TIM mirror the remit and resources of the NRA, which are not decided exclusively by the NRA and are accordingly subject to legislative arrangement [28]. They additionally rely upon the level of TIM inclusion, for example the extent of the road network where TIM is conveyed.

Inside these requirements, the NRA will build up its general technique for incident management. This characterizes its general goals and the online and offline parts required to accomplish them. Plans in this context relate to on-line activities and could incorporate advancement and organization projects just as reaction plans to meet as many as possible of the TIM objectives.

Finally, the NRA will survey and test its arrangements to decide their adequacy in empowering the NRA to satisfy its role and meet its duties.

2.1.3.2 National Management Systematics

Public authorities related to incident management in Turkey are as follows [31]:

- Ministry of Transport and Infrastructure
  - General Directorate of Highways is responsible for surveillance, ITS, cleaning, road construction, and maintenance. Duties and authorities of the General Directorate of Highways are as follows:
    * To prepare data related to the causes of traffic incidents, and to take or to have related organizations take preventive technical measures
    * To take or to have related organizations take recommended necessary precautions by taking into consideration traffic incident analysis result determined by competent authorities or traffic police, causes of traffic incidents related to substructure, physical structure of the road, and road marking

    As of 01.01.2019, the length of the highway, which is under the responsibility of the General Directorate of Highways, is 67 333 km and consists of 3 classes of roads [32]:
    * Highway
    * State Road
    * Provincial Road

    General Directorate of Highways is an organization with a legal personality affiliated to the Ministry of Transport and Infrastructure. The plan, project, construction, maintenance and operation of highways, state and provincial roads are given to the General Directorate of Highways with the Law No. 6001. The roads that are not within the road network of the General Directorate of Highways but under the responsibility of other organizations are as follows:

  * Village Roads
  * Touristic Roads
  * Forest Roads
  * Urban Roads

The construction and maintenance of touristic roads is carried out by the General Directorate of Highways, with the financing provided by the Ministry of Culture and Tourism. Village roads are under the responsibility of the Special Provincial Directorate of Administrations, Forest roads are under the responsibility of the Ministry of Forestry, and Urban roads are under the responsibility of the Municipalities.

- Ministry of Interior
  - General Directorate of Security Affairs is responsible for inspection, reportage, and administration in traffic in addition to its security and public order duty. Duties and authorities of the General Directorate of Security Affair's traffic organizations are as follows:
    * To help taking precautions of caring sick and injured people because of the incident immediately and let relatives of these people know that accident
    * To gather and evaluate statistical data and information covering all elements related to the causes of traffic incidents, to ensure taking necessary precautions according to their results, and to make proposals to related organizations

According to Highway Traffic Law, local general police takes traffic accidents in hand for judicial actions. Traffic police takes traffic accidents in hand to make traffic accident report by identifying the reasons for the accident, trace, and evidence. Traffic police peer-reviews for traffic accidents if s/he is tasked according to procedural laws.

Traffic accident report is made by local general police for accidents which occurred on highways where there is no traffic police, and one sample of this report is sent to traffic police of this location. If sides agree and the accident does not cause another crime, judicial proceeding is not made and Article 565 of Turkish Criminal Law is not applied.

In cases where the road is closed to traffic in traffic accidents; traffic police or general police is authorized to open the road to traffic after marking the signs and evidences in a way that they will not be lost and performing the necessary actions.

- General Commandership of Gendarmerie has the same function with General Directorate of Security Affair. Duties and authorities of the General Commandership of Gendarmerie's traffic organizations are as follows:
  - To help taking precautions of caring sick and injured people because of the incident immediately and let relatives of these people know that accident
  - To gather and evaluate statistical data and information covering all elements related to the causes of traffic incidents, to ensure taking necessary precautions according to their results, and to make proposals to related organizations

- Ministry of Justice

Prosecution office on duty in a region's forensic unit which subjects to Ministry of Justice has to take incident involving death in hand for following the process judicially. A road may be completely open if and only if prosecution office gives instructions after the evidence collection and research process. In cases it is understood that the public prosecutor will be delayed, if the road is closed to traffic because of accident involving death and life-threatening injury, and this accident affects safety of life, property and traffic, and the flow can not be possible from another way; the road is opened to traffic after making necessary markings, pulling over vehicles and the deads, and taking the statement down.

In order to provide a safe traffic environment on the road, after the traffic accident, measurements, fixations and photographs were made at the accident site and the vehicles were taken to a safe place; wreck generated on the road, spills of the transported material (oil, fuel, hazardous material, etc.), body fluids, vehicle parts, obstacles on the road, are removed by firefighters and cleaning teams. If collapses and potholes exist on the road, they are filled by related organization. After ensuring that the traffic flow on the road can be ensured safely, the traffic signs and precautions taken at the accident site will be removed in a controlled manner (from the impact point) and after a short time the traffic flow is monitored, teams in charge return from accident site to their normal duty locations [33].

- Ministry of Health and other institutions which are subjected to it are responsible for offering first aid service in incidents which occur in traffic. They are also responsible for the intervention to injuries as soon as possible and planning of this intervention.

  People report and request for help via emergency numbers of various institutions such as 155-156-158-110-112-177 in Turkey [34]. However, there are some difficulties in its implementation due to the numerous and different number of emergency numbers. In addition, even if all contact numbers are known, hesitation about which institution or institutions interest for that incident or which institution is prior, and necessity of calling different numbers may result in loss of time, life and property.

  Emergency services such as safety, health, and fire are coordinated from a single center in Western countries, 112 is used as an emergency line in the member states of the European Union and 911 in the USA. European Union envisaged the use of the 112 line as the "Single European Emergency Call Number" in all countries of the union with its decision dated July 29, 1991. In the process of harmonization with the European Union, efforts to create a Single Emergency Call Number in our country has begun in 2003 with MATRA Projects in cooperation with Government of the Netherlands and Republic of Turkey – Ministry of Interior. Antalya has designated as a Pilot Province on April 6, 2005.

112 emergency call center system has two main purposes and functions;

- In case of an emergency call, our citizens will learn a single number instead of multiple numbers.
- After receiving an emergency call, the relevant institution(s) will access to the scene of the incident or to the person in an emergency situation as soon as possible.

112 Emergency Call Center Directorate is established to meet, dispatch and coordinate any emergency calls within the provincial municipal boundaries within the scope of investment monitoring and coordination presidency in provinces with metropolitan municipalities, and in other provinces within the governorships [35]. Directorate consists of administrative, information processing and technical services, accounting and purchasing, quality coordination and evaluation offices.

Call center directorate is responsible for meeting the emergency calls entering the field of throughout the province; Provincial Gendarmerie Command, Provincial Security Directorate, Coast Guard Region or Group Command, if any, Municipalities, Forest District or Operation Directorate, Nature Protection and National Parks Regional or Branch Directorate, Provincial Health Directorate, Provincial Disaster and Emergency Directorate, and other institutions designated by the Governorate, on the basis of 24-hour continuous access and taking the necessary measures in this regard, forwarding the emergency calls to the institutions providing emergency services in the call center and providing necessary cooperation and coordination among the institutions providing emergency services.

Call recipients are responsible for answering any calls to their consoles, creating a case record by determining whether the call is in accordance with the operating rules of the call center, and if the call needs information from the call router about the case during the call, selecting the relevant call forwarder from the list and including it in the call and conferencing s/he is in charge of having an interview.

Call routers are supposed to meet the urgent calls transferred as soon as possible and to evaluate whether there is an urgent incident that falls within the scope of the incoming call, to coordinate with other units by confirming whether the representatives or officers of other institutions or departments have been notified by the call forwarder who received the call in cases requiring joint intervention of more than one institution; in cases where the air and other intervention and rescue tools of the relevant institutions are considered to be required, to coordinate with the call routers of institutions with suitable aircraft, taking into account their duties and responsibilities and their capabilities, and through the call center manager to notify the authority and deputy governor authorized to assign the aircraft and direct the most appropriate and closest enough teams to the case, and record any data related to the service provided in the computer environment.

Call routers are divided into different sections as Health, Safety, Gendarmerie, Fire Brigade, Forest Fire and Disaster and emergency call routers. Call routers in each group are supposed to record the exit time, reaching the scene, leaving the scene and returning to the station at the specified time and to ensure correct and complete entry and to enter the data terminal completely and to perform other works and operations specified in the relevant legislation from the vehicle tracking system.

EENA, the European Emergency Number Association, is a non-governmental organization which takes to promote to developing the safety and security of people as the mission for itself. They always try to answer how citizens can get the best help possible if they find themselves in an emergency [36]. More than 1500 emergency services representatives from over 80 countries world-wide, more than 100 solution providers, more than 100 researchers and more than 200 Members of the European Parliament are included in the EENA. They ensure an opportunity for collaboration and learning for everybody participated in the public safety community. They acquire that every citizen may reach emergency services and obtain the convenient information and care during an emergency or a disaster as their vision. They aim to be an organization in the sector which leaves a lasting impression.

EENA wants to have a common emergency number everywhere in Europe which is beneficial for citizens and visitors. 112 is the European emergency number, costless, 24/7, reachable anywhere in all European Union member states, Albania, Georgia, Moldova, Iceland, Montenegro, Norway, Serbia, Switzerland, and Turkey. Citizens may dial 112 to reach the emergency services, including the police, emergency medical services and the fire brigade. It may be reached by landlines as well as mobiles. 112 is a recallable number and the only number a person needs to know when travelling in the EU, that's why Council of the EU introduce 112 as the common emergency number in its all states.

- Municipalities have an important role in traffic incidents with Transportation Coordination Center, fire service, community policing, cleaning, road maintenance, Traffic Control Center, and Intelligent Transportation Systems. The duties of the Fire Department are to intervene in cases requiring technical rescue in case of any accident, collapse, explosion, being stuck and similar situations and to provide first aid services; to carry out all kinds of search and rescue activities in the field [37].

- Tow truck organizations are responsible for clearing of some wreckages and cars which are damaged. In some places, tow trucks which subject to local authorities or General Directorate of Highways are used. But in some places tow trucks which subject to private sector are used. Besides, tow trucks which subject to some foundations and associations give service for small vehicles like automobiles.

  Vehicle tractors are vehicles that come into operation in cases where the vehicle does not have the ability to move, for whatever reason, they ensure that the vehicle is towed and necessary operations are performed [38].

  Vehicle tractors are generally divided into 3 according to the methods of towing vehicles. Tractors that lift and load the vehicle, tractors that transport the vehicle in the truck's chassis with the help of a sliding body, tractors that lift and remove it from the front or rear two wheels of the vehicle through a mechanism. Another classification is single and multiple vehicle rescuers. As it is understood from their name, they are subject to this classification according to the number of vehicles they can carry.

  Rescuers in urban traffic services are used for lifting and transporting the parked vehicles in places and situations prohibited under the provisions of the Traffic Law and Regulations, and for lifting and towing vehicles that are overturned, colliding and not working on the road [39]. In Out of City Traffic Services, they are used to lift and park the vehicles parked against the Traffic Law and Regulations on the side of the road and to remove the vehicles that overturn, collide and do not operate by damage.

  Recovery and towing fee; in the recovery and towing services to be carried out within the boundaries of the municipality is determined according to the tariff to be given by the local municipalities on the hour, taking into account the fuel price and depreciation, and in the recovery and towing services to be made outside the municipal boundaries, is determined according to the tariff to be determined by the Governorship on an hourly basis.

In order to take the vehicles that are banned from traffic, to be kept under protection or to be removed from where they are located due to the violations specified in the laws and in this regulation, firstly, towing vehicles and vehicles of public institutions or organizations are used [40]. In case of need, provided that their fees and other procedures and principles are determined, vehicle towing, rescue and transport services can also be made to real or legal persons by taking decisions in transportation coordination centers in metropolitan cities, and in city and district traffic commissions in other provinces and districts.

Traffic accidents and vehicle malfunctions throughout Istanbul intensify Istanbul traffic [41]. The time spent in traffic varies according to the time of removal of the accident or vehicle malfunction from the scene. The longer it takes the tow trucks, which are provided by private towers, road assistance and insurance services, to reach the scene, the longer it takes to remove the vehicles involved in the accident or the malfunction from the scene. This causes an increase of time spent in traffic of the drivers, fuel consumption and, accordingly, the release of harmful gases and brings with it many negative consequences.

Istanbul Metropolitan Municipality has been providing free towing and crane services for a long time both to help the drivers of vehicles on the road or involved in the accident and to minimize the time lost by other drivers. In city traffic, tow trucks and cranes which can remove heavy tonnage vehicles have been deployed to the arteries, where accidents and vehicle malfunctions occur frequently, and in case of an accident or vehicle malfunction, which may adversely affect the traffic, in order to intervene as soon as possible. Traffic operators working at İBB Transportation Management Center 24/7, constantly checking over 1200 traffic surveillance cameras; when they see a traffic accident or defective vehicle, by contacting the tow trucks and cranes closest to the point where the negativity occurred; they make the necessary attempts to tow and remove vehicles involved in the accident or malfunction.

- Ministry of Environment and organizations which subject to it are responsible for controlling and beginning a legal process against dangerous, blinder, and disrupter things in highways.

2.2 Traffic Incident Models

To date, many different Traffic Incident Models have been developed out by many different researchers using various simulation software. Sheu et al. have offered stochastic prediction paradigm to real-time prediction of delays and queue lengths for incident-based congestion estimation on highways by using CORSIM [42]. Their results point out the convenience of the predicted lane traffic variables created from their proposed method. Bhavsar et al. have improved a Support Vector Regression (SVR) Decision Support System (DSS) to estimate probable effects of traffic diversion across transportation networks by using the Programmer module of the PARAMICS microscopic simulation model [43]. Improved DSS may be helpful for various transportation planning as well as traffic management implementations, and it does not force the user to improve a new simulation model for the network. Baykal-Gürsoy et al. have offered queueing models to identify the traffic flow on a road link exposed to traffic incidents and worked on related analytical solutions [44]. Comparison of analytical results with the INTEGRATION software shows that M / MSP / ∞ indicates an adequate approach for long links, while M / MSP / c may be more suitable for congested roads.

Rompis et al. have presented a methodology to develop incident-specific models in a microscopic traffic simulation environment, demonstrated how capacity reduction due to rubbernecking may be modeled in VISSIM, and how incident models may be calibrated [45]. Their results show that queue length may be correctly presumed in simulation models during both partial and complete closure of freeways for multiple durations. Chou et al. have measured the potential advantages and disadvantages of orientating general traffic into a managed lane when an incident shows up along the general purpose lanes [46]. By operating the advanced simulation techniques with VISSIM, continuous and access point diversion strategies were appraised for their effects on the mobility of general traffic and managed lane users along a equitemporaneous flow lane system on I-270 in Maryland. Kabit et al. have measured the excited delay due to a major incident on a motorway using microsimulation software, VISSIM, and hereby, they have purposed to forecast the associated incident costs [47]. The savings from incident influences were predicted if a two-hour incident clearance time was decreased by 30 minutes by unblocking the lanes slowly or contemporaneously. Raju et al. have concluded that features of the high-speed roads should not be studied with experimental observations alone, as variation in traffic volume will be less on these road sections, unlike the urban roads [48]. They have also observed that vehicular trajectory data is inevitable source for simulating the road sections efficaciously in robust way, but at present, very few vehicular trajectory data sets are available under Indian conditions. Liu et al. have improved a VISSIM simulation model and calibrated relying on the field collected video and sensor data for the Seattle SoDo area [49]. Their analysis looks for understanding the networkwide performance, by experimentally diverting traffic to the contiguous arterials in answer to incident management for freeway operations and multiple scenarios were raised into the simulation model to customize and sustain different diversion rates, as well as repeated and non repeated congestion situations.

Hamza-Lup et al. have improved the surface transportation perspectives of homeland security by applying new ITS technologies for developing a Smart Traffic Evacuation Management System (STEMS) by using CORSIM [50]. They have managed the real-time discharge operation by dynamically generating discharging plans given an incident location (and scope), and then automatically controlling the discharging signals to direct the evacuees according to the generated discharging plans. Hadi et al. have deduced in their research which three simulation models (CORSIM, VISSIM, and AIMSUN) studied let the users to simulate incident blockages either saliently or by using other happenings that have similar effects on traffic operations [51]. In all three models, there was a necessity to calibrate the simulation parameters for the incident location to generate the declines in capacity estimated by the HCM 2000 or based on field studies, but only CORSIM contained incident calibration parameters. The rubbernecking factor in CORSIM may be utilized successfully to generate simulated incident capacities close to those estimated by the HCM 2000, but AIMSUN and VISSIM do not have incident adjustment parameters but have other modeling potentials that may be used to adjust the models to generate the decided declines in capacity due to incidents. Chilukuri et al. have indicated principal research in understanding the utilities of adaptive traffic control systems during incidents by using CORSIM [52]. Their signal system (SCOOT) that detects and responds to incidents through signal timing regulations ensures a different advantage in managing and clearing incident-related congestion, and unbraces incident congestion by deciding an incident and then responding by reallocating green time on the incident-affected link while proceeding to protect coordination.

Schrock et al. have showed that FRESIM which is a microscopic simulation software is an influential tool in assigning suitable work zone traffic management plans (WZTMP) at interstate work zones [53]. Deciding the delay values for rivaling WZTMPs for upcoming projects would let highway agencies to own measurable estimates of what these delays will cost and supply them with the information required to select the most suitable alternative for a given situation. The methodology used in their study might be utilized to estimate congestion at future interstate work zones, letting highway agencies to state the suitable strategy to minimize congestion cost-effectively.

Hoogendoorn et al. have explained a new way to the on-line estimation of the effect of control scenario's under a variety of incidents in the network by using METANET [54]. The primary benefits of this way are the speed of calculation (compared to using traffic flow models), the capability to utilize exact knowledge directly (rather than general knowledge or simulated data), and the capability to gain something from previous experiences (continuous step-wise learning). Dabiri et al. have showed an amplification to the METANET model considering direct and indirect incident model parametrization [55]. Direct incident parameter affects the equilibrium speed as well as the expectation term, but indirect incident parameter defines the average drivers' response to unusual traffic conditions resulting in an increased, fictions density variable.

Fries et al. have appreciated the advantages of using traffic cameras for incident detection and confirmation, using random spatial and provisional happening of incidents in the network, and also appraised the random choice of incident detection, confirmation, and clearance time using PARAMICS [56]. The improved incident generator by them simulates the happening of incidents stochastically assigning locations, start time, and the duration of incidents. Hereby their study has ensured a helpful and realistic method for appraising the advantages of incident management strategies through traffic simulation. Dia et al. have showed a simulation approximation for modelling the effects of ITS and appraise the potential advantages of applying incident management programs and their effects on network performance [57]. Their model's calibration and confirmation outcomes, based on real-world data, ensure a good degree of reliance in the correctness of the model and its relevance for use in their assessment. Fries et al. have appraised the applicability of using PARAMICS as a decision support tool for real time incident management [58]. Huang et al. have demonstrated a way for reproducing an optimal dispatching strategy for incident response by integrating Geographic Information Systems (GIS), traffic simulation, and optimization systems by using PARAMICS [59]. In this way, the optimization model minimizes the total travel time of all the response units while maximizing the total levels of stringencies of the incidents to be overcome given under present available response resources.

Consequences of the study of Tupper et al. which is made via PARAMICS show that TIM using ITS strategies are able of ensuring sustainable advantages negotiating that of construction related strategies [60]. Their outcomes show that within the first year of implementations, applying the ITS strategy would ensure a fuel savings that is roundly 4 times bigger than the savings that might be achieved by applying all four construction phase strategies researched; the use of regionally supplied materials, decline of fossil fuel usement, pavement reuse and warm-mix asphalt. Within three to four years, savings from the ITS strategy would generate a larger increment of CO, NOx, and VOC emissions than any of the four construction strategies. Modeling proposal of Fehon et al. which is made via PARAMICS has let comprehensive simulation of combinations of improved traffic management strategies including variable speed limits, lane control signals and adaptive ramp metering [61]. Although formal consequences are not yet present for public release, beginning outcomes have endorsed that the notion is probably to demonstrate advantages of advanced travel times and decreased levels of congestion on both a day-to-day basis and in response to incidents.

The previous studies related to this issue that we mentioned are presented in Table (2.3).

YEAR	**ARTICLE**	**JOURNAL**	**AUTHOR**	**SIMULATION SOFTWARE**
2000	Evaluation of Rural Interstate Work Zone Traffic Management Plans in Iowa Using Simulation	Mid-Continent Transportation Symposium 2000 Proceedings	Steven D. Schrock and T. H. Maze	FRESIM

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YEAR	ARTICLE	JOURNAL	AUTHOR	SIMULATION SOFTWARE
2001	A stochastic estimation approach to real-time prediction of incident effects on freeway traffic congestion	Transportation Research Part B: Methodological, 35(6), 575–592	Sheu, J.-B., Chou, Y.-H., and Shen, L.-J.	CORSIM
2003	Decision support in Dynamic Traffic Management. Real-time Scenario Evaluation	EJTIR, 3, no. 1 (2003), pp. 21-38	Serge P. Hoogendoorn, Bart De Schutter and Henk Schuurman	METANET
2004	SCOOT and Incidents: Performance Evaluation in Simulated Environment	Transportation Research Record: Journal of the Transportation Research Board, 1867, 224–232.	Bhargava Rama Chilukuri, Joseph Perrin, Jr., and Peter T. Martin	CORSIM

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YEAR	ARTICLE	JOURNAL	AUTHOR	SIMULATION SOFTWARE
2005	A Maximum-Flow Approach to Dynamic Handling of Multiple Incidents in Traffic Evacuation Management	Proceedings. 2005 IEEE Intelligent Transportation Systems, 2005.	Georgiana L. Hamza-Lup, Kien A. Hua, Rui Peng, and Ai H. Ho	CORSIM
2006	Evaluation of arterial incident management impacts using traffic simulation	IEE Proceedings Intelligent Transportation Systems Vol. 153, No. 3, September 2006	H. Dia and N. Cottman	PARAMICS
2007	Decision Support System for Predicting Traffic Diversion Impact across Transportation Networks Using Support Vector Regression	Transportation Research Record: Journal of the Transportation Research Board, 2024(1), 100–106	Bhavsar, P., Chowdhury, M., Sadek, A., Sarasua, W., and Ogle, J.	PARAMICS

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YEAR	ARTICLE	JOURNAL	AUTHOR	SIMULATION SOFTWARE
2007	Modeling Reductions in Freeway Capacity due to Incidents in Microscopic Simulation Models	Transportation Research Record, 1999(1), 62–68	Hadi, M., Sinha, P., and Wang, A.	CORSIM, VISSIM, and AIMSUN
2007	Accelerated Incident Detection and Verification: A Benefit to Cost Analysis of Traffic Cameras	Journal of Intelligent Transportation Systems, 11(4), 191–203.	Ryan Fries, Mashrur Chowdhury, and Yongchang Ma	PARAMICS
2007	Feasibility of Traffic Simulation for Decision Support in Real-Time Regional Traffic Management	Transportation Research Record: Journal of the Transportation Research Board, 2035(1), 169–176.	Ryan Fries, Imran Inamdar, Mashrur Chowdhury, Kevin Taaffe, and Kaan Ozbay	PARAMICS

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YEAR	ARTICLE	JOURNAL	AUTHOR	SIMULATION SOFTWARE
2007	GIS coupled with traffic simulation and optimization for incident response	Computers, Environment and Urban Systems, 31(2), 116–132.	Bo Huang, Xiaohong Pan	PARAMICS
2009	Modeling traffic flow interrupted by incidents	European Journal of Operational Research, 195(1), 127–138	Baykal-Gürsoy, M., Xiao, W., and Ozbay, K.	INTEGRATION
2010	Modeling Active Traffic Management with Paramics	IEEE Intelligent Transportation Systems Magazine, 2(3), 14–18.	Kevin Fehon and Terry Klim	PARAMICS
2011	Exploiting the Capacity of Managed Lanes in Diverting Traffic Around an Incident	Transportation Research Record: Journal of the Transportation Research Board, 2229(1), 75–84	Chih-Sheng Chou and Elise Miller-Hooks	VISSIM

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YEAR	ARTICLE	JOURNAL	AUTHOR	SIMULATION SOFTWARE
2012	Measuring Sustainability: How Traffic Incident Management through Intelligent Transportation Systems has Greater Energy and Environmental Benefits than Common Construction-Phase Strategies for “Green” Roadways	International Journal of Sustainable Transportation Vol. 6, No. 5, 2012	Lee L. Tupper, Mashrur A. Chowdhury, Leidy Klotz, and Ryan N. Fries	PARAMICS
2013	Simulation-Based, Scenario-Driven Integrated Corridor Management Strategy Analysis	Transportation Research Record: Journal of the Transportation Research Board, 2396(1), 38–44.	Xiaoyue (Cathy) Liu, Guohui Zhang, Carmen Kwan, Yinhai Wang, and Brian K. Kemper	VISSIM

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YEAR	ARTICLE	JOURNAL	AUTHOR	SIMULATION SOFTWARE
2014	A Methodology for Calibrating Microscopic Simulation for Modeling Traffic Flow under Incidents	17th International IEEE Conference on Intelligent Transportation Systems (ITSC)	Semuel Y.R. Rompis, Filmon G. Habtemichael, and Mecit Cetin	VISSIM
2014	Modelling major traffic incident impacts and estimation of their associated costs	Transportation Planning and Technology, 37(4), 373–390.	Mohamad Raduan bin Kabit, Phil Charles, Luis Ferreira and Inhi Kim	VISSIM
2015	Freeway traffic incident reconstruction – A bi-parameter approach	Transportation Research Part C: Emerging Technologies, 58, 585–597.	A. Dabiri and B. Kulcsár	METANET

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YEAR	**ARTICLE**	**JOURNAL**	**AUTHOR**	**SIMULATION SOFTWARE**
2019	Methodological Framework for Modeling Following Behavior of Vehicles Under Indian Traffic Scenario	Innovative Research in Transportation Infrastructure, Lecture Notes in Intelligent Transportation and Infrastructure.	Narayana Raju, Shriniwas Arkatkar and Gaurang Joshi	VISSIM

Table 2.3: Some previous studies related to Traffic Incident Modeling.

Chapter 3

Incident Simulation Modeling Methodology

3.1 Incident Data Collection and Analysis

We determined some traffic incidents from different types such as vehicle breakdown and traffic accident at different locations within the boundaries of Istanbul, on different days of the weekdays and weekend, during the peak hours of traffic by using Traffic Density Map of Istanbul Metropolitan Municipality – Directorate of Transportation Management Center. Each incident was observed minute by minute for approximately 30-40 minutes including the moments of beginning, intervention, clearance, and post-incident. Speed data of incident's segment, and incident's 5 upstream and 5 downstream segments were collected manually minute by minute for every incident. Besides general screenshots of incidents were saved minute by minute. GIF images were obtained with the screenshots that we saved in order to see the realization of incidents more clearly and to make their analyzes more accurately as shown in Figure (3.1).

The collected speed data were put in order in an excel table. After that conditional formatting were applied to these data. Different colors are determined for each speed range. An edited excel table is shown in Figure (3.2).

At the end, a consistent result was obtained between these edited excel tables and GIFs which are gained before. According to this result, a reduction in speed values of incident's segment and its upstream segments are observed depending

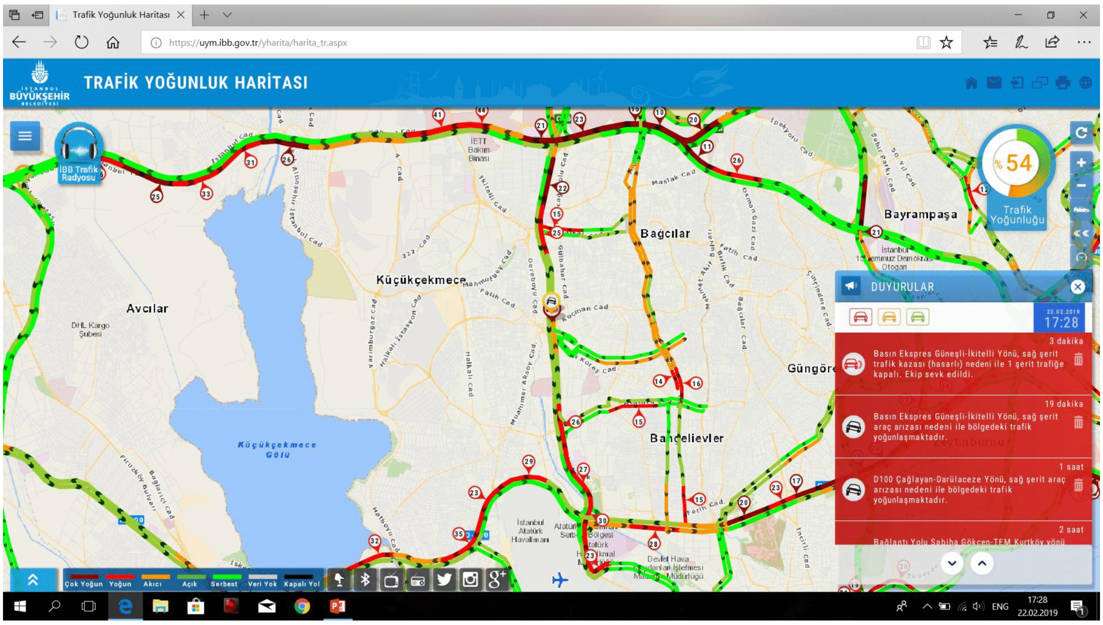

Figure 3.1: GIF of an incident.

on time. The shockwave from the incident's segment to its upstream segments may be seen clearly. We can say that incidents influence the back part of the roads. When we look at the downstream segments' speed values, it is obvious that traffic relieves in process of time. Downstream segments' speed values show a tendency to increase.

Moreover, we detected an interesting thing when we analyzed the map. There are rubber necks in counter lanes of the roads. Rubber neck is the situation of slowing of drivers involuntarily because of the desire to watch the incident which is occurred in counter direction. Rubber necks have serious effects on roads. They influence the flow like there is a real incident. We obtained this result with the analysis of the counter lanes' speed values. There was no incident notification but their speed values are like there were real incidents at these roads.

There are lots of parameters which influence the incident in real life. It is impossible to change and comment these variables in the incident area transiently. That's why we choose simulation method to achieve our goal. We had more accurate and reliable results with this way. Also, using this traffic density map, we

← Direction of flow

Time \ Segment	10128	10127	10126	10125	10124	10123	10122	10121	10120	10119	1829	
17:28	23	30	27	26	62	53	59	23	17	50	79	km/h
17:30	24	30	23	27	66	62	61	23	17	40	72	km/h
17:31	24	31	23	26	67	63	62	23	17	40	72	km/h
17:32	27	31	26	26	67	61	62	22	18	34	68	km/h
17:33	28	33	29	26	66	61	60	22	18	34	68	km/h
17:34	28	33	29	26	66	62	60	20	18	33	67	km/h
17:35	30	31	30	26	64	62	58	20	18	33	67	km/h
17:36	30	31	30	26	64	60	58	19	17	34	69	km/h
17:37	33	32	29	27	65	61	53	17	18	40	74	km/h
17:38	35	34	28	28	65	54	46	17	18	40	74	km/h
17:39	35	34	28	28	65	54	46	15	20	41	75	km/h
17:40	24	37	27	28	62	46	36	12	18	41	75	km/h
17:41	24	40	27	28	61	46	40	12	18	39	73	km/h
17:42	24	33	27	28	61	45	32	12	18	39	73	km/h
17:43	24	39	31	28	59	41	28	12	18	19	57	km/h
17:44	24	37	31	28	60	41	28	12	18	19	57	km/h
17:45	23	37	30	28	60	40	22	12	19	19	57	km/h
17:46	24	36	30	28	61	36	21	12	20	16	55	km/h
17:47	24	36	30	28	61	36	21	12	20	37	72	km/h
17:48	23	33	31	29	54	30	20	12	23	37	72	km/h
17:49	23	33	31	29	54	30	20	12	23	36	71	km/h
17:50	23	34	29	29	39	22	22	11	18	36	71	km/h
17:51	25	35	33	30	34	19	23	12	23	35	69	km/h
17:52	25	35	33	30	34	19	23	12	23	35	69	km/h
17:53	26	36	35	31	31	18	23	13	24	33	67	km/h
17:54	28	37	37	30	29	20	23	11	21	33	67	km/h
17:55	28	39	39	30	29	20	23	11	21	33	65	km/h
17:56	32	39	39	29	28	20	22	11	20	33	65	km/h
17:58	38	45	40	30	32	22	22	11	15	42	75	km/h

Incident start	22.02.2019 - 17:25
Incident end	22.02.2019 - 17:57
Observation duration	30 min
Incident's segment	10123

Speed (km/h)	Color	
0-15	black	
16-25	brown	
26-35	red	
36-45	orange	
46-55	yellow	
56-65	dark green	
66-75	green	
76-100	light green	

Figure 3.2: Speed ranges of an incident over time.

can only obtain speed as a basic traffic flow parameter. Apart from speed, we don't have a parameter to use. This is another factor that pushed us to simulate.

3.2 Incident Simulation

3.2.1 Traffic Simulation Modeling

Traffic simulation models can be sorted into three main categories [51]:

- Macroscopic simulation models which are based on the flow's deterministic relationships, speed, and density of the traffic stream;
- Microscopic simulation models which simulate the movement of individual vehicles based on car-following and lane-changing theories; and
- Mesoscopic simulation models which combine the features of both microscopic and macroscopic simulation models; as in microscopic models, the mesoscopic models' unit of traffic flow is the individual vehicle; nevertheless, the movements of vehicles are modeled by using macroscopic models.

In this research we used VISSIM as the simulation software. VISSIM is a microscopic, behavior-based multi-purpose traffic simulation software which analyzes and optimizes traffic flows. It provides a large diversity of urban and highway implementations, integrating public and private transportation. Complex traffic events are visualized in high level of detail assisted by realistic traffic models. Based on various mathematical models the position of each vehicle is recalculated every 0.1–1 s [62].

3.2.2 Incident Simulation Modeling

Driving behavior parameters command driving behavior of the simulation software used. For this reason it is not recommended for inexperienced users to change these parameters. Because this might lead to drastically different outcomes.

Driving behavior characteristics of a road may be identified by driving behavior parameter set which is listed below [63]:

- The following behavior and car following model according to Wiedemann
- Lateral behavior
- Lane change behavior

- Behavior at signal controls
- Parameters for mesoscopic simulation

Traffic flow model of Vissim is a stochastic, time step based, and microscopic model that processes driver-vehicle units as basic elements [63].

The traffic flow model involves a psycho-physical car following model for longitudinal car motion and an algorithm based on rule for lateral car motion. The models performed are relying on Wiedemann's comprehensive research work [63].

Wiedemann's traffic flow model is based upon the hypothesis that there are essentially four distinctive driving conditions for a driver which are free driving, approaching, following, and braking [63].

All driving behavior parameters for following behavior, car following model, lane change, and lateral behavior can be edited. However, we used default values. There are two reasons for this. The first reason is that the parameters of our modeling are very similar to the default parameters. The second reason is that the slightest change in a single parameter affects other parameters and it causes false results. Descriptions of these parameters are mentioned below.

Minimum and maximum look ahead distance is that a car may see forward so as to response to other cars either in front or to the side of it (within the same link) [63]. Cars take cognizance of the minimum and maximum look-ahead distance the entered number of previous cars additively. Minimum look ahead distance is 0.00 m and maximum look ahead distance is 250.00 m.

Minimum and Maximum look back distance identifies the minimum and maximum space that a car may see backwards so as to response to other cars behind (within the same link) [63]. Minimum look back distance is 0.00 m and maximum look back distance is 150.00 m.

Temporary lack of attention duration is the time duration when cars can't give reaction to a previous car [63]. They do give reaction but to emergency braking.

It is 0 s. Probability is the Frequency of the lack of attention [63]. If values increase, influenced links' capacity reduces. It is 0.00%.

Standstill distance (ax) is upstream of static impediments such as precedence orders, stop signs, signal heads, conflict areas, PT stops [63]. It is not acceptable for stop signs in parking lots. The attribute Smooth closeup behavior must be selected. If a user doesn't choose this behavior, cars manage a normally distributed random value [0.5; 0.15]. This option is not selected by default .

Car following behavior is relying upon the selected car following model's parameters. Vissim uses two car following models which are Wiedemann 74 and Wiedemann 99 [63]. We used Wiedemann 99. Because our road is a freeway and it doesn't have a merging area. It's parameters are CC0, CC1, CC2, . . . , and CC9.

CC0 is the average desired standstill space between 2 cars [63]. It is 1.50 m. CC1 is the time range of velocity-dependent part of desired safety gap [63]. Every time range can be normal or empirical. It is 0.9 s. CC2 limits the space difference for longitudinal oscillation [63]. It is 4.00 m. CC3 manages the beginning of the deceleration process [63]. It is -8.00 s. CC4 describes nonpositive velocity difference while following [63]. If there is a low value, it causes a more sensitive driving reaction for acceleration or deceleration of the previous car. It is -0.35 m/s. CC5 describes nonnegative velocity difference while following [63]. A nonnegative number suitable with CC4 should be entered for CC5. Low values cause same effect with CC4. It is 0.35 m/s. CC6 is the impact of space on velocity oscillation during following [63]. If CC6 is 0, the velocity oscillation is independent of the space. If big numbers are entered, it causes to a greater velocity oscillation with increasing speed distance. It is 11.44 [1/(m*s)]. CC7 is the oscillation during acceleration [63]. It is 0.25 m/s2. CC8 is the desired acceleration when beginning for standstill [63]. It is restricted by maximum acceleration described within the acceleration curves. It is 3.50 m/s2. CC9 is the desired acceleration at 80 km/h

[63]. It is restricted by maximum acceleration described within the acceleration curves. It is 1.50 m/s2.

General Behavior of Lane Change is selected as Free lane. In free lane option cars can overtake on each lane [63].

In Necessary lane change (route) part there are some terms. Lane changing delay relying on the determined routings for their own overtaking vehicle and the trailing vehicle is admitted by the motorist [63]. Own and Trailing vehicle columns are symbolized this. In Maximum deceleration it is stated the maximum deceleration for lane changing relying on the determined routings for own vehicle overtaking and the trailing vehicle. It is majorant of deceleration for own vehicle and tailing vehicle for a lane change [63]. Own vehicle value is – 4.00 m/s2 and trailing vehicle value is – 3.00 m/s2. Accepted deceleration is sublimit of deceleration for own vehicle and trailing vehicle for a lane change [63]. Own vehicle value is – 1.00 m/s2 and trailing vehicle value is – 0.50 m/s2. The alteration of the deceleration is in meters per -1 m/s2. -1m/s2 per distance decreases the Maximum deceleration [63]. Own vehicle distance and trailing vehicle distance are both 200.00 m.

Diffusion time is the maximum time period that a car may wait at the emergency stop distance for a necessary lane change [63]. It is 60.00 s. Minimum headway is the minimum space between two cars that must be existing after a lane change, so that the change may occur [63]. It is 0.50 m. A lane change while normal flow may entail a bigger minimum distance between cars so as to retain the velocity-dependent safety distance. Safety distance reduction factor is considered for each lane change [63]. It is 0.60. It interests the following parameters [63]:

- The safety distance of the trailing vehicle on the new lane for assignation whether a lane change will be performed
- The safety distance of the lane changer itself
- The distance to the preceding, slower lane changer

During the lane change Vissim decreases the safety space to the value that results from the following multiplication [63]:

*Original safety distance * safety distance reduction factor*

0.6 which is the default value decreases the safety distance by 40%. The original safety distance is considered again after lane change completion.

Maximum cooperative deceleration determines to what extent the trailing vehicle A is braking cooperatively, in order to let a preceding vehicle B to change lanes into its own lane as shown in Figure (3.3) [63]. It is – 3.00 m/s2.

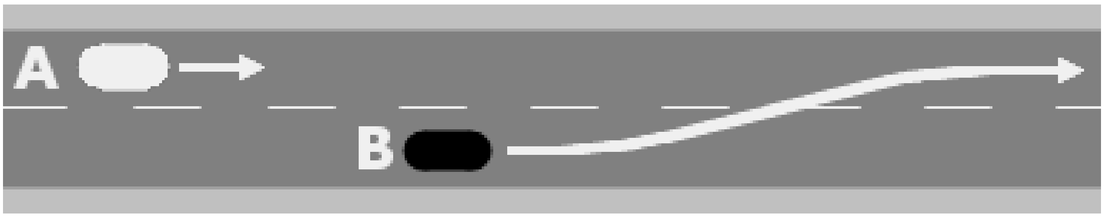

Figure 3.3: Representation of Vehicle A and Vehicle B for understanding Maximum Cooperative Deceleration [63].

A car decreases its speed with the following values while cooperative braking [63]:

- 0% to a maximum of 50% of the desired deceleration, until the car in front starts to change lanes
- Between 50% of the desired deceleration and the maximum deceleration (100%) determined in the Maximum deceleration field. Generally, the deceleration during the lane change will be substantially less than the maximum deceleration, as the previous vehicle, which changes lanes, does not expect such a high deceleration from the trailing vehicle.

Overtake reduced speed areas choice isn't chosen by default. If a user chooses this, cars instantly upstream of a reduced speed area can perform a free lane change [63]. If a user doesn't choose this, vehicles never begin a free lane change directly upstream of a reduced speed area. Advanced merging option is selected by default. This option is determined for any necessary lane change towards the next connector along the route [63].

- If a user chooses this, more cars may change lanes earlier. Herewith, an increase in the capacity and a decrease in the probability that vehicles come to a stop to wait for a gap occur.

  This box should be selected to obtain the desired lane change behavior [63]:

  - As shown in Figure (3.4) if car A has to change lanes and realizes that the neighboring car in front B on the target lane has almost the same velocity or is only slightly faster (-1.0 m/s $<$ dv $<$ 0.1 m/s), A slows down slightly (by 0.5 m/s^2) to move into the space behind B, if this box is chosen.

Figure 3.4: Representation of Vehicle A and Vehicle B for understanding Advanced Merging [63].

If Vehicle routing decisions look ahead box is chosen, cars leaving the route determine new routing decisions on the same link beforehand and consider them when choosing the lane [63]. For routing decisions further downstream that cars should determine beforehand, the box Combine static routing decisions must be chosen.

If car A sees that a leading car B on the adjacent lane wants to change to his lane A, then vehicle A will try to change lanes itself to the next lane to help lane changing for vehicle B. It is called Cooperative lane change [63]. If a user doesn't choose this, cooperative lane changing behavior will not be operative for the particular driving behavior parameter set. This option is not selected by default.

If a lane change happens at a lower velocity than determined in the Maximum velocity box, the car's rear end moves laterally. The rear correction retrieves for this movement. This induces the car to line up to the middle of the lane at the end of the lane change, instead of at angle in the original lane. The rear correction is carried out completely, even when the vehicle comes to a standstill. A rear correction influences the capacity. Rear correction is only carried out if the Keep lateral distance to cars on next lane(s) selection is chosen for the driving behavior parameter Lateral behavior [63]. This option is not selected by default.

Desired position at free flow is Lateral orientation of a vehicle within its lane while it is in free traffic flow [63]. Middle of lane option is selected by default. If a user doesn't choose the Observe adjacent lanes box, cars on adjacent lanes are ignored even if they are wider than their lanes, except when they carry out a lane change. This option is not selected by default. Diamond queuing option is not selected. But if a user choose this box, queues consider a realistic shape of the cars with cars positioned offset, such as bikes [63]. Vehicles are internally represented not as a rectangle, but as a rhombus.

Collision time gain is the Minimum value of the collision time gain for the next car or signal head, which must be approached so that a change of the lateral position on the lane is useful and will be carried out [63]. The collision time is computed relying on the desired velocity of the car. The default value for collision time gain is 2 seconds. Smaller values cause a livelier lateral behavior, because cars also have to dodge sideways for minor progresses.

Minimum longitudinal speed is the Minimum longitudinal speed which still permits for lateral movements [63]. It is 3.60 km/h.

Time between direction changes - minimum time Standard 0.0 s identifies the minimum simulation time which must pass between the beginning of a lateral movement in one direction and the beginning of a lateral movement in the reverse direction [63]. The higher this value, the smaller are the lateral movements of cars.

These lateral movements only occur if overtaking on the same lane is allowed. Lateral movement for a lane change is not influenced by this parameter.

Default behavior when overtaking vehicles on the same lane or on adjacent lanes implements for all vehicle classes, excluding the vehicles classes listed under Exceptions for overtaking vehicles of the following vehicle classes [63].

- Overtake on same lane: When modeling traffic that is not lane-bound, you can permit vehicles to overtake within a lane.
- Left: Vehicles are permitted to overtake on a lane to the left. This option is not selected by default.
- Right: Vehicles are permitted to overtake on a lane to the right. This option is not selected by default.
- Minimum lateral distance: Minimum distance between vehicles when overtaking within the lane and keeping the distance to vehicles in the adjacent lanes.
- Distance standing at 0 km/h: lateral distance of the passing vehicle in meters. It is 0.20 m.
- Distance driving at 50 km/h: lateral distance of the passing vehicle in meters. It is 1.00 m.

3.2.3 Scenarios

An incident generally has a complex scenario. Lots of factors may affect the incident scenario. We determined the most effective ones and generated our experimental setup table as in Table (3.1) below.

According to this experimental setup table, we have five different parameter which affect the incident such as incident duration, vehicle input, number of lanes, incident position, and lane width. When we made a necessary combination of these

Exp. No	Incident Duration (Minute)	Vehicle Input (Vehicle/ (Hour*Lane))	Number of Lane (Unitless)	Incident Position (Lane)	Lane Width (Meter)
1	5	1000	2	1st	3
2	5	1000	2	1st	3,25
3	5	1000	2	1st	3,5
4	5	1000	2	2nd	3
...	...	...	...	...	...
7	5	1000	3	1st	3
...	...	...	...	...	...
10	5	1000	3	2nd	3
...	...	...	...	...	...
13	5	1000	3	3rd	3
...	...	...	...	...	...
16	5	1500	2	1st	3
...	...	...	...	...	...
31	5	2000	2	1st	3
...	...	...	...	...	...
46	10	1000	2	1st	3
...	...	...	...	...	...
91	15	1000	2	1st	3
...	...	...	...	...	...
135	15	2000	3	3rd	3,5

Table 3.1: Experimental Setup Table.

parameters, we understood that we needed to make 135 different simulations. Considering the parameters that we mentioned earlier, we determined some scenario groups in a total of 135 simulations to analyze the simulation results. Our scenario groups are shown in Tables (3.2 - 3.11) below.

For starting the simulations, we drew a 1 km simple link in VISSIM as shown in Figure (3.5).

EXP. NO	INC. DUR.	VEH. INPUT	N. OF LANE	INC. POS.	LANE WTH.
EXP 18	**5 min**	1500 veh/lane	2 lanes	1st lane	3.50 m
EXP 63	**10 min**	1500 veh/lane	2 lanes	1st lane	3.50 m
EXP 108	**15 min**	1500 veh/lane	2 lanes	1st lane	3.50 m

Table 3.2: Parameter Values of Incident Duration Scenario Group 1.

EXP. NO	INC. DUR.	VEH. INPUT	N. OF LANE	INC. POS.	LANE WTH.
EXP 39	**5 min**	2000 veh/lane	3 lanes	1st lane	3.50 m
EXP 84	**10 min**	2000 veh/lane	3 lanes	1st lane	3.50 m
EXP 129	**15 min**	2000 veh/lane	3 lanes	1st lane	3.50 m

Table 3.3: Parameter Values of Incident Duration Scenario Group 2.

EXP. NO	INC. DUR.	VEH. INPUT	N. OF LANE	INC. POS.	LANE WTH.
EXP 48	10 min	**1000 veh/lane**	2 lanes	1st lane	3.50 m
EXP 63	10 min	**1500 veh/lane**	2 lanes	1st lane	3.50 m
EXP 78	10 min	**2000 veh/lane**	2 lanes	1st lane	3.50 m

Table 3.4: Parameter Values of Vehicle Input Scenario Group 1.

EXP. NO	INC. DUR.	VEH. INPUT	N. OF LANE	INC. POS.	LANE WTH.
EXP 99	15 min	**1000 veh/lane**	3 lanes	1st lane	3.50 m
EXP 114	15 min	**1500 veh/lane**	3 lanes	1st lane	3.50 m
EXP 129	15 min	**2000 veh/lane**	3 lanes	1st lane	3.50 m

Table 3.5: Parameter Values of Vehicle Input Scenario Group 2.

EXP. NO	INC. DUR.	VEH. INPUT	N. OF LANE	INC. POS.	LANE WTH.
EXP 18	5 min	1500 veh/lane	**2 lanes**	1st lane	3.50 m
EXP 24	5 min	1500 veh/lane	**3 lanes**	1st lane	3.50 m

Table 3.6: Parameter Values of Number of Lane Scenario Group 1.

EXP. NO	INC. DUR.	VEH. INPUT	N. OF LANE	INC. POS.	LANE WTH.
EXP 108	15 min	1500 veh/lane	**2 lanes**	1st lane	3.50 m
EXP 114	15 min	1500 veh/lane	**3 lanes**	1st lane	3.50 m

Table 3.7: Parameter Values of Number of Lane Scenario Group 2.

EXP. NO	INC. DUR.	VEH. INPUT	N. OF LANE	INC. POS.	LANE WTH.
EXP 18	5 min	1500 veh/lane	2 lanes	**1st lane**	3.50 m
EXP 21	5 min	1500 veh/lane	2 lanes	**2nd lane**	3.50 m

Table 3.8: Parameter Values of Incident Position Scenario Group 1.

EXP. NO	INC. DUR.	VEH. INPUT	N. OF LANE	INC. POS.	LANE WTH.
EXP 114	15 min	1500 veh/lane	3 lanes	**1st lane**	3.50 m
EXP 117	15 min	1500 veh/lane	3 lanes	**2nd lane**	3.50 m
EXP 120	15 min	1500 veh/lane	3 lanes	**3rd lane**	3.50 m

Table 3.9: Parameter Values of Incident Position Scenario Group 2.

EXP. NO	INC. DUR.	VEH. INPUT	N. OF LANE	INC. POS.	LANE WTH.
EXP 1	5 min	1000 veh/lane	2 lanes	1st lane	**3.00 m**
EXP 2	5 min	1000 veh/lane	2 lanes	1st lane	**3.25 m**
EXP 3	5 min	1000 veh/lane	2 lanes	1st lane	**3.50 m**

Table 3.10: Parameter Values of Lane Width Scenario Group 1.

EXP. NO	INC. DUR.	VEH. INPUT	N. OF LANE	INC. POS.	LANE WTH.
EXP 67	10 min	1500 veh/lane	3 lanes	1st lane	**3.00 m**
EXP 68	10 min	1500 veh/lane	3 lanes	1st lane	**3.25 m**
EXP 69	10 min	1500 veh/lane	3 lanes	1st lane	**3.50 m**

Table 3.11: Parameter Values of Lane Width Scenario Group 2.

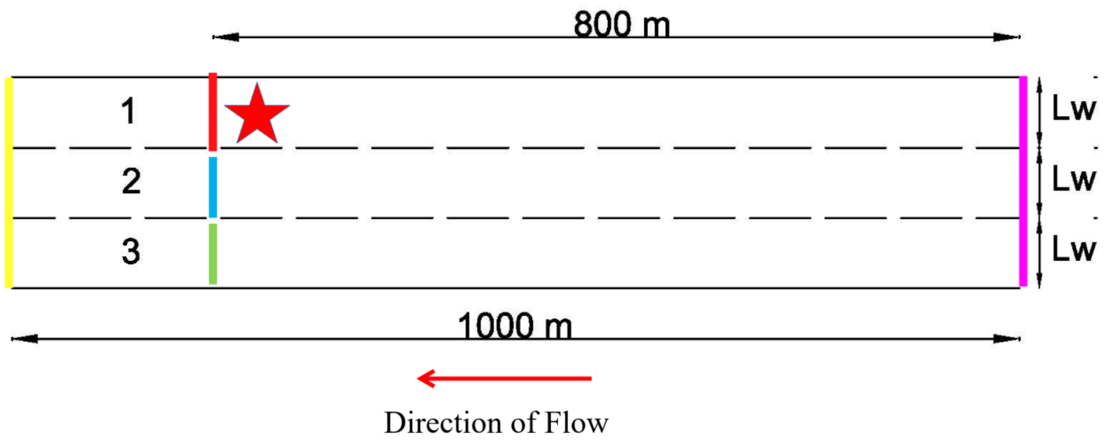

Figure 3.5: Representation of the VISSIM model's road properties.

The pink line is the starting point of the road. The yellow line is the end point of the road. The incident occurs at 800th meter. It is demonstrated with red line. Incident Position has changed by us during simulation from 1 to 3. Red, blue and green lines indicate the positions of the incident in the first, second and third lanes, respectively. Lane width (LW) has also changed. We determined 3 different vehicle types for our simulation which are Car, HGV, and Bus. Since vehicle composition on highways is usually like this we determined their percentages as 85%, 10%, and 5% respectively. We also stated some speed values for these types. Their speed values are 120 km/h, 90 km/h, and 90 km/h respectively. We specified the "incident vehicle" as a Car. That's why its speed is 120 km/h, too. The red star symbolizes the incident vehicle. The incident vehicle generates at the starting point (pink line) between 255th and 260th second. It arrives the incident position between 270th and 300th second. In addition, detectors are placed at where incident position lines are located to make the necessary measurements. These detectors make the necessary measurements in the region from where they are located to the starting of the road.

After doing requirements we decided to make our research in 3 steps. Firstly, we made 135 different simulations considering the experimental setup table. In the end, we gained some data about these simulations such as queue length, number of vehicles, total travel time, and speed. When we finished data collection, we created some graphs to comment these simulations' results.

Secondly, we implemented a different procedure to these experiments' data. In this different procedure, we focused on the changes of the speed in only incident period and immediately after incident period. In this way we could see and comment discharge.

Lastly, we applied some statistical tests for in depth analysis. Firstly, we applied Anova Single Factor Test. After that Tukey – Kramer Post Hoc Test was applied when there was a need.

Chapter 4

Results and Discussion

4.1 Analysis of Incident Scenarios

Firstly, we analyzed the 135 simulations. We had to choose remarkable ones to see the change correctly. We determined some performance evaluation criteria such as QLEN, VEHS(ALL), TRAVTM(ALL), and SPEEDAVGHARM(ALL) to analyze the graphs [63].

QLEN means Queue Length. The queue length is the maximum distance between the traffic counter and the vehicle that meets the queue conditions defined. It is specified as average queue length: With each time step, the current queue length is measured upstream by the queue counter and the arithmetic mean is thus calculated per time interval. This also includes zero values, if there is no vehicle that meets the queue condition.

VEHS(ALL) means number of vehicles. It is defined as the total number of vehicles in the network at the end of the simulation. It refers to all vehicles in the network that have been recorded during data collection measurement.

TRAVTM(ALL) means travel time. It is defined as average travel time(s) of vehicles in the network. It is related to all vehicles in the network that have been recorded during vehicle travel time measurement.

SPEEDAVGHARM(ALL) means speed. It is defined as the harmonic mean of speed of the vehicles. It refers to all vehicles in the network that have been recorded during data collection measurement.

4.1.1 Impact of Incident Duration on Queue Length

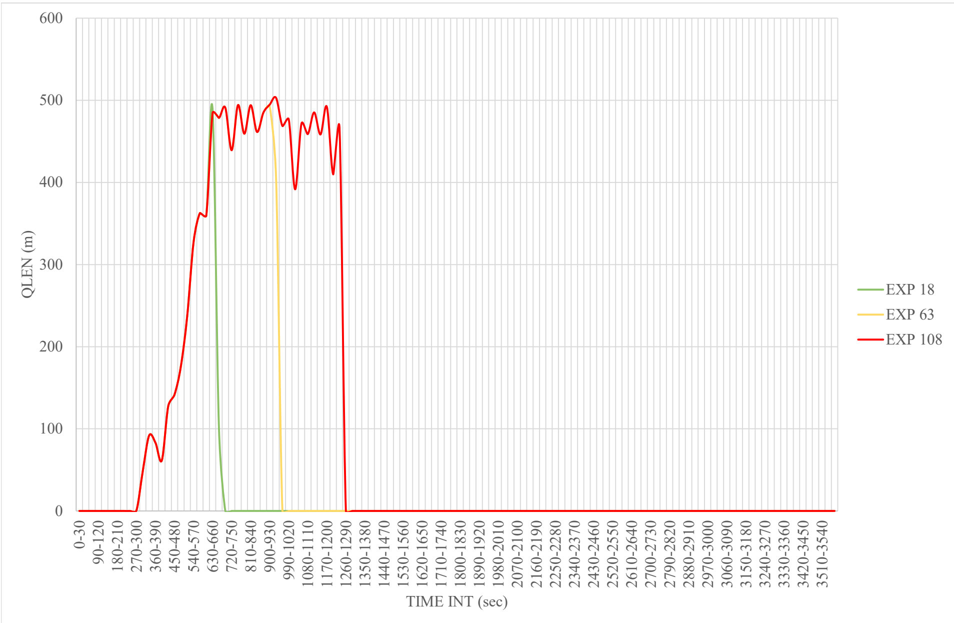

Figure 4.1: QLEN Graph of Incident Duration Scenario Group 1.

When an incident occurs in the 1st lane of a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for incident duration which are 5 minutes (EXP 18), 10 minutes (EXP 63), and 15 minutes (EXP 108) as shown in Figure (4.1). Provided that all other variables are the same, when only different incident durations are identified it is seen that the shape of queue length's graph shows consistency with incident durations. As duration increases, the graph gets longer. When incident starts at 270th second, each experiment's queue length increases from zero to 83 m until 360th second, decreases to 62 m until 390th second, increases to 127 m until 420th second, leaps up to 363 m until 570th second, decreases to 360 m until 600th second.

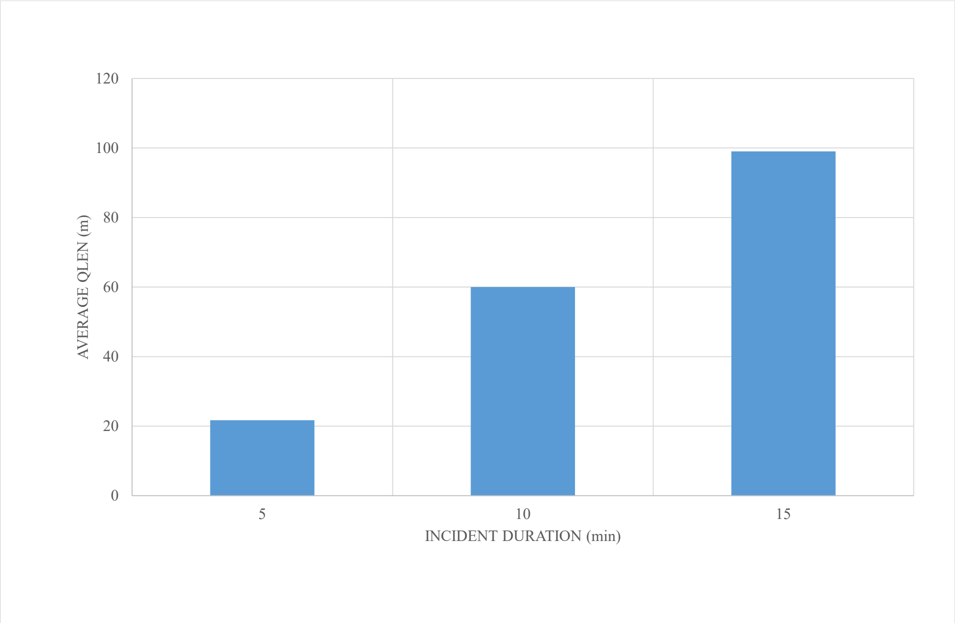

Figure 4.2: AVERAGE QLEN Graph of Incident Duration Scenario Group 1.

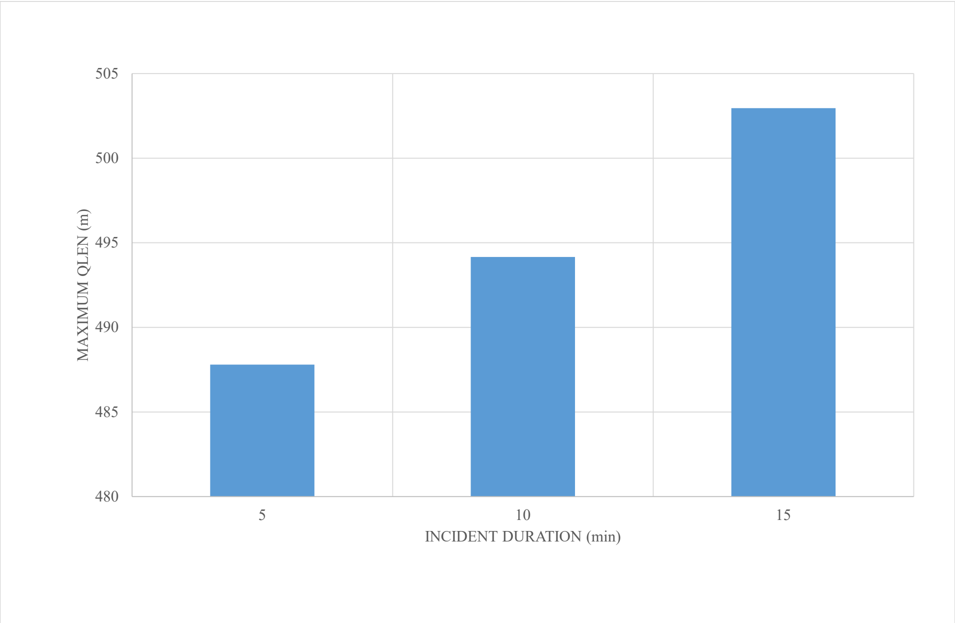

Figure 4.3: MAXIMUM QLEN Graph of Incident Duration Scenario Group 1.

After that EXP 18's queue length increases to 488 m which is its top point until 630th second. EXP 63's queue length and EXP 108's queue length increase to 485 m until 630th second. After 630th second which is a few minutes after the end of the EXP 18's incident, EXP 18's queue length starts to slump to zero until 720th second, and becomes stable until the end of the simulation.

After 630th second EXP 63's queue length and EXP 108's queue length fluctuates between 439 m and 494 m which is their top point until 900th second. After 900th second EXP 63's queue length slumps to zero until 960th second, and becomes stable until the end of the simulation.

After 900th second EXP 108's queue length fluctuates between 392 m and 492 m until 1230th second. After that it slumps to zero until 1290th second, and becomes stable until the end of the simulation. When we look at the average queue length's graph in Figure (4.2) and maximum queue length's graph in Figure (4.3); if duration increases, average queue length and maximum queue length increase.

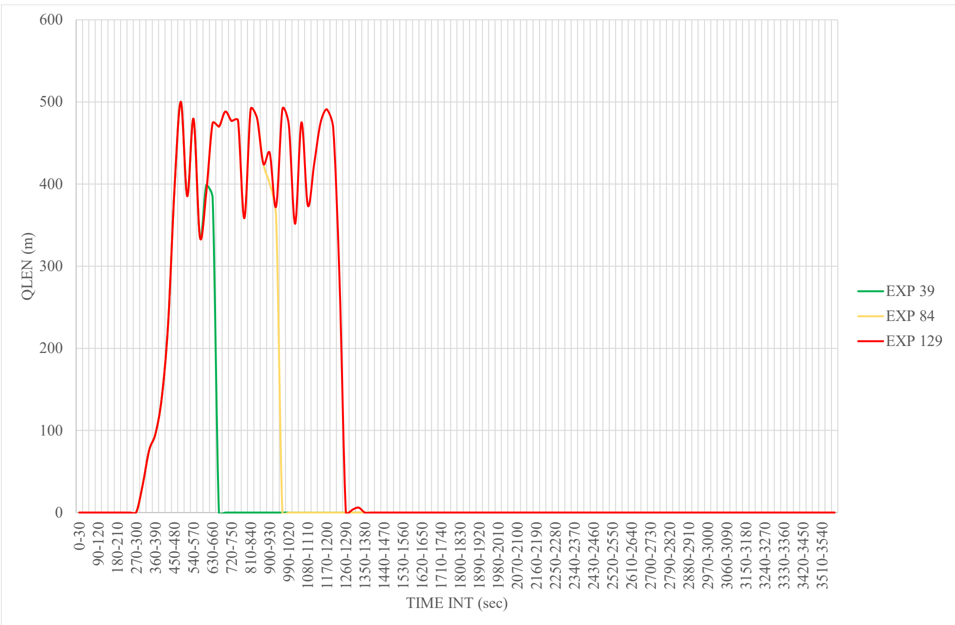

Figure 4.4: QLEN Graph of Incident Duration Scenario Group 2.

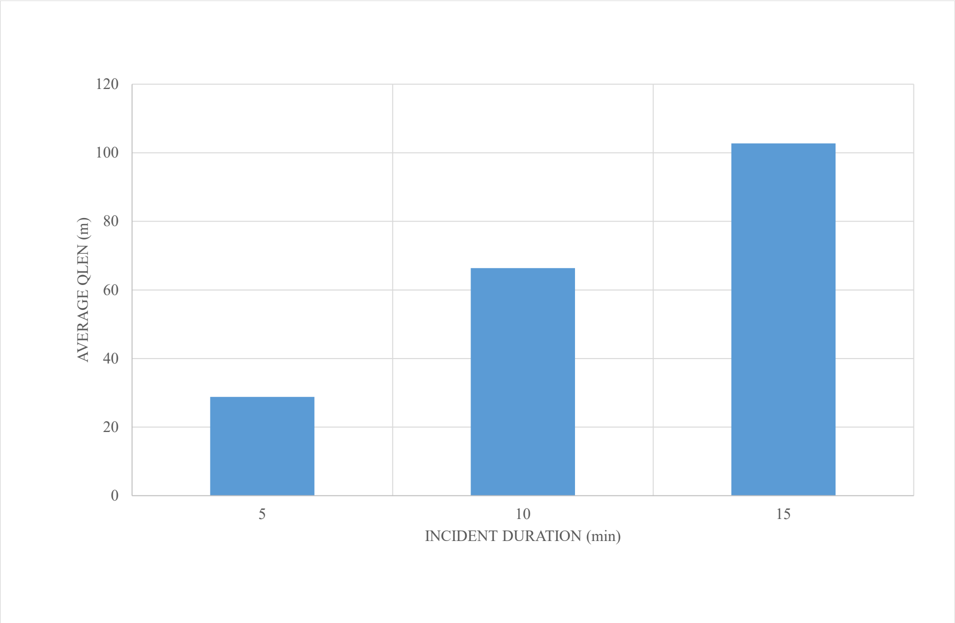

Figure 4.5: AVERAGE QLEN Graph of Incident Duration Scenario Group 2.

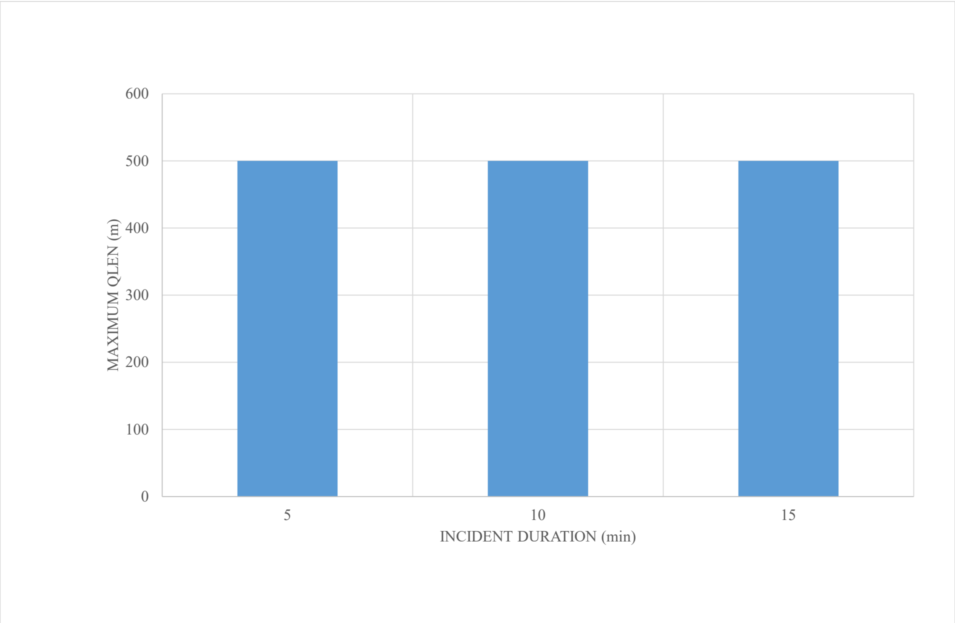

Figure 4.6: MAXIMUM QLEN Graph of Incident Duration Scenario Group 2.

When an incident occurs in the 1st lane of a three-lane road whose lane width is 3,50 m and vehicle input is 2000 veh/lane, we have 3 different experiment scenarios for incident duration which are 5 minutes (EXP 39), 10 minutes (EXP 84), and 15 minutes (EXP 129) as shown in Figure (4.4). When incident starts at 270th second, each experiment's queue length starts to increase continuously to 500 m which is their top point until 480th second. After 480th second they fluctuate between 335 m and 500 m until 600th second. After 600th second which is a few minutes after the end of the EXP 39's incident, EXP 39's queue length slumps to zero until 660th second, and becomes stable until the end of the simulation.

After 600th second EXP 84's queue length and EXP 129's queue length fluctuate between 358 m and 491 m until 900th second. After 900th EXP 84's queue length slumps to zero until 960th second, and becomes stable until the end of the simulation.

After 900th second EXP 129's queue length fluctuates between 352 m and 491 m until 1170th seconds. After 1170th second EXP 129's queue length slumps to zero until 1260th second, and becomes stable until the end of the simulation. When we look at the average queue length's graph in Figure (4.5) and maximum queue length's graph in Figure (4.6); if duration increases, average queue length increases. However maximum queue lengths are all same. It is because of the length of the network.

4.1.2 Impact of Incident Duration on Number of Vehicles

When the same examples are examined, as shown in Figure (4.7), in 2 lanes roads each experiment's number of vehicles continuously increases from 3 vehicles to 26 vehicles until 30th second. After this second there are some fluctuations between 21 vehicles and 29 vehicles until 270th second. After 270th second which is the beginning of incident, each experiment's number of vehicles starts to decrease to 13 vehicles until 360th second, and fluctuates between 11 vehicles and 16 vehicles until 570th second. After 570th second which is a few minutes after the end of the

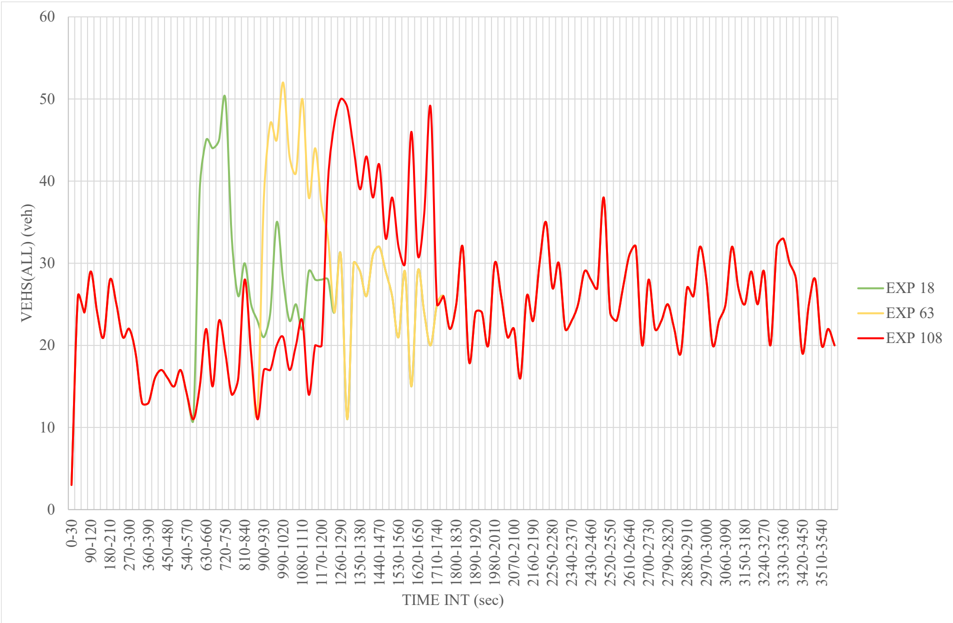

Figure 4.7: VEHS(ALL) Graph of Incident Duration Scenario Group 1.

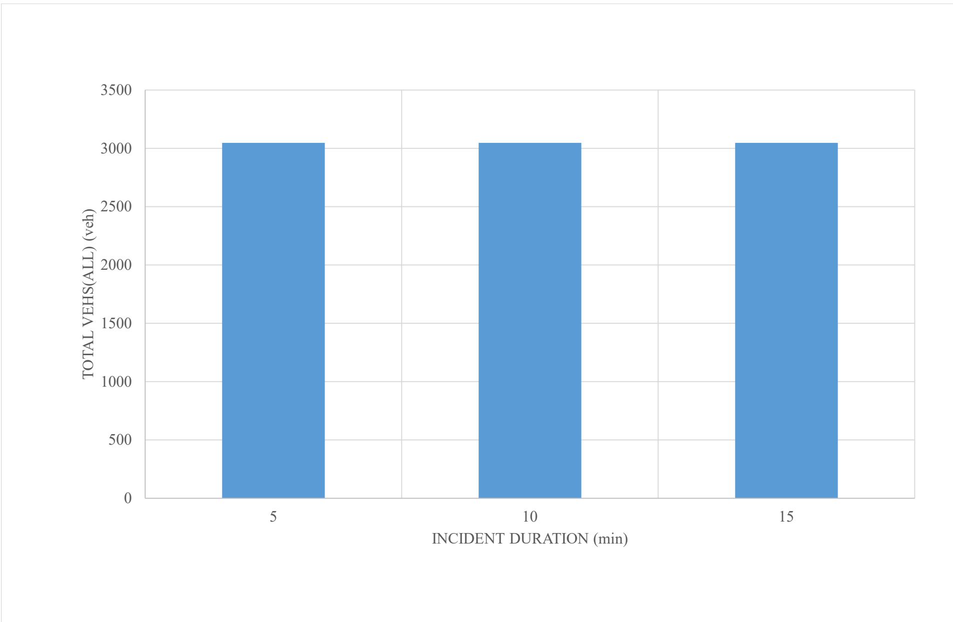

Figure 4.8: TOTAL VEHS(ALL) Graph of Incident Duration Scenario Group 1.

EXP 18's incident, EXP 18's number of vehicles starts to leap up to 45 vehicles until 630th second, decreases to 44 vehicles until 660th second, increases to 50 vehicles which is its top point until 720th second. After 720th second it slumps to 26 vehicles until 780th second, and fluctuates between 21 vehicles and 35 vehicles until 1230th second. EXP 18's number of vehicles merges with EXP 63's number of vehicles at 1200th second.

EXP 63's number of vehicles fluctuates between 11 vehicles and 28 vehicles from 570th second to 870th second. After 870th second which is a few minutes after the end of the EXP 63's incident, EXP 63's number of vehicles starts to leap up to 47 vehicles until 930th second, decreases to 45 vehicles until 960th second, increases to 52 vehicles until 990th second. After 990th second it fluctuates between 38 vehicles and 52 vehicles until 1140th second, slumps to 24 vehicles until 1230th second, fluctuates between 11 vehicles and 31 vehicles until 1740th second. After 1740th second EXP 63's number of vehicles merges with EXP 108's number of vehicles.

EXP 108's number of vehicles fluctuates between 11 vehicles and 23 vehicles from 870th second to 1170th second. After 1170th second which is a few minutes after the end of the EXP 108's incident, EXP 108's number of vehicles starts to leap up to 50 vehicles until 1260th second. After 1260th second, it decreases to 39 vehicles until 1350th second, fluctuates between 26 vehicles and 49 vehicles until 1740th second, between 16 vehicles and 38 vehicles from 1740th second to the end of the simulation. When we look at the total number of vehicles' graph in Figure (4.8), they are all same.

When the same examples are examined, as shown in Figure (4.9), in 3 lanes roads all experiments' numbers of vehicles have same value until 570th second. Firstly, each experiment's number of vehicles continuously increases from 7 vehicles to 55 vehicles until 60th second. After this second there are some fluctuations between 40 vehicles and 61 vehicles until 180th second. After 180th second they start to

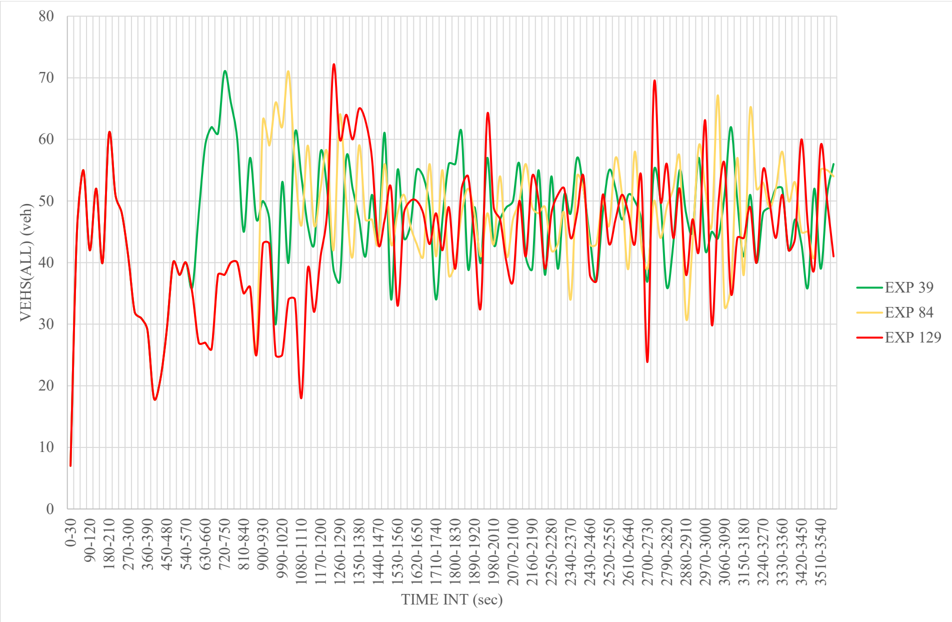

Figure 4.9: VEHS(ALL) Graph of Incident Duration Scenario Group 2.

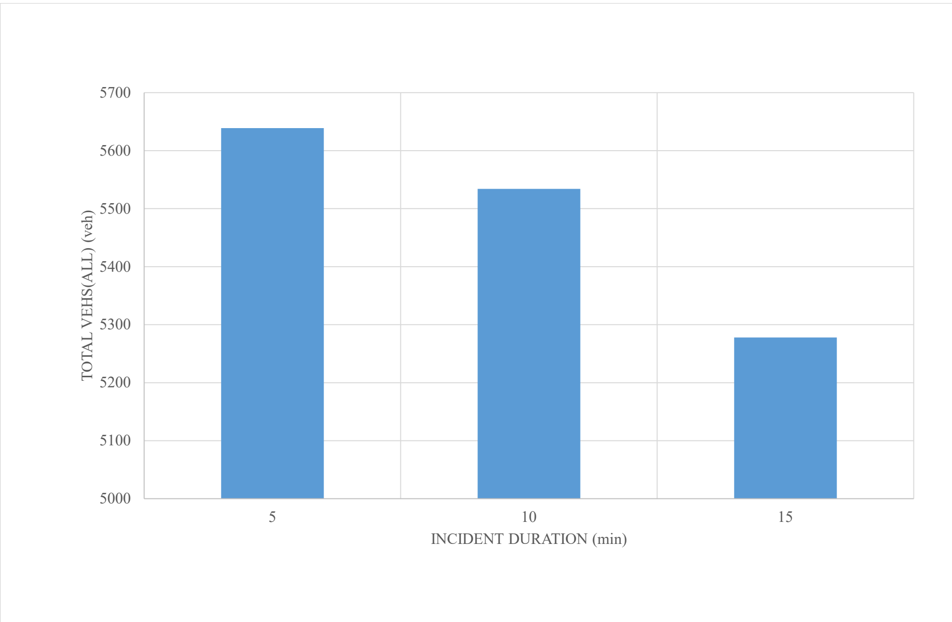

Figure 4.10: TOTAL VEHS(ALL) Graph of Incident Duration Scenario Group 2.

decrease to 48 vehicles until 240th second. After 240th second which is the beginning of the incident they slump to 32 vehicles until 300th second, and continue to decrease to 18 vehicles until 390th second. After 390th second they start to increase to 40 vehicles until 480th second, and fluctuates between 38 vehicles and 40 vehicles until 540th second. At 570th second which is a few minutes after the end of the EXP 39's incident, EXP 39's number of vehicles leaps up to 62 vehicles until 660th second, decreases to 61 vehicles until 690th second, increases to 71 vehicles which is its top point until 720th second. After 720th EXP 39's number of vehicles slumps to 45 vehicles until 810th second, and fluctuates between 30 vehicles and 62 vehicles until the end of the simulation.

From 540th second to 870th second EXP 84's number of vehicles and EXP 129's number of vehicles fluctuate between 25 vehicles and 40 vehicles. After 870th second which is a few minutes after the end of the EXP 84's incident, EXP 84's number of vehicles leaps up to 63 vehicles until 900th second, and it continues to increase to 71 vehicles which is its top point until 1020th second with some fluctuations. After 1020th second it slumps to 46 until 1080th second, and fluctuates between 34 vehicles and 57 vehicles until 2850th second, between 31 vehicles and 67 vehicles from 2850th second to the end of simulation.

From 870th second to 1140th second EXP 129's number of vehicles fluctuate between 18 vehicles and 43 vehicles. After 1140th second which is a few minutes after the end of the EXP 129's incident, EXP 129's number of vehicles leaps up to 72 vehicles which is its top point until 1230th second, decreases to 60 vehicles until 1260th second, fluctuates between 60 vehicles and 65 vehicles until 1410th second, slumps to 43 vehicles until 1440th second, fluctuates between 33 vehicles and 54 vehicles until 1920th second, leaps up to 64 vehicles until 1950th second, decreases to 49 vehicles until 1980th second, fluctuates between 37 vehicles and 54 vehicles until 2670th second, between 24 vehicles and 69 vehicles from 2670th second to the end of the simulation. When we look at the total number of vehicles' graph in Figure (4.10); if incident duration increases, total number vehicles decreases.

4.1.3 Impact of Incident Duration on Travel Time

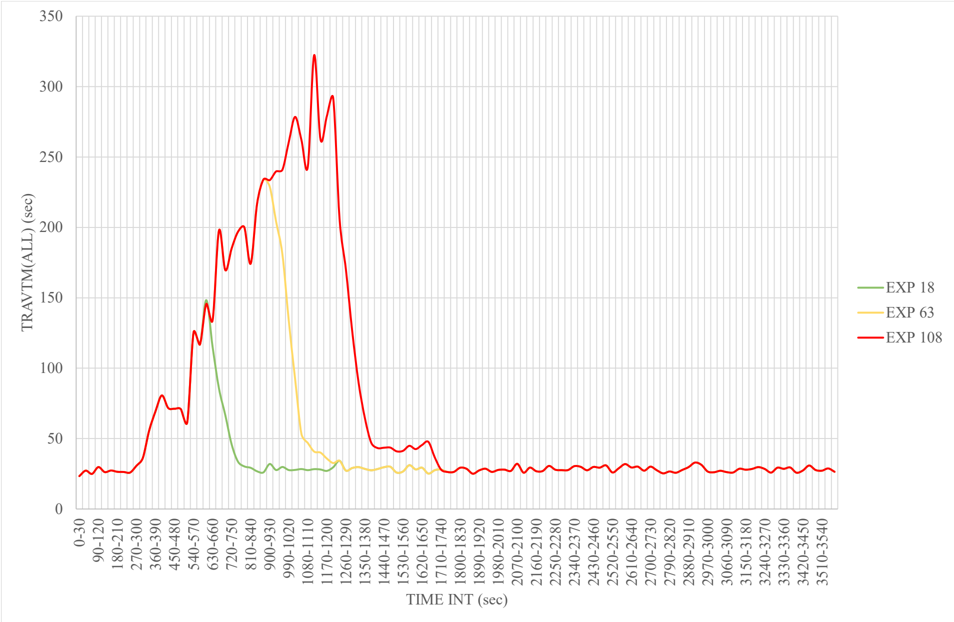

Figure 4.11: TRAVTM(ALL) Graph of Incident Duration Scenario Group 1.

When the same examples are examined, as shown in Figure (4.11), in 2 lanes roads all experiments' travel times have same value until 630th second. Each experiment's travel time is stable until 300th second which is the beginning of the incident. After that each experiment's travel time continuously increases from 31 seconds to 81 seconds until 390th second. After that they decrease to 71 seconds until 450th second, and becomes stable until 480th second. After that it decreases to 62 seconds until 510th second. After 510th second they leap up 125 seconds until 540th second, and continue to increase to 146 seconds with some fluctuations until 600th second. After 600th second which is a few minutes after the end of the EXP 18's incident, EXP 18's travel time slumps to 30 seconds until 780th second, and becomes stable until the end of the simulation.

After 600th second, EXP 63's travel time and EXP 108's travel time decrease to 134 seconds until 630th second, increase to 198 seconds until 660th second,

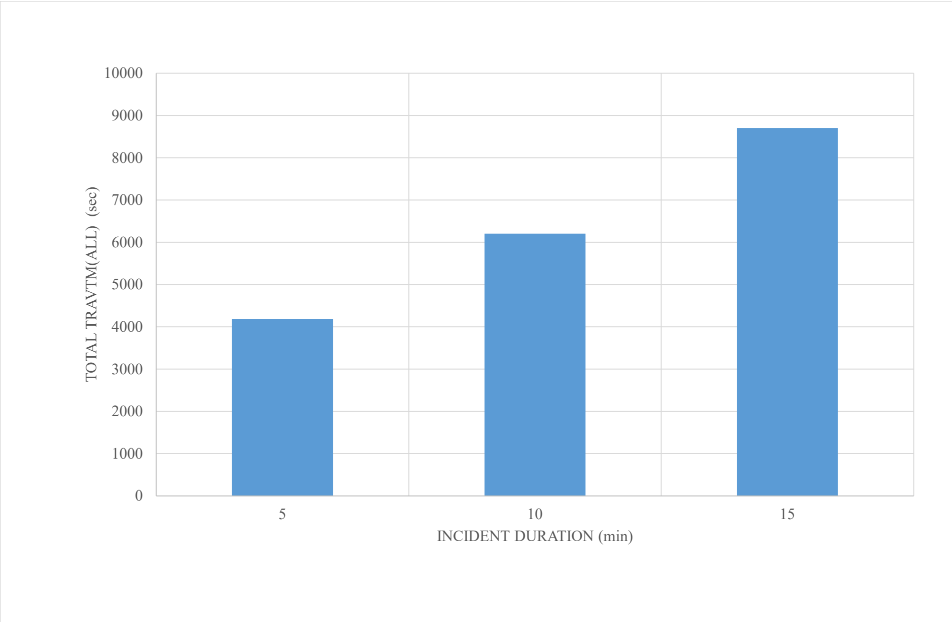

Figure 4.12: TOTAL TRAVTM(ALL) Graph of Incident Duration Scenario Group 1.

fluctuate between 170 seconds and 198 seconds until 810th second, and increase to 234 seconds until 900th second. After 900th second which is a few minutes after the end of the EXP 63's incident, EXP 63's travel time slumps to 47 seconds until 1080th second, continues to decrease to 29 seconds until 1290th second, and becomes stable until the end of the simulation.

After 900th second EXP 108's travel time increases to 278 seconds until 1020th second, decreases to 243 seconds until 1080th second, increases to 322 seconds until 1110th second, decreases to 262 seconds until 1140th second, increases to 292 seconds until 1200th second. After 1200th second which is a few minutes after the end of the EXP 108's incident, EXP 108's travel time slumps to 43 seconds until 1410th second, increases to 48 seconds until 1650th second, decreases to 26 seconds until 1740th second, and becomes stable until the end of the simulation. When we look at the total travel time's graph in Figure (4.12); if incident duration increases, total travel time increases.

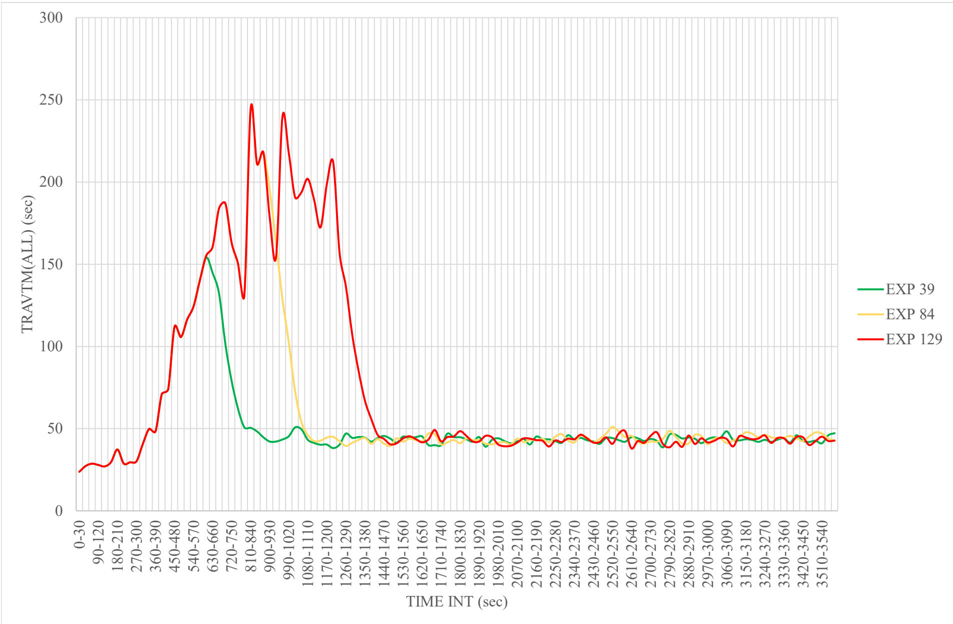

Figure 4.13: TRAVTM(ALL) Graph of Incident Duration Scenario Group 2.

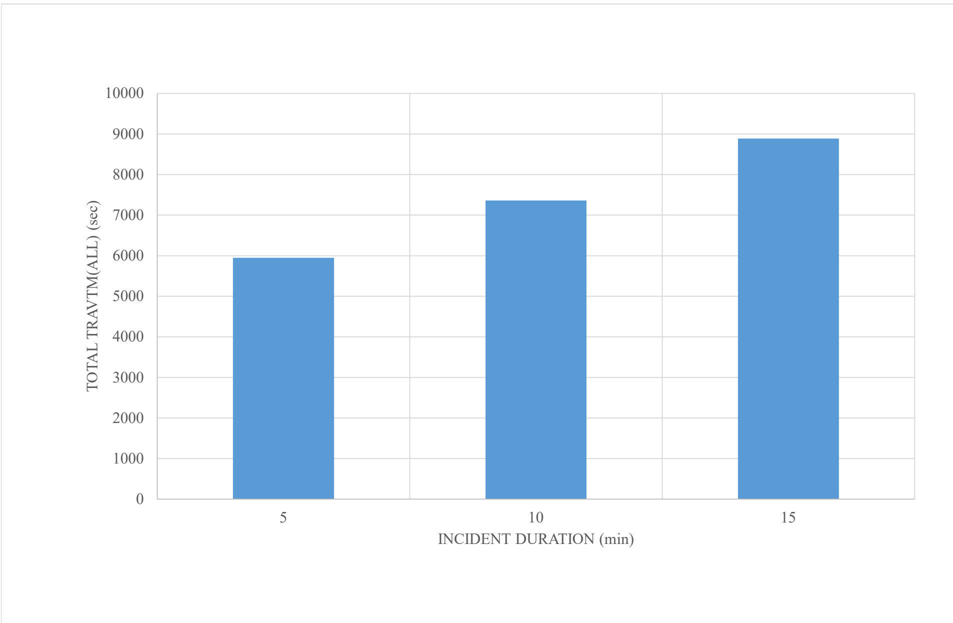

Figure 4.14: TOTAL TRAVTM(ALL) Graph of Incident Duration Scenario Group 2.

When the same examples are examined, as shown in Figure (4.13), in 3 lanes roads all experiments' travel times have same value until 630th second. We can say that each experiment's travel time is stable with 1 exception until 270th second which is the beginning of the incident. After 270th second they start to increase to 155 seconds with some fluctuations until 600th second. After 630th second which is a few minutes after the end of the EXP 39's incident, EXP 39's travel time slumps to 51 seconds until 870th second, and becomes stable with some little fluctuations until the end of the simulation.

After 630th second other experiments' travel times increase to 184 seconds until 660th second, decrease to 131 seconds until 780th second, and leap up to 245 seconds until 810th second. After 810th second they decrease to 211 seconds until 840th second, increase to 218 seconds until 870th second. After 870th second which is a few minutes after the end of the EXP 84's incident, EXP 84's travel time slumps to 42 seconds until 1110th second, and becomes stable with some little fluctuations until the end of the simulation.

After 870th second EXP 129's travel time decreases to 155 seconds until 930th second, leaps up to 240 seconds until 960th second, decreases to 191 seconds until 1020th second, increases to 202 seconds until 1080th second, decreases to 172 seconds until 1140th second, and increases to 212 seconds until 1200th second. After 1200th second which is a few minutes after the end of the EXP 129's incident, EXP 129's travel time slumps to 44 seconds until 1440th second, and becomes stable with some little fluctuations until the end of the simulation. When we look at the total travel time's graph in Figure (4.14); if incident duration increases, total travel time increases.

4.1.4 Impact of Incident Duration on Speed

When the same examples are examined, as shown in Figure (4.15), in 2 lanes roads all experiments' speeds have same value until 600th second. They start to decrease from 122 km/h to 106 km/h until 30th second, fluctuate between 96 km/h and

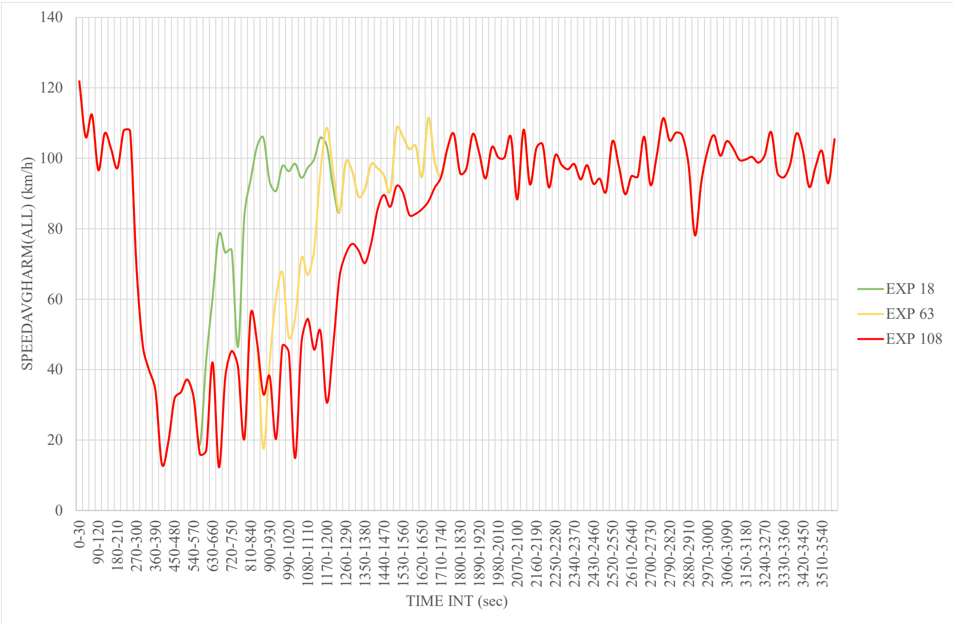

Figure 4.15: SPEEDAVGHARM(ALL) Graph of Incident Duration Scenario Group 1.

112 km/h until 270th second. After 270th second which is the beginning of the incident they slump to 40 km/h until 330th second, and continue to decrease to 13 km/h until 390th second. After 390th second they increase to 32 km/h until 540th second, and decrease to 16 km/h until 570th second. After 570th second which is a few minutes after the end of the EXP 18's incident, EXP 18's speed leaps up to 78 km/h until 660th second, decreases to 73 km/h until 690th second, increases to 74 km/h until 720th second, decreases to 46 km/h until 750th second, leaps up to 106 km/h until 870th second. After 870th second it decreases to 93 km/h until 900th second, and fluctuates between 85 km/h and 111 km/h until 2760th second, between 78 km/h and 107 km/h from 2760th second to the end of the simulation.

After 570th second other experiments' speeds fluctuate between 12 km/h and 56 km/h until 840th second. After 840th second EXP 63's speed decreases to 18 km/h until 870th second. After 870th second which is a few minutes after the

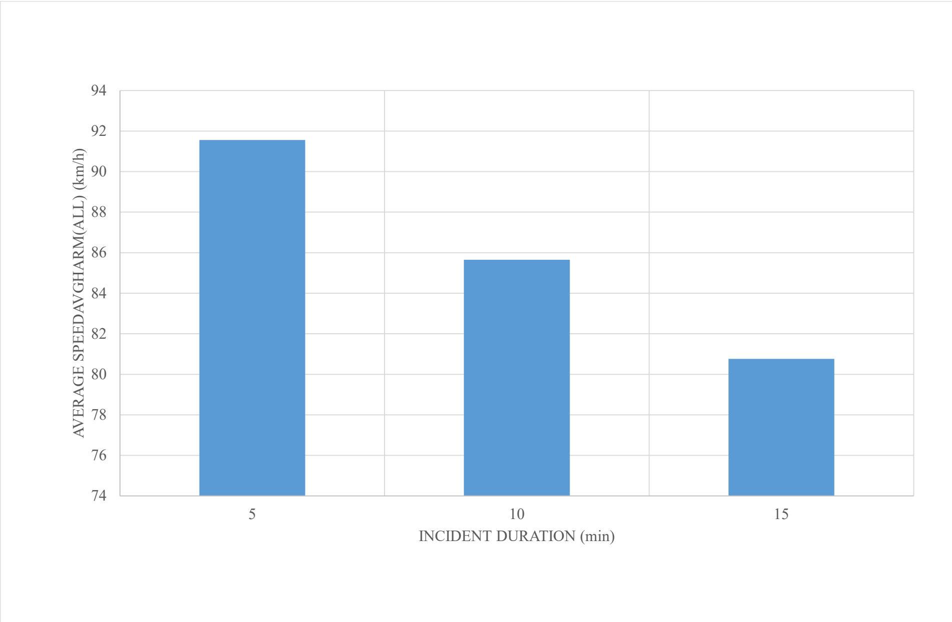

Figure 4.16: AVERAGE SPEEDAVGHARM(ALL) Graph of Incident Duration Scenario Group 1.

end of the EXP 63's incident, EXP 63's speed leaps up to 68 km/h until 960th second, decreases to 49 km/h until 990th second, increases to 72 km/h until 1050th second, decreases to 67 km/h until 1080th second, and leaps up to 109 km/h until 1170th second. After 1170th second it fluctuates between 85 km/h and 111 km/h until 2760th second, between 78 km/h and 107 km/h from 2760th second to the end of the simulation.

After 840th second EXP 108's speed fluctuates between 15 km/h and 54 km/h until 1170th second. After 1170th second which is a few minutes after the end of the EXP 108's incident, EXP 108's speed increases to 74 km/h until 1320th second, decreases to 70 km/h until 1350th second, increases to 90 km/h until 1440th second, decreases to 86 km/h until 1470th second, increases to 90 km/h until 1530th second, decreases to 84 km/h until 1590th second, and increases to 107 km/h until 1770th second. After 1770th second it fluctuates between 88 km/h and 111 km/h until 2760th second, between 78 km/h and 107 km/h from

2760th second to the end of the simulation. When we look at the average speed's graph in Figure (4.16); if incident duration increases, average speed decreases.

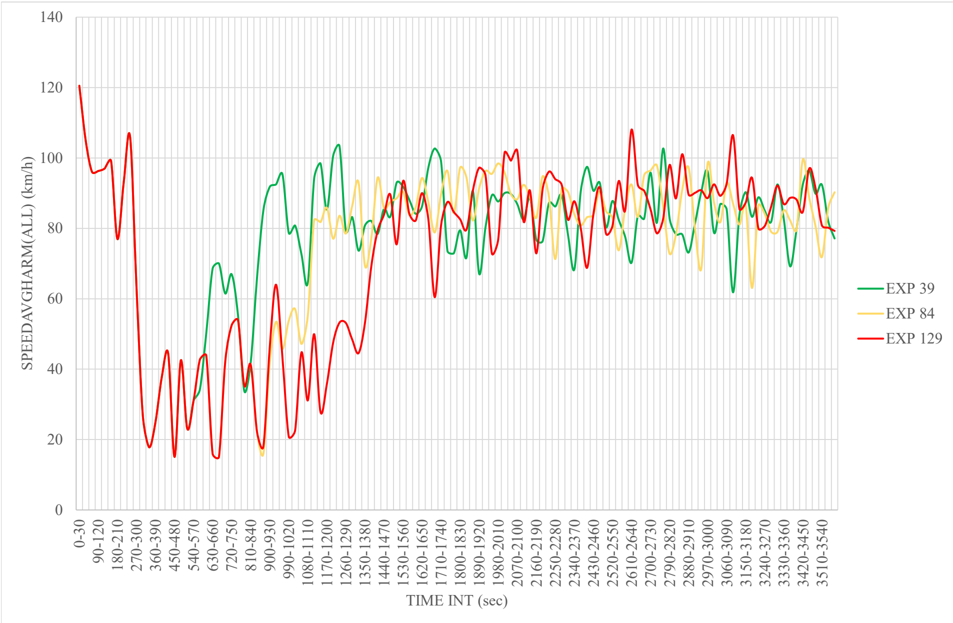

Figure 4.17: SPEEDAVGHARM(ALL) Graph of Incident Duration Scenario Group 2.

When the same examples are examined, as shown in Figure (4.17), in 3 lanes roads all experiments' speeds have same value until 540th second. They decrease from 121 km/h to 96 km/h until 60th second, increase to 97 km/h until 120th second, decrease to 77 km/h until 180th second, and increase to 106 km/h until 240th second. After 240th second which is the beginning of the incident they slump to 18 km/h until 330th second. After 330th second they fluctuate between 15 km/h and 44 km/h until 540th second. After 540th second which is a few minutes after the end of the EXP 39's incident, EXP 39's speed leaps up to 70 km/h until 660th second, decreases to 62 km/h until 690th second, increases to 67 km/h until 720th second, slumps to 34 km/h until 780th second, and then leaps up to 95 km/h until 960th second. After 960th second it fluctuates between 62 km/h and 103 km/h until the end of the simulation.

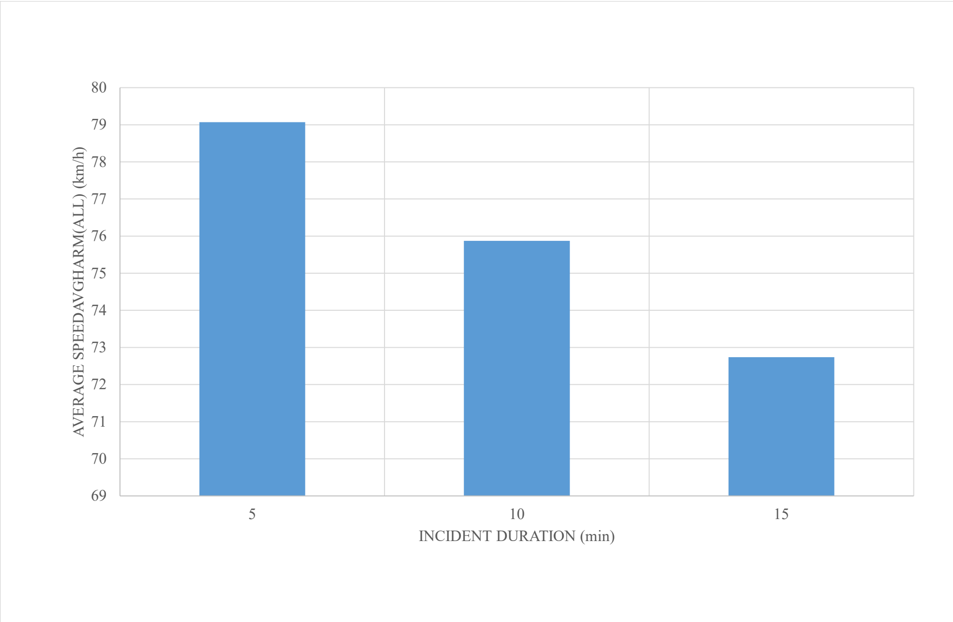

Figure 4.18: AVERAGE SPEEDAVGHARM(ALL) Graph of Incident Duration Scenario Group 2.

After 540th second other experiments' speeds fluctuate between 16 km/h and 52 km/h until 870th second. After 870th second which is a few minutes after the end of the EXP 84's incident, EXP 84's speed leaps up to 54 km/h until 930th second, fluctuates between 46 km/h and 57 km/h until 1050th second, leaps up to 82 km/h until 1110th second, and fluctuates between 63 km/h and 98 km/h until the end of the simulation.

After 870th second EXP 129's speed increases to 64 km/h until 930th second, decreases to 21 km/h until 990th second, fluctuates between 22 km/h and 50 km/h until 1170th second. After 1170th second which is a few minutes after the end of the EXP 129's incident, EXP 129's speed increases to 53 km/h until 1260th second, decreases to 45 km/h until 1320th second, and then leaps up to 90 km/h until 1470th second. After 1470th second it fluctuates between 60 km/h and 108 km/h until the end of the simulation. When we look at the average speed's graph in Figure (4.18); if incident duration increases, average speed decreases.

4.1.5 Impact of Vehicle Input on Queue Length

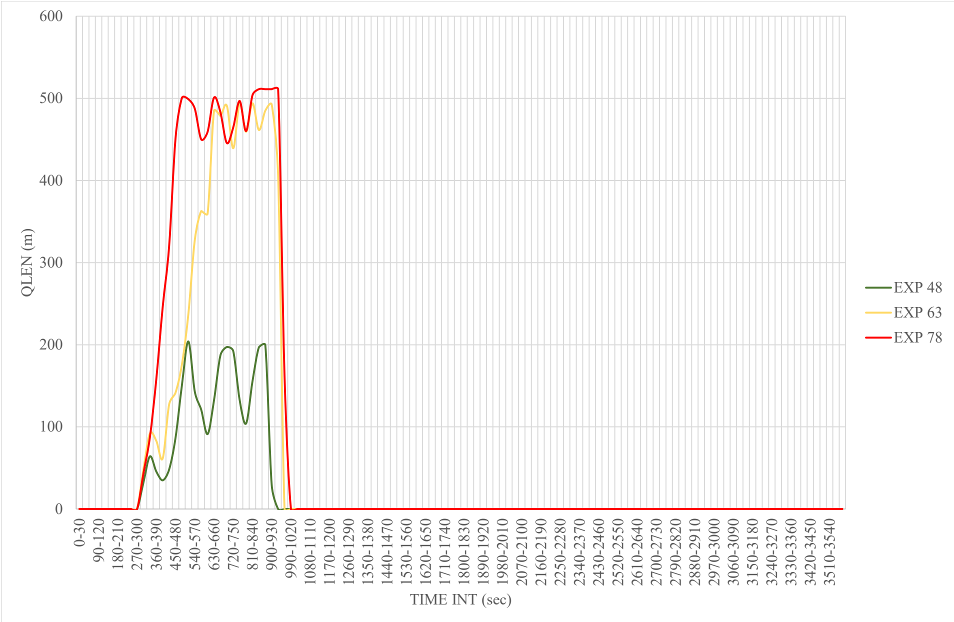

Figure 4.19: QLEN Graph of Vehicle Input Scenario Group 1.

When an incident whose duration is 10 minutes occurs in the 1st lane of a two-lane road whose lane width is 3,50 m, we have 3 different experiment scenarios for vehicle input which are 1000 veh/lane (EXP 48), 1500 veh/lane (EXP 63), and 2000 veh/lane (EXP 78) as shown in FİgURE (4.19). Provided that all other variables are the same, when only different vehicle inputs are used, in 2 lanes roads, after 270th second which is the beginning of the incident, EXP 48's queue length starts to increase with some fluctuations. It reaches its top point 210 m at 510th second. After that it continues to fluctuate between 90 m and 210 m values until 870th second which is the end of the incident. After 870th second it slumps to zero until 930th second and becomes stable until the end of the simulation.

After 270th second EXP 63's queue length starts to increase with some fluctuations. It reaches its top point 480 m at 630th second. After that it continues to fluctuate between 450 m and 500 m values until 900th second which is the

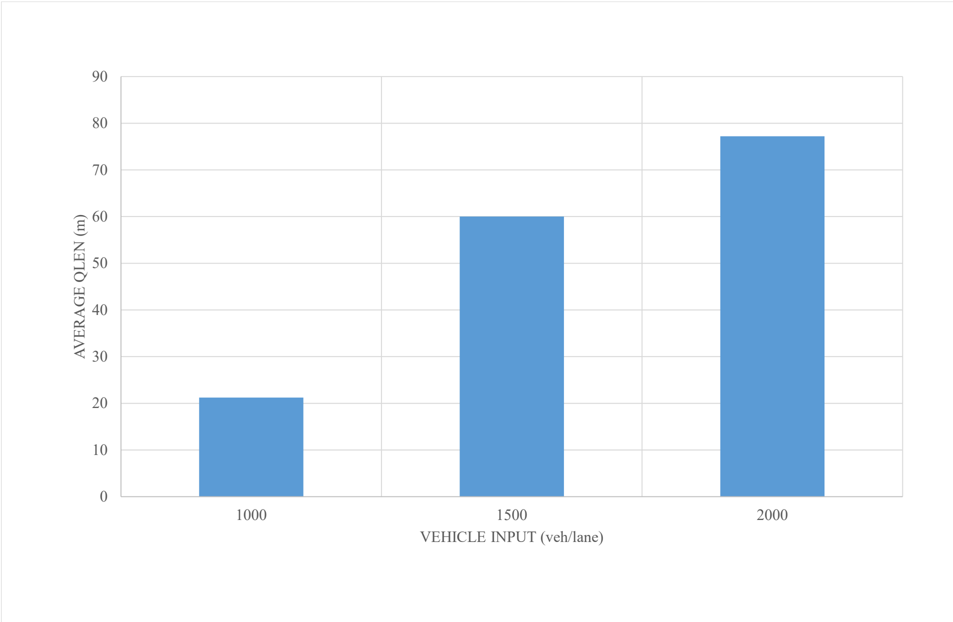

Figure 4.20: AVERAGE QLEN Graph of Vehicle Input Scenario Group 1.

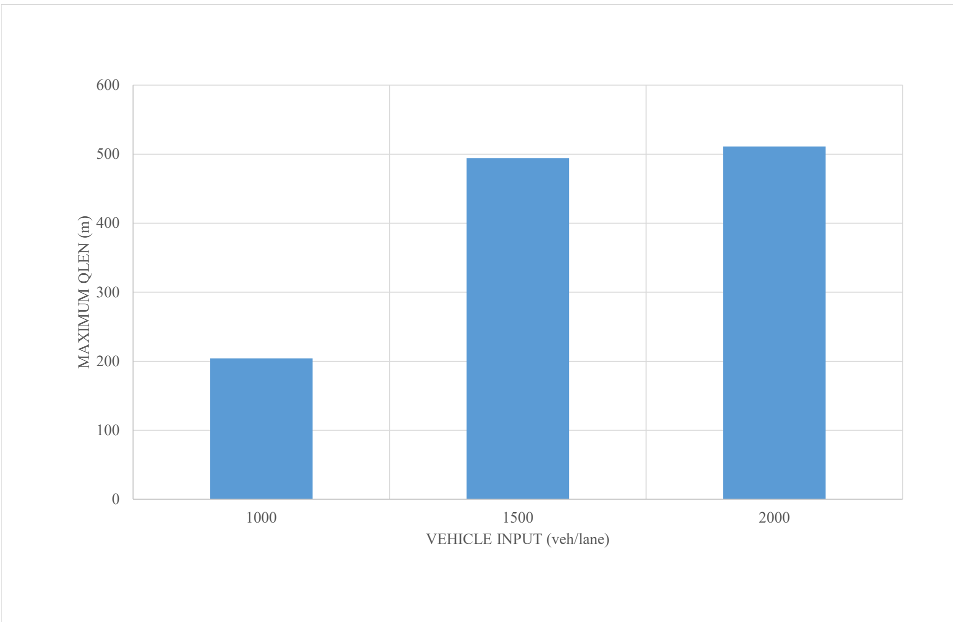

Figure 4.21: MAXIMUM QLEN Graph of Vehicle Input Scenario Group 1.

end of the incident. After 900th second it slumps to zero until 960th second and becomes stable until the end of the simulation.

After 270th second EXP 78's queue length continuously increases. It reaches 500 m at 510th second. It reaches 500 m faster than EXP 63's queue length. After that it fluctuates between 460 m and 510 m values until 900th second which is the end of the incident. After 900th second it slumps to zero until 1020th second and becomes stable until the end of the simulation. When we look at the average queue length's graph in Figure (4.20) and maximum queue length's graph in Figure (4.21); if vehicle input increases, average queue length and maximum queue length increase.

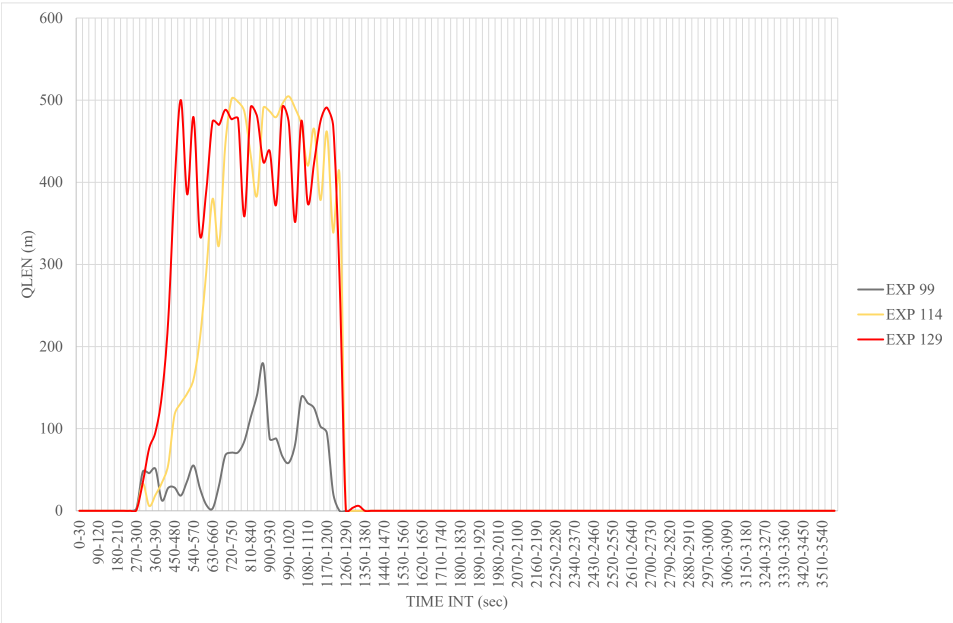

Figure 4.22: QLEN Graph of Vehicle Input Scenario Group 2.

When an incident whose duration is 15 minutes occurs in the 1st lane of a three-lane road whose lane width is 3,50 m, we have 3 different experiment scenarios for vehicle input which are 1000 veh/lane (EXP 99), 1500 veh/lane (EXP 114), and 2000 veh/lane (EXP 129) as shown in Figure (4.22). Provided that all other variables are the same, when only different vehicle inputs are used, in 3 lanes

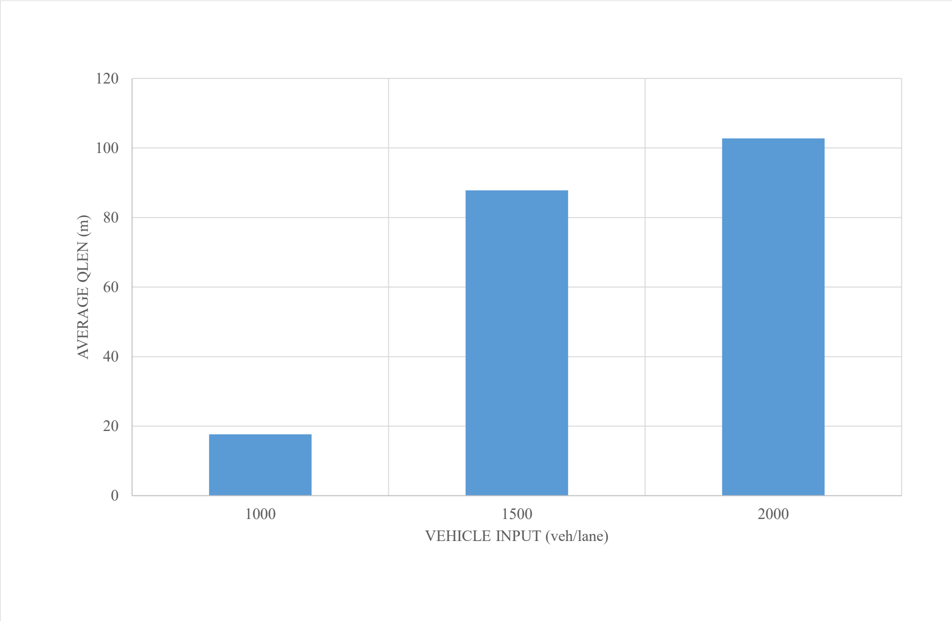

Figure 4.23: AVERAGE QLEN Graph of Vehicle Input Scenario Group 2.

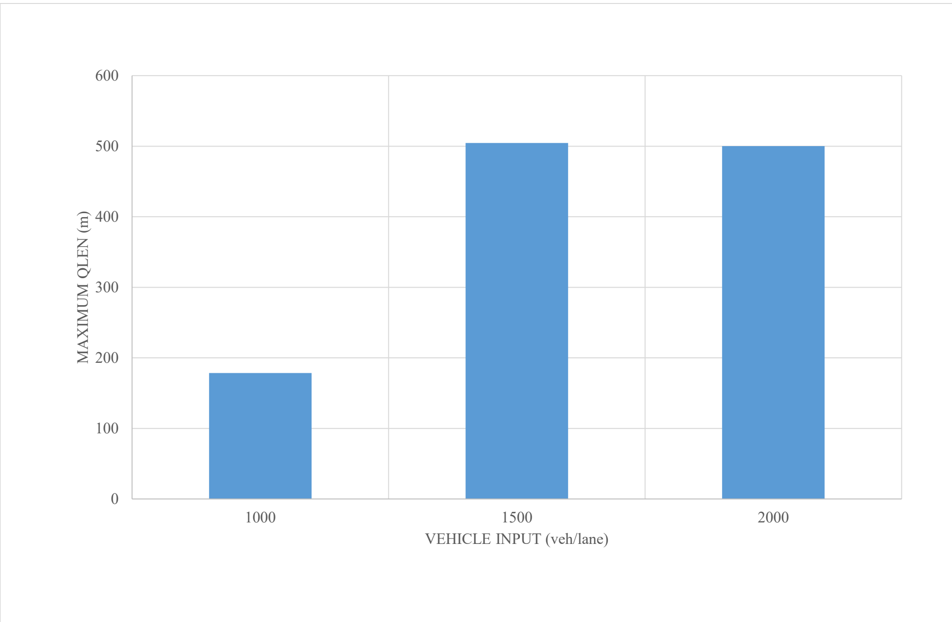

Figure 4.24: MAXIMUM QLEN Graph of Vehicle Input Scenario Group 2.

roads, after 270th second which is the beginning of the incident, EXP 99's queue length increases until 300th second. After that it fluctuates between 28 m and 36 m values until 510th second. After 510th second it decreases to 7 m until 600th second. After 600th second it continuously increases to 70 m until 720th second and becomes stable until 750th second. After 750th second it continuously increases. It reaches its top point 178 m at 870th second. After 870th second it starts to decrease with some fluctuations until 960th second. After 960th second it starts to increase until 1080th second. After 1080th second it starts to decrease with some fluctuations until 1170th second which is the end of the incident. After 1170th second it continuously decreases to zero until 1230th second and becomes stable until the end of the simulation.

After 270th second EXP 114's queue length starts to increase with some fluctuations. It reaches its top point 500 m at 720th second. After that it continues to fluctuate between 380 m and 500 m values until 1170th second which is the end of the incident. After 1170th second it decreases to zero with 1 exception until 1290th second and becomes stable until the end of the simulation.

After 270th second EXP 129's queue length continuously increases. It reaches 500 m at 480th second. It reaches 500 m faster than EXP 114's queue length. After that it fluctuates between 335 m and 510 m values until 1170th second which is the end of the incident. After 1170th second it slumps to zero until 1290th second and becomes stable until the end of the simulation. When we look at the average queue length's graph in Figure (4.23) and maximum queue length's graph in Figure (4.24); if vehicle input increases, average queue length increases. However maximum queue length of EXP 114 is a little bit bigger than EXP 129's maximum queue length. That's why we can not say same thing for maximum queue length. The sort of maximum queue length from the highest to the lowest is 1500 >2000 >1000.

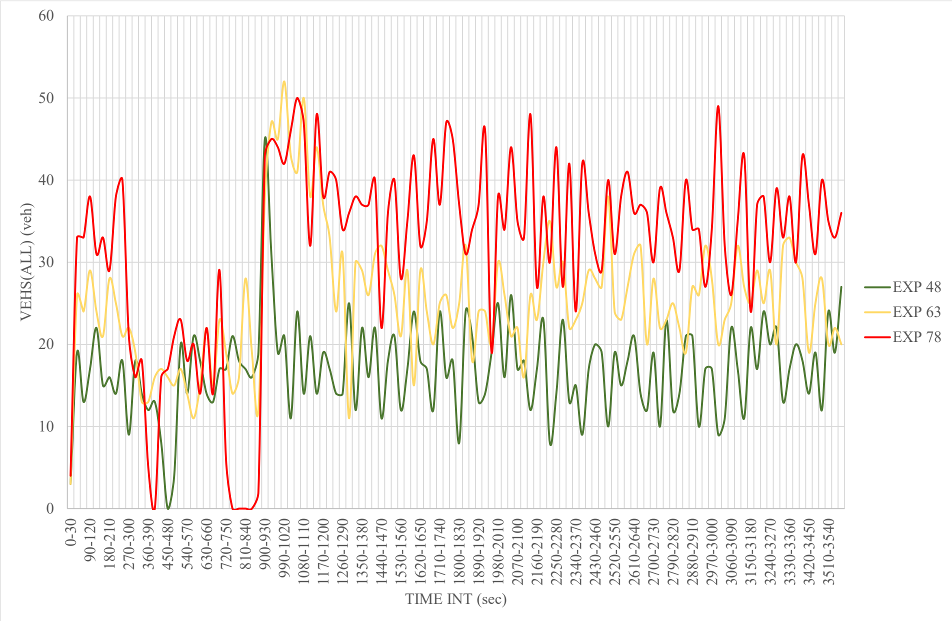

Figure 4.25: VEHS(ALL) Graph of Vehicle Input Scenario Group 1.

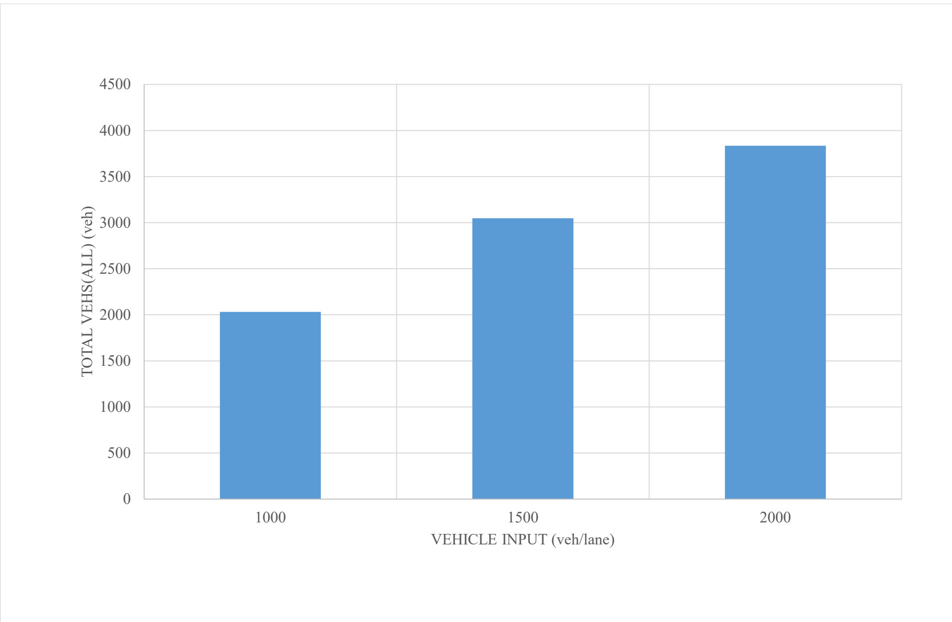

Figure 4.26: TOTAL VEHS(ALL) Graph of Vehicle Input Scenario Group 1.

4.1.6 Impact of Vehicle Input on Number of Vehicles

When the same examples are examined, as shown in Figure (4.25), in 2 lanes roads EXP 48's number of vehicles firstly increases to 20 vehicles until 30th second and starts to fluctuate between 10 vehicles and 20 vehicles until 270th second which is the beginning of the incident. After 270th second it starts to decrease to zero with some fluctuations until 450th second. After that it increases to 20 vehicles until 480th second and starts to fluctuate between 15 vehicles and 20 vehicles. After 870th second which is the end of the simulation, EXP 48's number of vehicles leaps up to 45 vehicles until 900th second. After 900th second it decreases to 19 vehicles until 960th second and starts to fluctuate between 8 vehicles and 26 vehicles until the end of the simulation.

EXP 63's number of vehicles firstly increases to 25 vehicles until 30th second and starts to fluctuate between 20 vehicles and 30 vehicles until 300th second. After 300th second it decreases and fluctuates between 11 vehicles and 28 vehicles until 870th second. After 870th second EXP 63's number of vehicles leaps up to 52 vehicles until 990th second. After 990th second it decreases to 24 vehicles until 1230th second and starts to fluctuate between 11 vehicles and 35 vehicles until the end of the simulation.

EXP 78's number of vehicles firstly increases to 33 vehicles until 30th second and starts to fluctuate between 29 vehicles and 40 vehicles until 240th second. After 240th second it starts to decrease to zero with some fluctuations until 390th second. After that it increases to 23 vehicles until 510th second and starts to fluctuate between 14 vehicles and 29 vehicles. After 690th second it slumps to zero until 750th second and becomes stable until 840th second. After 840th second which is the end of the simulation, EXP 78's number of vehicles leaps up to 45 vehicles until 930th second. After 930th second it fluctuates between 19 vehicles and 50 vehicles until the end of the simulation. When we look at the total number of vehicles' graph in Figure (4.26); if vehicle input increases, total number of vehicles increases.

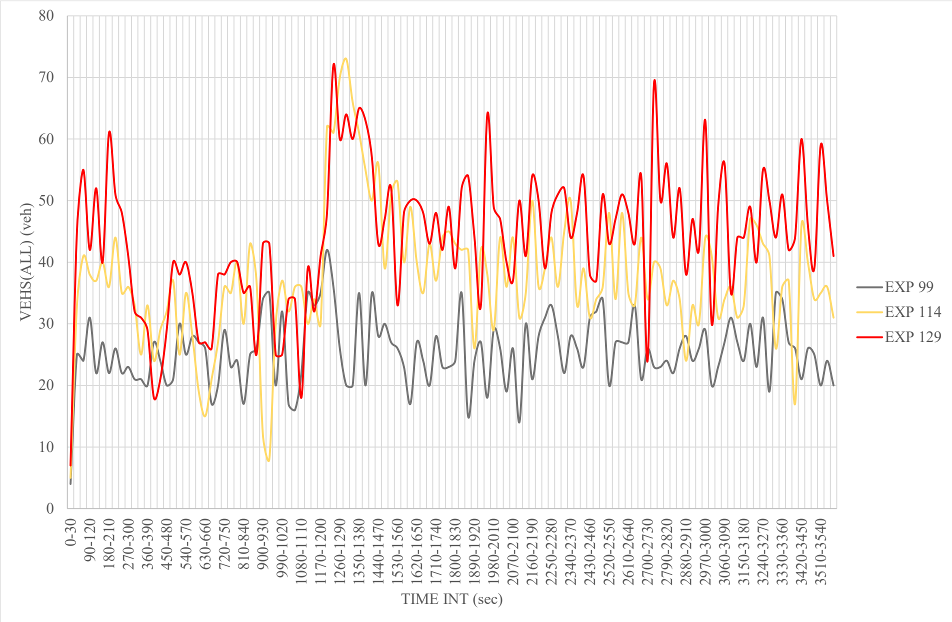

Figure 4.27: VEHS(ALL) Graph of Vehicle Input Scenario Group 2.

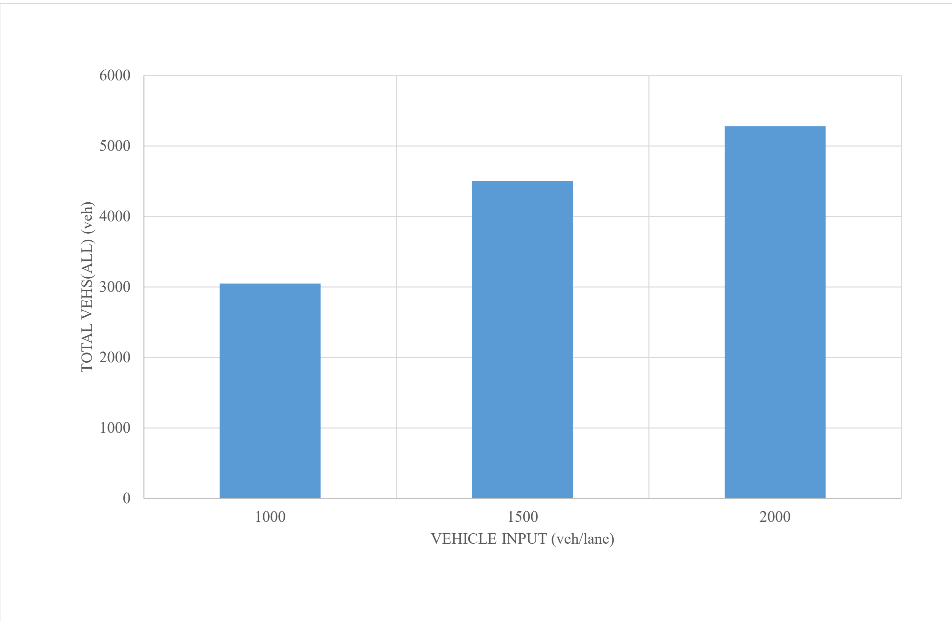

Figure 4.28: TOTAL VEHS(ALL) Graph of Vehicle Input Scenario Group 2.

When the same examples are examined, as shown in Figure (4.27), in 3 lanes roads EXP 99's number of vehicles firstly increases to 25 vehicles until 30th second and starts to fluctuate between 23 vehicles and 31 vehicles until 270th second which is the beginning of the incident. After 270th second it fluctuates between 17 vehicles and 34 vehicles until 1170th second which is the end of the incident. After that it increases to 42 vehicles until 1200th second and starts to fluctuate between 14 vehicles and 42 vehicles until the end of the simulation.

EXP 114's number of vehicles firstly increases to 41 vehicles until 60th second and starts to fluctuate between 36 vehicles and 44 vehicles until 270th second. After 270th second it decreases and fluctuates between 8 vehicles and 43 vehicles until 1170th second. After 1170th second EXP 114's number of vehicles leaps up to 62 vehicles until 1200th second and increases to 73 vehicles until 1290th second. After 1290th second it decreases to 50 vehicles until 1410th second and starts to fluctuate between 17 vehicles and 56 vehicles until the end of the simulation.

EXP 129's number of vehicles firstly increases to 55 vehicles until 60th second and starts to fluctuate between 40 vehicles and 61 vehicles until 240th second. After 240th second it starts to decrease to 18 vehicles with 1 fluctuation until 390th second. After that it starts to fluctuate between 18 vehicles and 43 vehicles until 1170th second. After 1170th second it leaps up to 72 vehicles until 1230th second. After that it fluctuates between 24 vehicles and 69 vehicles until the end of the simulation. When we look at the total number of vehicles' graph in Figure (4.28); if vehicle input increases, total number of vehicles increases.

4.1.7 Impact of Vehicle Input on Travel Time

When the same examples are examined, as shown in Figure (4.29), in 2 lanes roads all experiments' travel times have same value until 270th second. Each experiment's travel time is stable until 270th second which is the beginning of the incident. After 270th second EXP 48's travel time increases to 50 seconds until 390th second. After that it decreases to 30 seconds until 420th second,

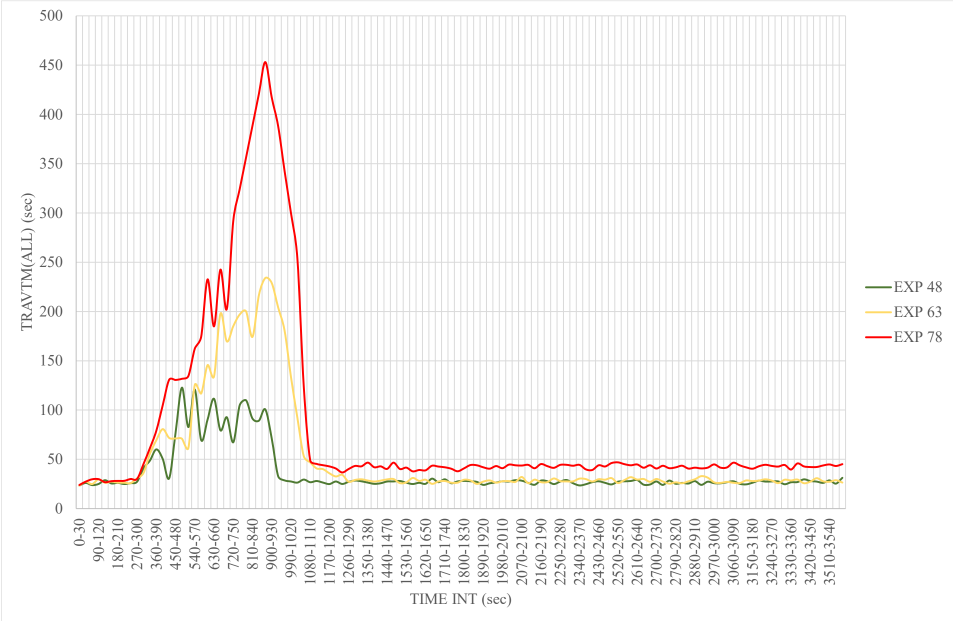

Figure 4.29: TRAVTM(ALL) Graph of Vehicle Input Scenario Group 1.

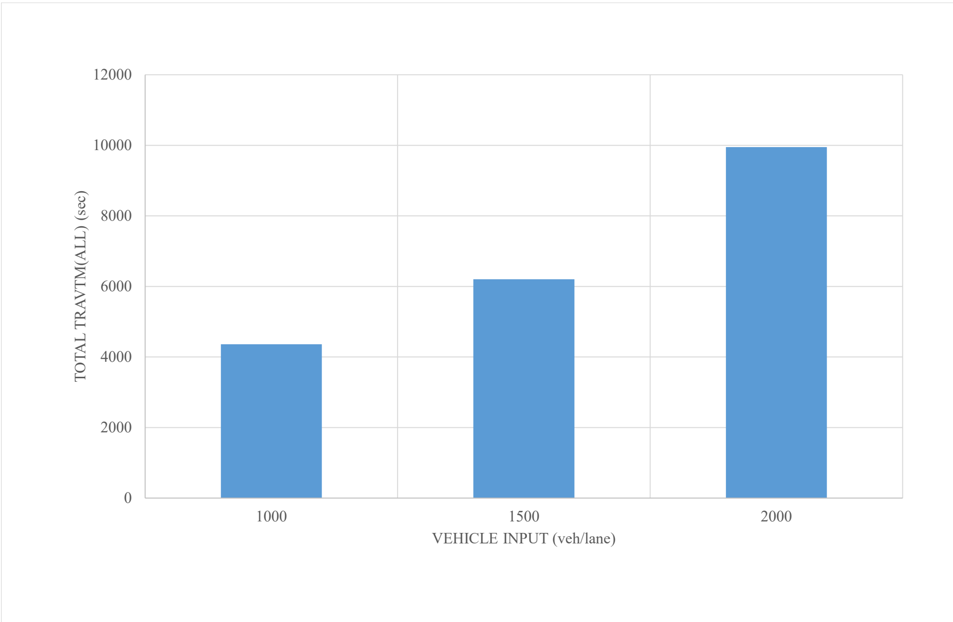

Figure 4.30: TOTAL TRAVTM(ALL) Graph of Vehicle Input Scenario Group 1.

increases to 123 seconds until 480th second. After 480th second it fluctuates between 70 seconds and 123 seconds until 870th second which is the end of the incident. After 870th second EXP 48's travel time starts to decrease to 29 seconds until 960th second and becomes stable until the end of the simulation.

After 270th second EXP 63's travel time increases to 72 seconds until 420th second. After that it decreases a little bit to 71 seconds until 480th second. After 480th second it starts to increase with some fluctuations to 234 seconds until 900th second which is the end of the incident. After 900th second EXP 63's travel time slumps to 53 seconds until 1050th second and then continues to decrease to 28 seconds until 1260th second, and becomes stable until the end of the simulation.

After 270th second EXP 78's travel time increases to 131 seconds until 420th second. After 420th second it starts from 131 seconds and becomes stable until 480th second. After 480th second it starts to increase to 292 seconds with some fluctuations until 720th second. After that it leaps up to 453 seconds until 870th second. Then it slumps to 45 seconds until 1110th second and becomes stable until the end of the simulation. When we look at the total travel time's graph in Figure (4.30); if vehicle input increases, total travel time increases.

When the same examples are examined, as shown in Figure (4.31), in 3 lanes roads all experiments' travel times have almost same value until 270th second. After 270th second EXP 99's travel time fluctuates between 30 seconds and 50 seconds until 660th second. After that it increases from 30 seconds to 54 seconds and starts to fluctuate between 40 seconds and 85 seconds until 1170th second which is the end of the incident. After 1170th second EXP 99's travel time starts to decrease to 26 seconds until 1260th second and becomes stable until the end of the simulation.

After 270th second EXP 114's travel time continuously increases with some little exceptions to 140 seconds until 690th second. After 690th second it continues to increase with some big fluctuations to 259 seconds until 1110th second. After

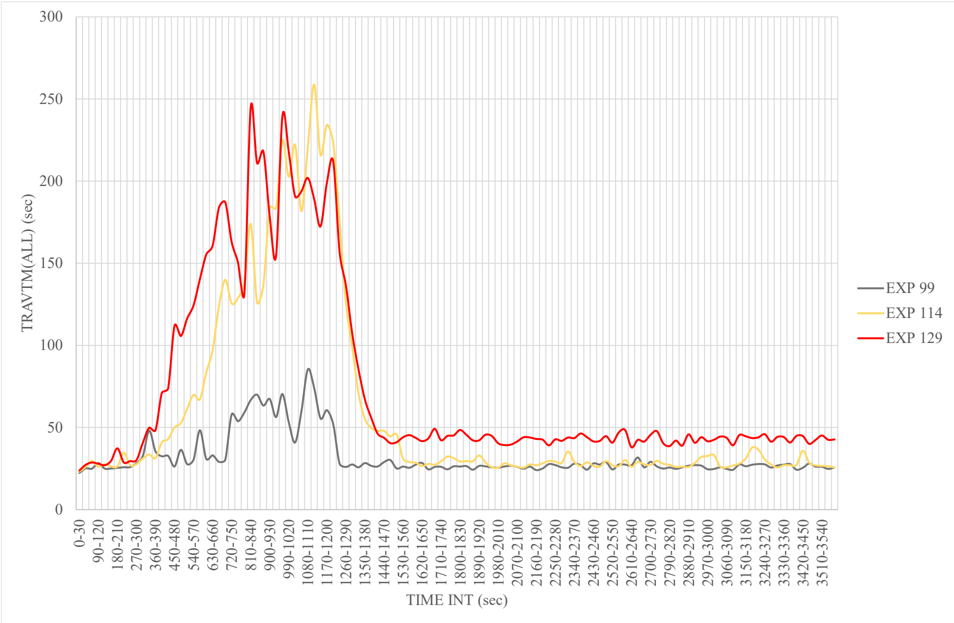

Figure 4.31: TRAVTM(ALL) Graph of Vehicle Input Scenario Group 2.

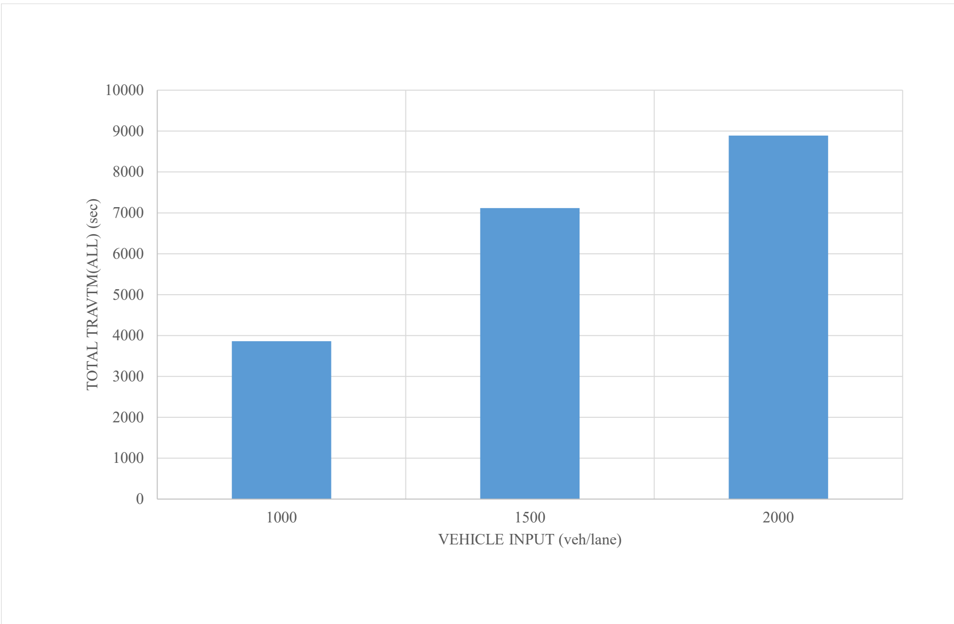

Figure 4.32: TOTAL TRAVTM(ALL) Graph of Vehicle Input Scenario Group 2.

that it decreases a little bit to 234 seconds until 1170th second which is the end of the incident. After 1170th second it slumps to 29 seconds until 1560th second and becomes stable until the end of the simulation.

After 270th second EXP 129's travel time continuously increases with some little exceptions to 184 seconds until 660th second. After 660th second it decreases to 131 seconds until 780th second. After 780th second it continuously increases to 245 seconds until 810th second. After 810th second it decreases to 155 seconds with 1 exception until 930th second. After 930th second it continuously increases to 240 seconds until 960th second. After 960th second it starts to decrease to 199 seconds with some fluctuations until 1170th second. After that it firstly increases to 212 seconds until 1200th second, then slumps to 41 seconds until 1500th second, and becomes stable until the end of the simulation. When we look at the total travel time's graph in Figure (4.32); if vehicle input increases, total travel time increases.

4.1.8 Impact of Vehicle Input on Speed

When the same examples are examined, as shown in Figure (4.33), in 2 lanes roads all experiments' speeds start from 120 km/h and decrease to 100 km/h with some fluctuations until 270th second. After 270th second which is the beginning of the incident, EXP 48's speed slumps to 9 km/h until 360th second. After that it leaps up to 62 km/h until 420th second, slumps to 3 km/h until 480th second. After 480th second it fluctuates between 2 km/h and 40 km/h until 870th second. After 870th second which is a few minutes after the end of the incident, EXP 48's speed leaps up to 100 km/h until 990th second and then fluctuates between 89 km/h and 117 km/h until the end of the simulation.

After 270th second EXP 63's speed slumps to 40 km/h until 330th second and continues to decrease to 19 km/h until 420th second. After 420th second it fluctuates between 18 km/h and 56 km/h until 870th second. After 870th second EXP 63's speed leaps up from 18 km/h to 68 km/h until 960th second, then

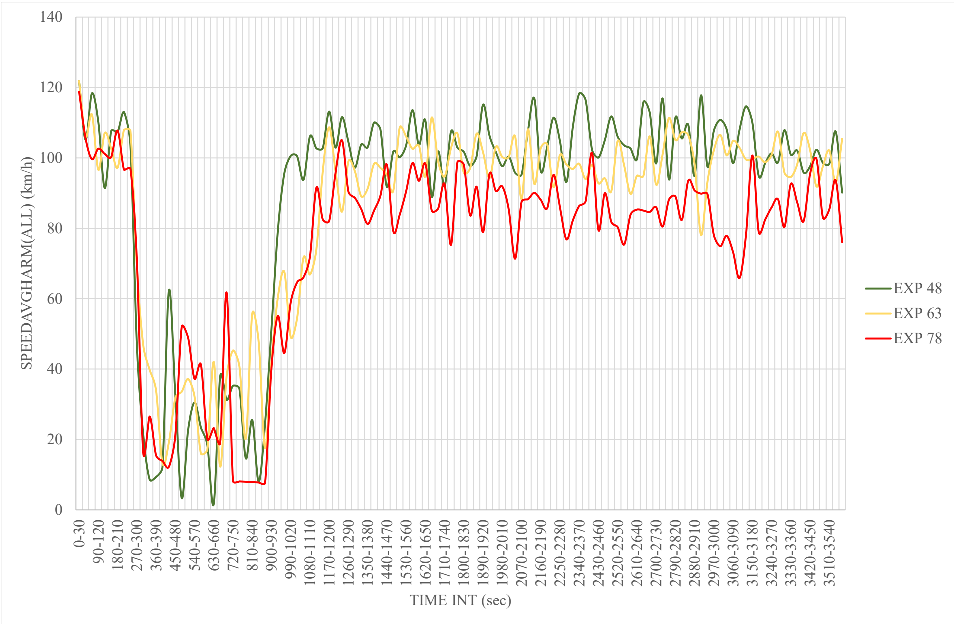

Figure 4.33: SPEEDAVGHARM(ALL) Graph of Vehicle Input Scenario Group 1.

decreases to 49 km/h until 990th second, leaps up to 109 km/h until 1170th second, and fluctuates between 78 km/h and 111 km/h until the end of the simulation.

After 270th second EXP 78's speed slumps to 16 km/h until 300th second, increases to 27 km/h until 330th second, decreases to 12 km/h until 420th second. After that is leaps up to 52 km/h until 480th second, decreases to 37 km/h until 540th second, increases to 41 km/h until 570th second, slumps to 20 km/h until 600th second, and fluctuates between 19 km/h and 20 km/h until 660th second. Then it leaps up to 62 km/h until 690th second, slumps to 8 km/h until 720th second, and becomes stable until 870th second. After 870th second EXP 78's speed leaps up from 8 km/h to 55 km/h until 930th second, then decreases to 45 km/h until 960th second, leaps up to 92 km/h until 1110th second, and fluctuates between 65 km/h and 105 km/h until the end of the simulation. When we look

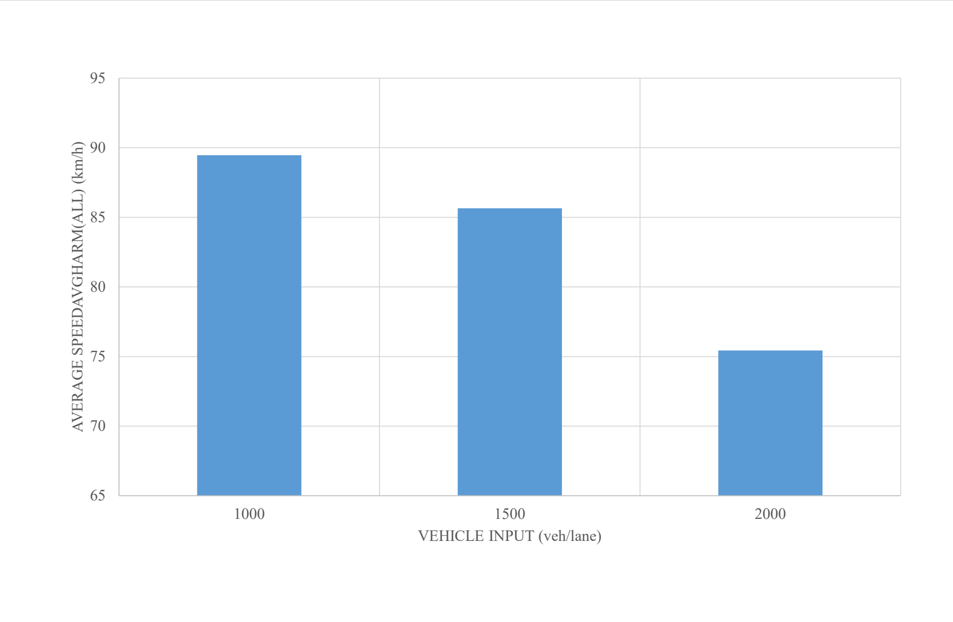

Figure 4.34: AVERAGE SPEEDAVGHARM(ALL) Graph of Vehicle Input Scenario Group 1.

at the average speed's graph in Figure (4.34); if vehicle input increases, average speed decreases.

When the same examples are examined, as shown in Figure (4.35), in 3 lanes roads all experiments' speeds start from 120 km/h. EXP 99's speed decreases to 110 km/h until 30th second and fluctuates between 97 km/h and 111 km/h until 240th second. After 240th second which is the beginning of the incident, EXP 99's speed slumps to 21 km/h until 300th second. After 300th second it fluctuates between 9 km/h and 87 km/h until 1170th second. After 1170th second which is a few minutes after the end of the incident, EXP 99's speed leaps up from 36 km/h to 109 km/h until 1260th second and then fluctuates between 91 km/h and 118 km/h until the end of the simulation.

EXP 114's speed decreases to 104 km/h until 60th second and fluctuates between 93 km/h and 106 km/h until 240th second. After 240th second EXP 114's speed

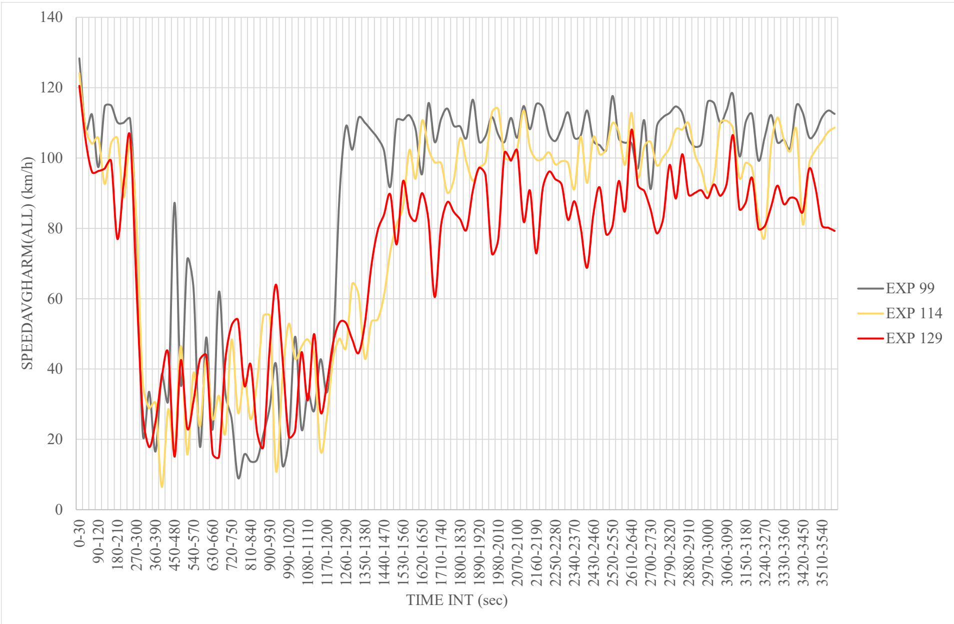

Figure 4.35: SPEEDAVGHARM(ALL) Graph of Vehicle Input Scenario Group 2.

slumps to 29 km/h until 330th second. After 330th second it fluctuates between 6 km/h and 55 km/h until 1170th second. After 1170th second EXP 114's speed increases from 26 km/h to 61 km/h until 1320th second, decreases to 43 km/h until 1350th second, leaps up to 111 km/h until 1620th second, and then fluctuates between 78 km/h and 113 km/h until the end of the simulation.

EXP 129's speed decreases to 96 km/h until 90th second and becomes almost stable until 120th second. After 120th second it decreases to 77 km/h until 180th second, then increases to 106 km/h until 240th second. After 240th second EXP 129's speed slumps to 18 km/h until 330th second. After 330th second it fluctuates between 15 km/h and 64 km/h until 1170th second. After 1170th second EXP 129's speed increases from 36 km/h to 53 km/h until 1260th second, then decreases 48 km/h until 1290th second, and leaps up to 90 km/h until 1470th second. After 1470th second it fluctuates between 60 km/h and 109 km/h until

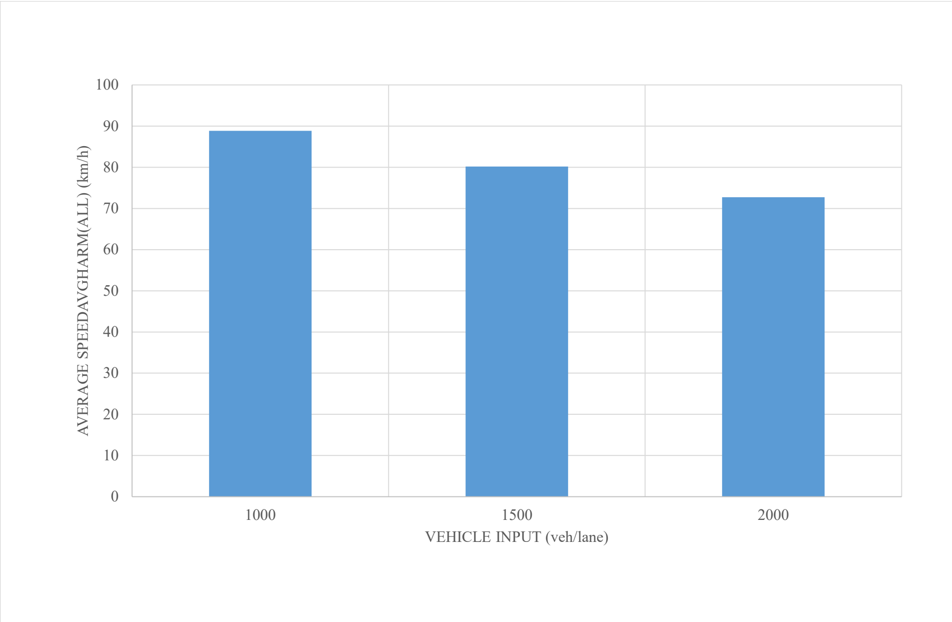

Figure 4.36: AVERAGE SPEEDAVGHARM(ALL) Graph of Vehicle Input Scenario Group 2.

the end of the simulation. When we look at the average speed's graph in Figure (4.36); if vehicle input increases, average speed decreases.

4.1.9 Impact of Number of Lane on Queue Length

When an incident whose duration is 5 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 2 different experiment scenarios for number of lane which are 2 lanes (EXP 18) and 3 lanes (EXP 24) as shown in Figure (4.37). Provided that all other variables are the same, when only different numbers of lane are used, in 5 minutes duration, after 270th second which is the beginning of the incident, EXP 18's queue length leaps up from zero to 92 m until 330th second, decreases to 83 m until 360th second, then leaps up again to 363 m until 570th second. After that it decreases a little bit to 360 m until 600th second and continues to increase to 488 m. It reaches

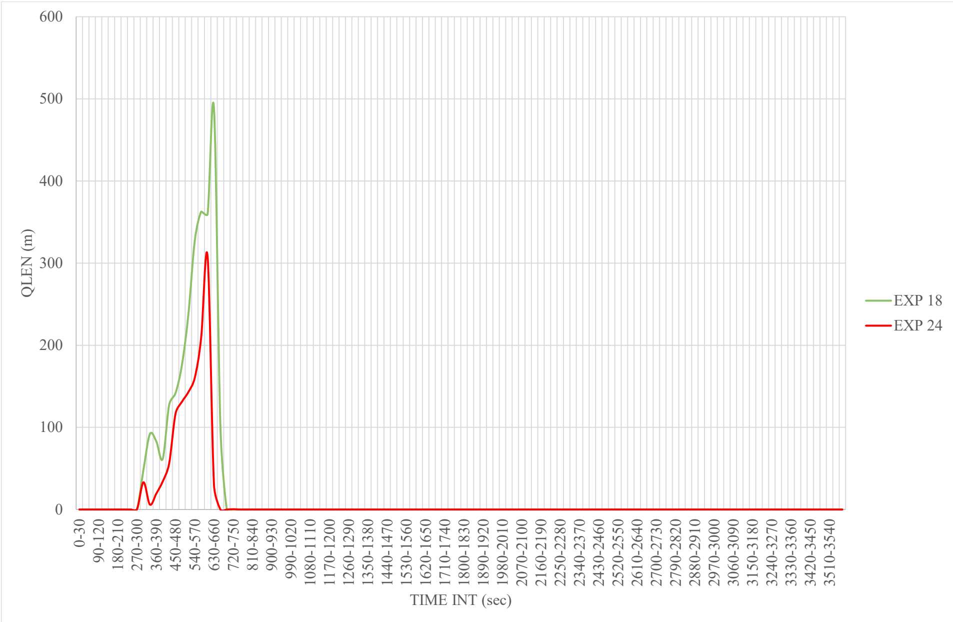

Figure 4.37: QLEN Graph of Number of Lane Scenario Group 1.

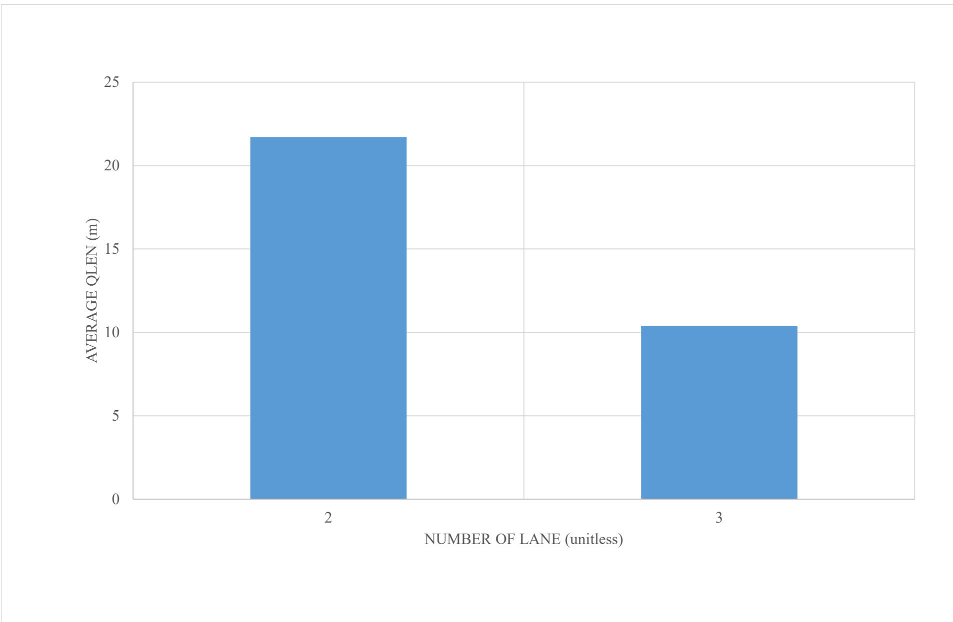

Figure 4.38: AVERAGE QLEN Graph of Number of Lane Scenario Group 1.

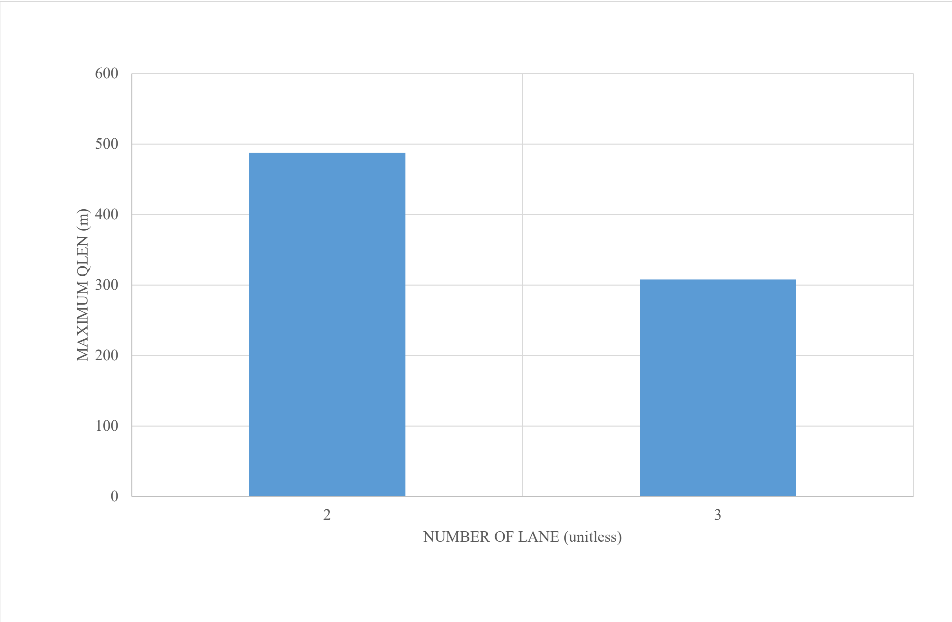

Figure 4.39: MAXIMUM QLEN Graph of Number of Lane Scenario Group 1.

its top point 488 m at 630th second. After 630th second it slumps to zero until 690th second and becomes stable until the end of the simulation.

After 270th second EXP 24's queue length increases from zero to 33 m until 300th second, decreases to 6 m until 330th second, increases to 210 m until 570th second, and then leaps up to 308 m which is its top point until 600th second. After that it slumps to zero until 660th second and becomes stable until the end of the simulation. When we look at the average queue length's graph in Figure (4.38) and maximum queue length's graph in Figure (4.39); if number of lane increases, average queue length and maximum queue length decrease.

When an incident whose duration is 15 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 2 different experiment scenarios for number of lane which are 2 lanes (EXP 108) and 3 lanes (EXP 114) as shown in Figure (4.40). When the same examples are examined, in 15 minutes duration, after 270th second which is the beginning of the incident,

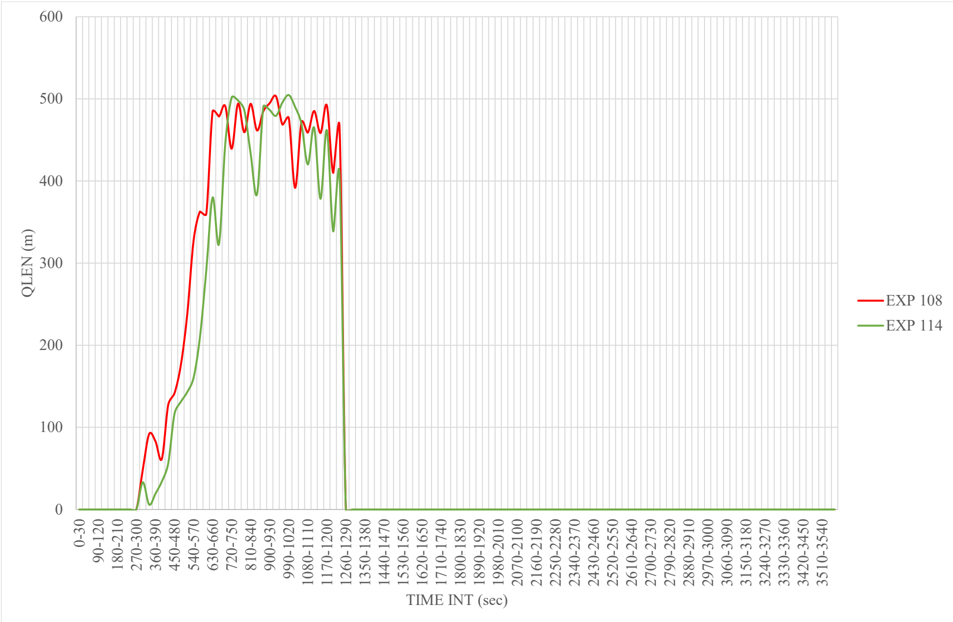

Figure 4.40: QLEN Graph of Number of Lane Scenario Group 2.

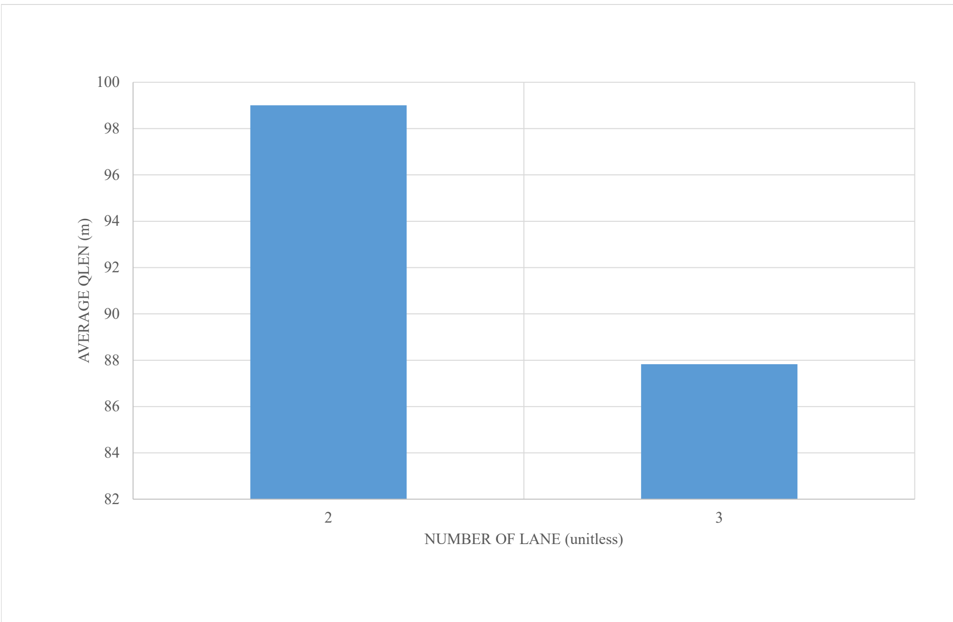

Figure 4.41: AVERAGE QLEN Graph of Number of Lane Scenario Group 2.

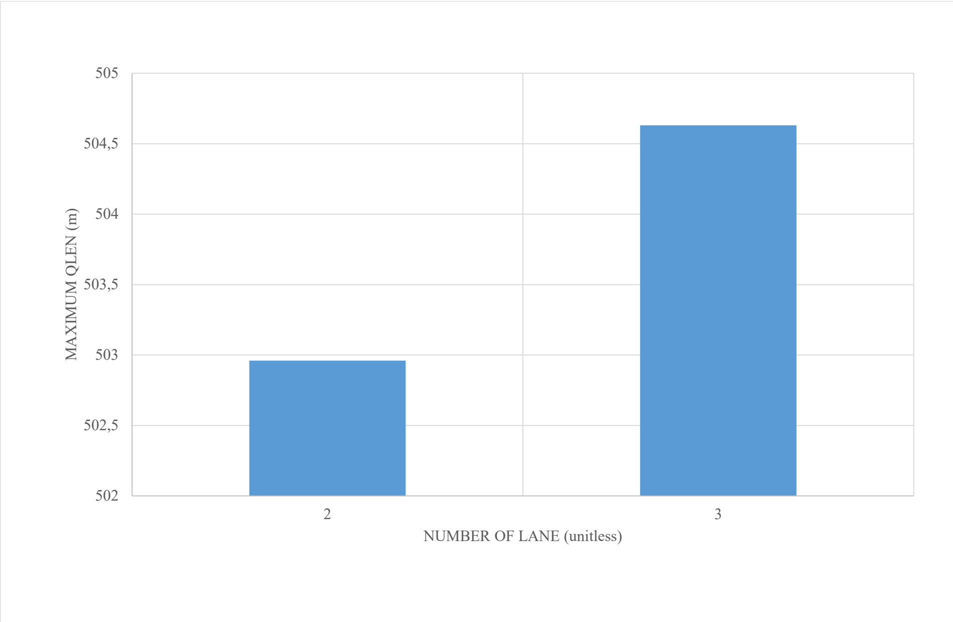

Figure 4.42: MAXIMUM QLEN Graph of Number of Lane Scenario Group 2.

EXP 108's queue length increases to 92 m until 330th second, decreases to 62 m until 390th second, increases to 142 m until 450th second, leaps up to 363 m until 570th second, decreases to 360 m until 600th second, increases to 485 m until 630th second. After that it fluctuates between 439 m and 503 m which is its top point until 930th second. After that it decreases to 469 m until 960th second, increases to 477 m until 990th second, increases to 459 m until 1080th second. After that it fluctuates between 458 m and 492 m until 1170th second which is the end of the incident. After that it slumps to zero until 1260th second and becomes stable until the end of the simulation.

After 270th second EXP 114's queue length increases to 33 m until 300th second, decreases to 6 m until 330th second, increases to 131 m until 480th second, leaps up to 380 m until 630th second. After that it decreases a little bit to 323 m until 660th second and continues to increase to 505 m. It reaches its top point 505 m at 690th second. After that it decreases to 384 m until 840th second, increases to 491 m until 870th second, fluctuates between 339 m and 505 m until 1230th second, slumps to zero until 1290th second and becomes stable until the end of the simulation. When we look at the average queue length's graph in Figure (4.41) and maximum queue length's graph in Figure (4.42); if number of lane increases, average queue length decreases. However maximum queue length increases.

4.1.10 Impact of Number of Lane on Number of Vehicles

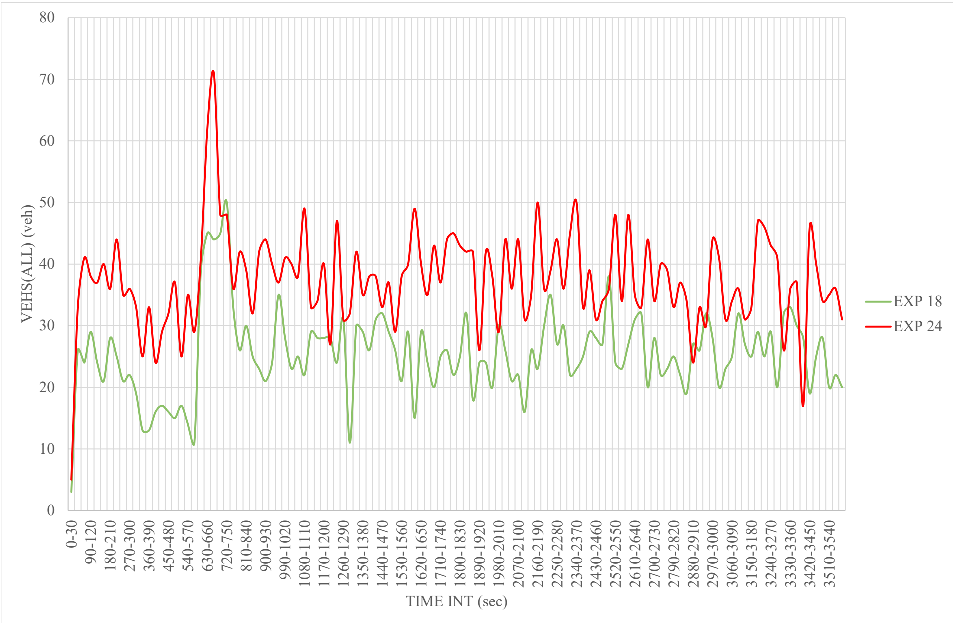

Figure 4.43: VEHS(ALL) Graph of Number of Lane Scenario Group 1.

When the same examples are examined, as shown in Figure (4.43), in 5 minutes duration EXP 18's number of vehicles starts from 3 vehicles and leaps up to 26 vehicles until 30th second. After that it fluctuates between 29 vehicles and 21 vehicles until 270th second which is the beginning of the incident. After 270th second it decreases to 13 vehicles until 330th second, increases 16 vehicles until 450th second, and then fluctuates between 14 vehicles and 17 vehicles until 510th second. After 510th second it decreases to 13 vehicles until 570th second which is the end of the incident. After 570th second EXP 18's number of vehicles leaps

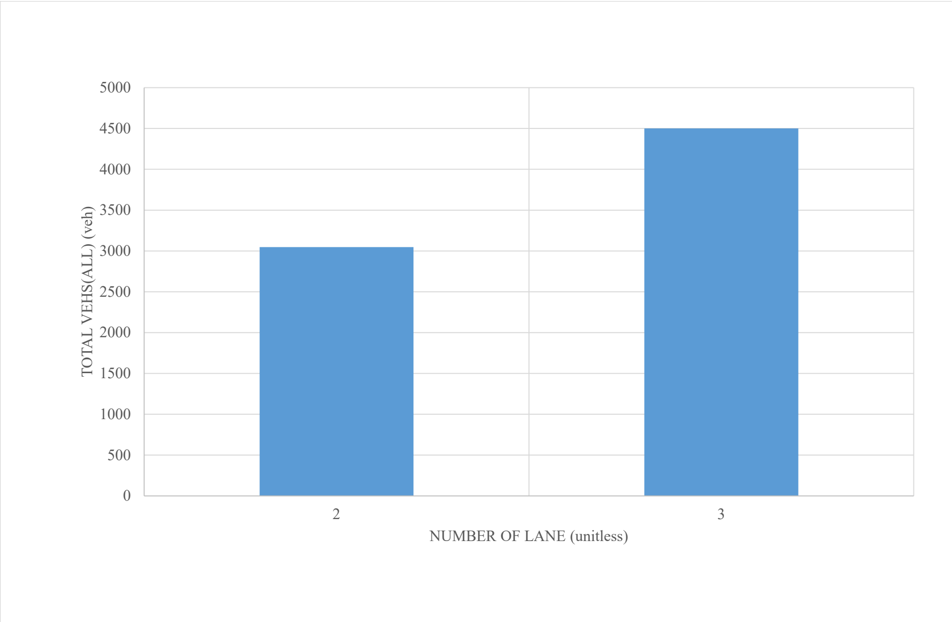

Figure 4.44: TOTAL VEHS(ALL) Graph of Number of Lane Scenario Group 1.

up to 45 vehicles until 630th second, decreases 44 vehicles until 690th second, increases 50 vehicles which is its top point until 720th second, slumps to 26 vehicles until 780th second. After that it fluctuates between 21 vehicles and 35 vehicles until 1260th second, between 11 vehicles and 32 vehicles from 1260th second to 2160th second, between 20 vehicles and 38 vehicles from 2160th second to 2670th second, and between 19 vehicles and 32 vehicles from 2670th second to end of the simulation.

EXP 24's number of vehicles starts from 5 vehicles and leaps up to 41 vehicles until 60th second. After that it fluctuates between 35 vehicles and 44 vehicles until 270th second. After 270th second it decreases to 25 vehicles until 330th second, and then fluctuates between 24 vehicles and 37 vehicles until 570th second. After 570th second it leaps up to 71 vehicles which is its top point until 660th second, decreases 48 vehicles until 690th second. After that it fluctuates between 26 vehicles and 50 vehicles until 2850th second, between 17 vehicles and 47 vehicles from 2850th second to end of the simulation. When we look at the total number of vehicles' graph in Figure (4.44); if number of lane increases, total number of vehicles increases.

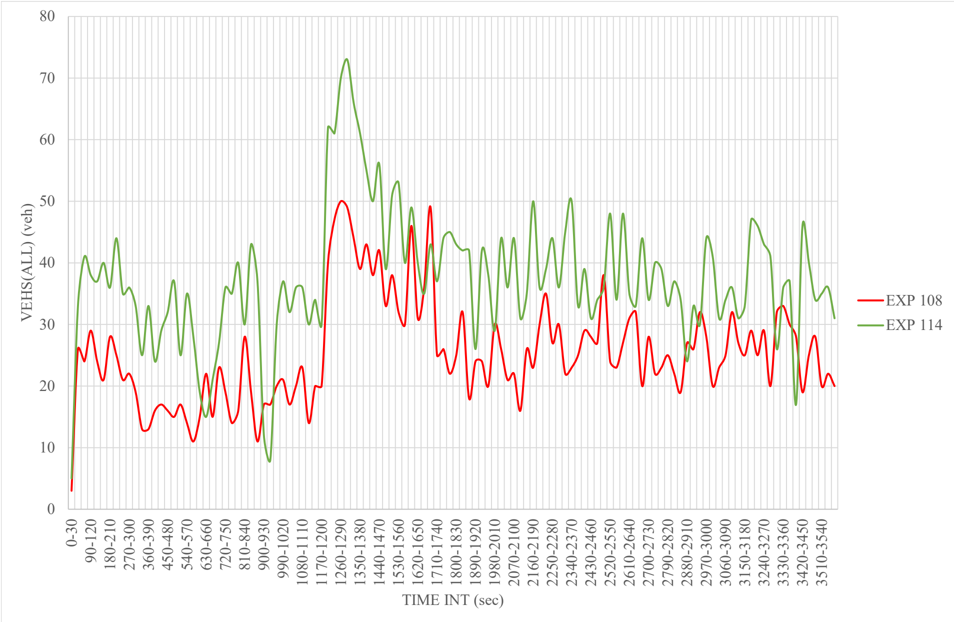

Figure 4.45: VEHS(ALL) Graph of Number of Lane Scenario Group 2.

When the same examples are examined, as shown in Figure (4.45), in 15 minutes duration EXP 108's number of vehicles leaps up to 26 vehicles until 30th second, then fluctuates between 21 vehicles and 29 vehicles until 270th second which is the beginning of the incident. After that it decreases to 13 vehicles until 330th second, fluctuates between 11 vehicles and 17 vehicles until 570th second, between 11 vehicles and 28 vehicles from 570th second to 870th second, between 11 vehicles to 23 vehicles from 870th second to 1170th second which is the end of the incident. After that it leaps up to 50 vehicles until 1260th second, fluctuates between 25 vehicles and 49 vehicles until 1710th second, between 16 vehicles and 38 vehicles from 1710th second to the end of the simulation.

EXP 114's number of vehicles leaps up to 42 vehicles until 90th second, then fluctuates between 38 vehicles and 44 vehicles until 210th second. After that it decreases to 37 vehicles until 270th second which is the beginning of the incident.

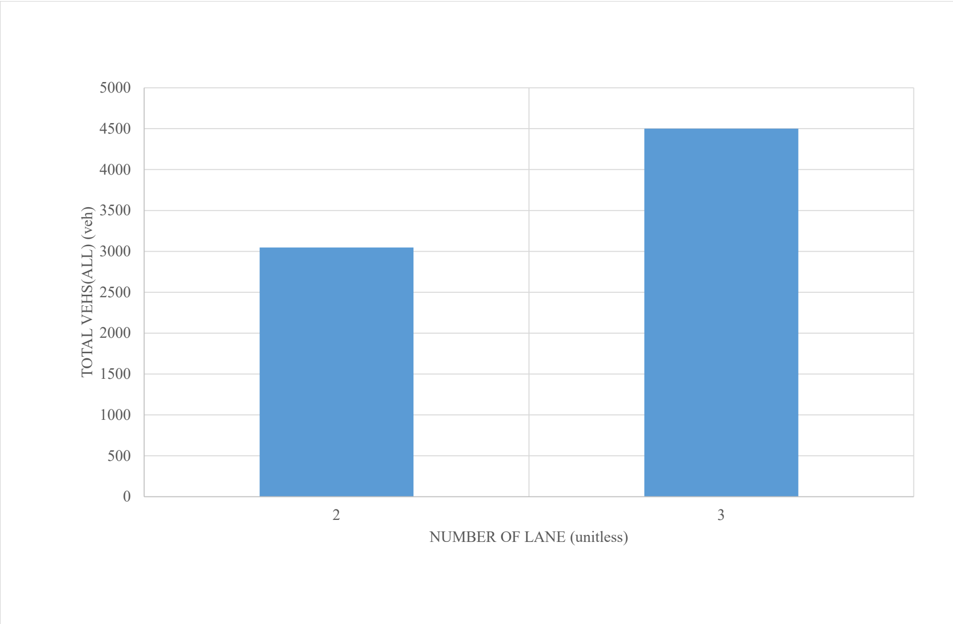

Figure 4.46: TOTAL VEHS(ALL) Graph of Number of Lane Scenario Group 2.

After that it decreases to 26 vehicles until 330th second, increases to 33 vehicles until 360th second, decreases to 26 vehicles 390th second, increases to 37 vehicles until 480th second, decreases to 25 vehicles until 510th second, increases to 35 vehicles until 540th second, slumps to 15 vehicles 630th second, leaps up to 36 vehicles 720th second, decreases a little bit to 35 vehicles until 750th second, increases to 40 vehicles until 780th second, decreases to 30 vehicles until 810th second, increases to 43 vehicles until 840th second, slumps to 8 vehicles until 930th second, leaps up to 37 vehicles until 990th second, and fluctuates between 30 vehicles and 37 vehicles until 1170th second which is the end of the incident. After that it leaps up to 62 vehicles until 1200th second, decreases a little bit to 61 vehicles until 1230th second, increases to 73 vehicles which is its top point until 1290th second. After that it starts to decrease to 35 vehicles with some big fluctuations until 1650th second. After 1650th second it fluctuates between 17 vehicles and 50 vehicles until the end of the simulation. When we look at the total number of vehicles' graph in Figure (4.46); if number of lane increases, total number of vehicles increases.

4.1.11 Impact of Number of Lane on Travel Time

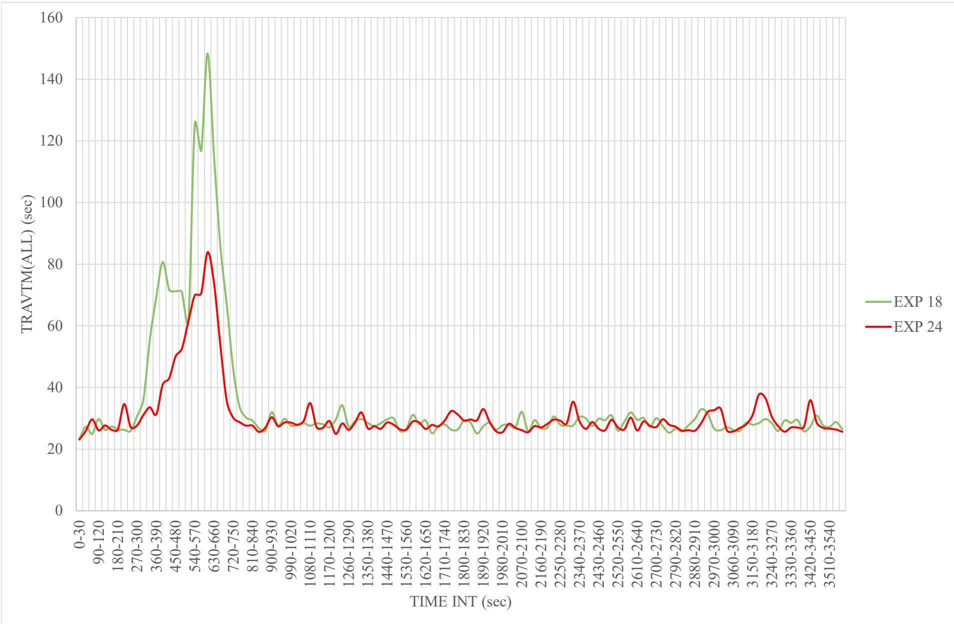

Figure 4.47: TRAVTM(ALL) Graph of Number of Lane Scenario Group 1.

When the same examples are examined, as shown in Figure (4.47), in 5 minutes duration EXP 18's travel time fluctuates between 26 seconds and 30 seconds from the beginning of the simulation to 240th second. After that it starts to increase to 60 seconds until 330th second. After 330th second EXP 18's travel time increases to 81 seconds until 390th second, decreases to 71 seconds until 420th second and becomes stable until 480th second. After 480th second it continues to decrease to 62 seconds until 510th second. After that it leaps up to 125 seconds until 540th second, decreases to 117 seconds until 570th second, and increases to 148 seconds which is its top point until 600th second which is a few minutes after the end of the incident. After that it slumps to 32 seconds until 810th second and starts to fluctuate between 26 seconds and 34 seconds until the end of the simulation.

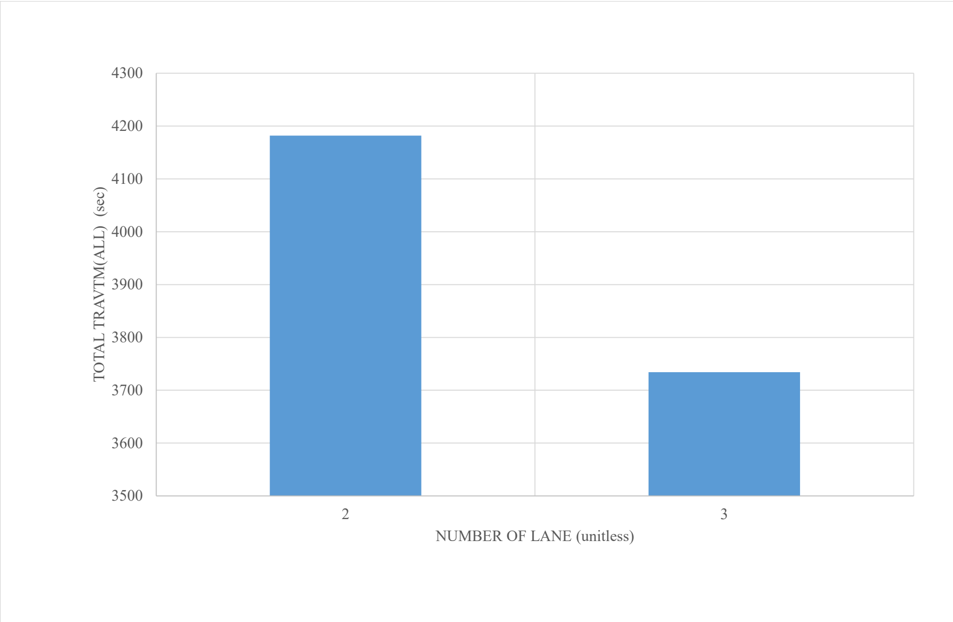

Figure 4.48: TOTAL TRAVTM(ALL) Graph of Number of Lane Scenario Group 1.

EXP 24's travel time fluctuates between 23 seconds and 26 seconds from the beginning of the simulation to 180th second, increases to 37 seconds until 210th second, decreases to 27 seconds until 240th second. After that it starts to increase to 84 seconds with some fluctuations until 600th second. After 600th second it slumps to 26 seconds until 840th second and starts to fluctuate between 25 seconds and 38 seconds until the end of the simulation. When we look at the total travel time's graph in Figure (4.48); if number of lane increases, total travel time decreases.

When the same examples are examined, as shown in Figure (4.49), in 15 minutes duration, EXP 108's travel time fluctuates between 24 seconds and 26 seconds from the beginning of the simulation to 240th second. After 240th second it increases to 81 seconds until 390th second, decreases to 72 seconds until 420th second, to 71 seconds until 480th second, to 61 seconds until 510th second, slumps to 125 seconds until 540th second. After that it starts to increase with some big

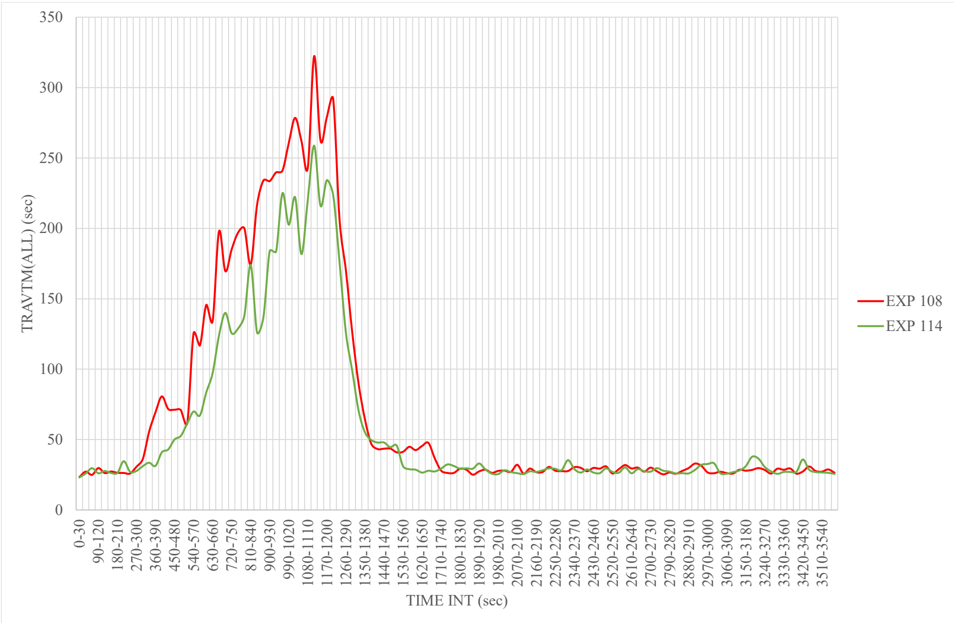

Figure 4.49: TRAVTM(ALL) Graph of Number of Lane Scenario Group 2.

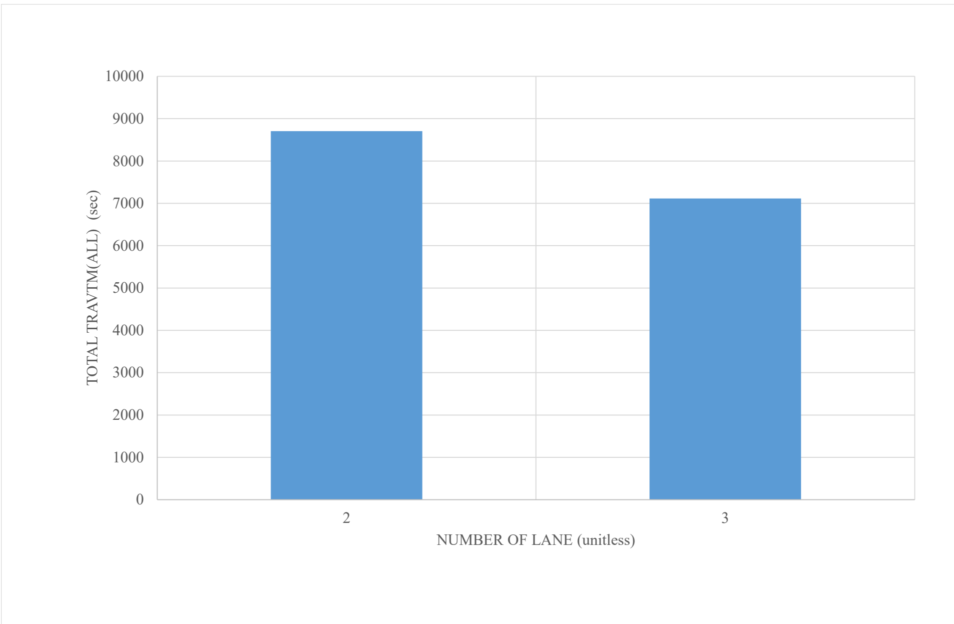

Figure 4.50: TOTAL TRAVTM(ALL) Graph of Number of Lane Scenario Group 2.

fluctuations to 323 seconds which is its top point until 1110th second. After that it decreases to 262 seconds until 1140th second, increases to 292 seconds until 1200th second which is the end of the incident. After that it slumps to 43 seconds until 1410th second and fluctuates between 41 seconds and 48 seconds until 1650th second, decreases to 26 seconds until 1740th second, and then fluctuates between 25 seconds and 33 seconds until the end of the simulation.

EXP 114's travel time fluctuates between 26 seconds and 30 seconds from the beginning of the simulation to 240th second. After 240th second it increases to 126 seconds until 720th second. After that it decreases to 129 seconds until 750th second, increases to 184 seconds until 840th second, decreases to 137 seconds until 870th second, increases to 184 seconds until 900th second. After that it starts to fluctuate between 181 seconds and 259 seconds which is its top point until 1110th second. After that it decreases to 216 seconds until 1140th second, increases to 234 seconds until 1170th second which is the end of the incident. After that it slumps to 54 seconds until 1380th second and fluctuates between 29 seconds and 38 seconds until the end of the simulation. When we look at the total travel time's graph in Figure (4.50); if number of lane increases, total travel time decreases.

4.1.12 Impact of Number of Lane on Speed

When the same examples are examined, as shown in Figure (4.51), in 5 minutes duration, EXP 18's speed starts from 122 km/h and decreases to 106 km/h until 30th second. After that it fluctuates between 97 km/h and 112 km/h until 240th second. After 240th second it slumps to 40 km/h until 330th second and continues to decrease to 13 km/h until 390th second. After that it leaps up to 34 km/h until 480th second and continues to increase to 37 km/h until 510th second. After that it decreases to 20 km/h until 570th second which is the end of the incident. After that it leaps up to 78 km/h until 660th second, decreases to 71 km/h until 690th second, increases to 77 km/h until 720th second, and then slumps to 46 km/h until 750th second. After that it leaps up to 106 km/h until 870th second.

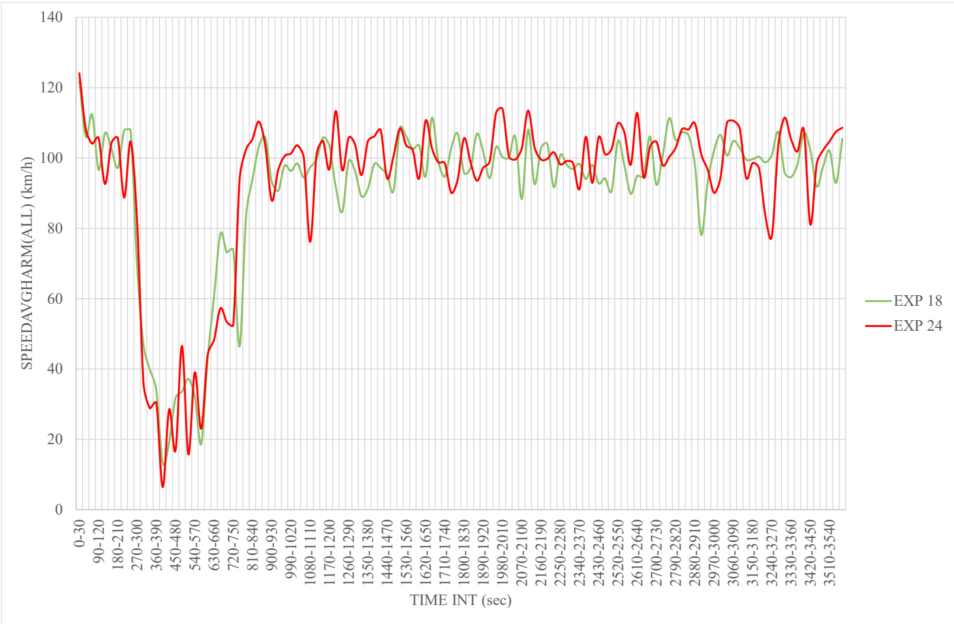

Figure 4.51: SPEEDAVGHARM(ALL) Graph of Number of Lane Scenario Group 1.

After 870th second it starts to fluctuate between 78 km/h and 111 km/h until the end of the simulation.

EXP 24's speed starts from 124 km/h and decreases to 105 km/h until 60th second. After that it fluctuates between 89 km/h and 106 km/h until 240th second. After 240th second it slumps to 29 km/h until 330th second, increases to 30 km/h until 360th second, decreases to 6 km/h until 390th second. After that it leaps up to 29 km/h until 420th second and fluctuates between 16 km/h and 47 km/h until 570th second. After that it leaps up from 23 km/h to 57 km/h until 660th second, decreases to 53 km/h until 720th second, leaps up to 110 km/h until 840th second, fluctuates between 76 km/h and 110 km/h until 1140th second, between 90 km/h and 113 km/h from 1140th second to 3150th second, between 78 km/h to 111 km/h from 3150th second to the end of the simulation. When we look at the average speed's graph in Figure (4.52); if number of lane increases, average speed increases.

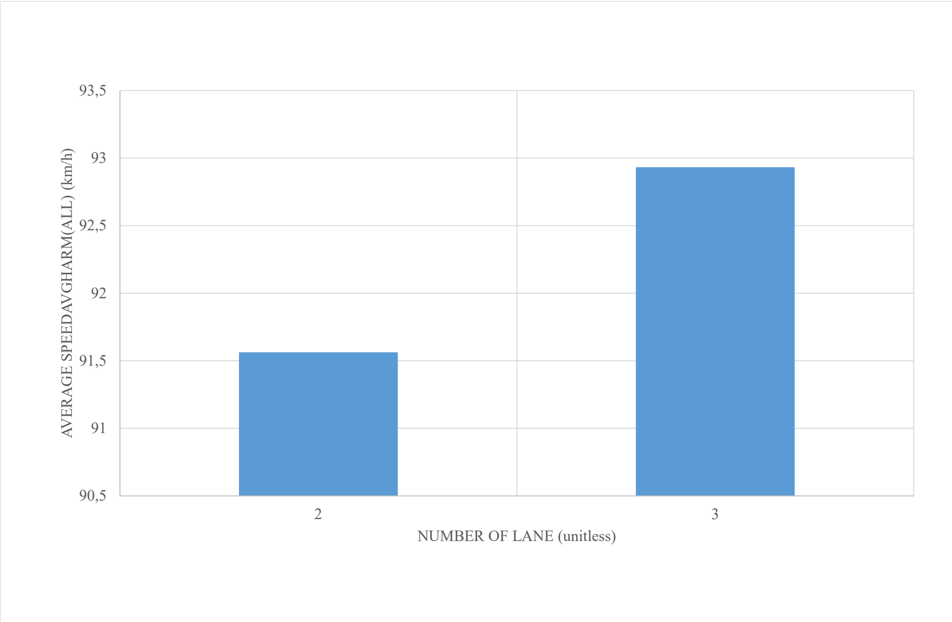

Figure 4.52: AVERAGE SPEEDAVGHARM(ALL) Graph of Number of Lane Scenario Group 1.

When the same examples are examined, as shown in Figure (4.53), in 15 minutes duration, EXP 108's speed starts from 122 km/h and decreases to 106 km/h until 30th second. After that it fluctuates between 97 km/h and 112 km/h until 240th second which is the beginning of the incident. After 240th second it slumps to 40 km/h until 330th second, and continues to decrease to 13 km/h until 390th second. After that it starts to fluctuate between 12 km/h and 56 km/h until 1170th second which is the end of the incident. After 1170th second it leaps up from 30 km/h to 76 km/h until 1290th second, decreases to 70 km/h until 1350th second, increases to 90 km/h until 1440th second, decreases to 86 km/h until 1470th second, increases to 92 km/h until 1500th second, decreases to 84 km/h until 1560th second, and increases to 107 km/h until 1770th second. After that it fluctuates between 88 km/h and 111 km/h which is its top point until 2760th second. After that it decreases to 105 km/h until 2790th second, increases to 106 km/h until 2850th second, slumps to 78 km/h until 2910th second, leaps up

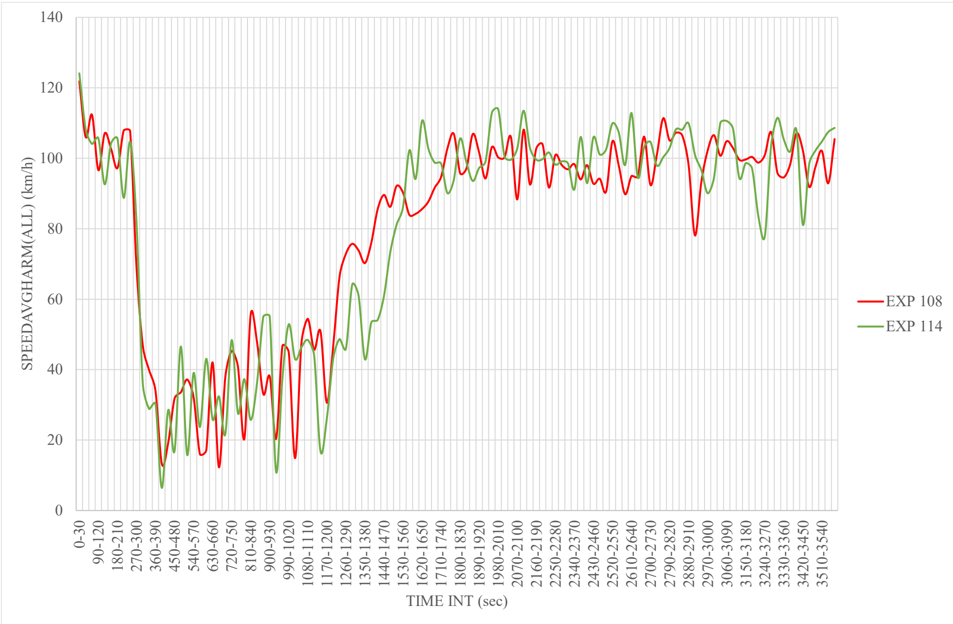

Figure 4.53: SPEEDAVGHARM(ALL) Graph of Number of Lane Scenario Group 2.

to 107 km/h until 3000th second, and then fluctuates between 92 km/h and 108 km/h until the end of the simulation.

EXP 114's speed starts from 124 km/h and decreases to 110 km/h until 30th second. After that it fluctuates between 89 km/h and 112 km/h until 240th second which is the beginning of the incident. After 240th second it slumps to 28 km/h until 300th second, increases a little bit to 30 km/h until 360th second, and then slumps to 6 km/h until 390th second. After 390th second it increases to 29 km/h until 420th second, decreases to 19 km/h until 450th second, and then fluctuates between 11 km/h and 55 km/h until 1170th second which is the end of the incident. After 1170th second it increases from 22 km/h to 46 km/h until 1200th second, decreases to 49 km/h until 1230th second, increases to 62 km/h until 1290th second, decreases to 43 km/h until 1350th second. After 1350th second it starts to increase to 102 km/h until 1560th second with some fluctuation. After that it fluctuates between 91 km/h and 113 km/h until 3030th

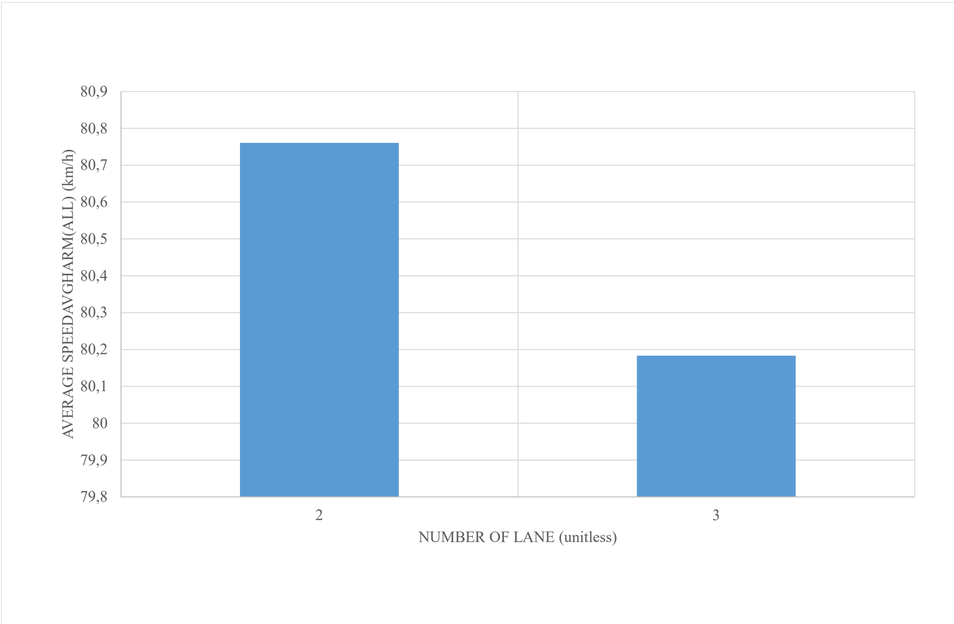

Figure 4.54: AVERAGE SPEEDAVGHARM(ALL) Graph of Number of Lane Scenario Group 2.

second, and after 3030th second between 78 km/h and 111 km/h until the end of the simulation. When we look at the average speed's graph in Figure (4.54); if number of lane increases, average speed decreases.

4.1.13 Impact of Incident Position on Queue Length

When an incident whose duration is 5 minutes occurs in a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 2 different experiment scenarios for incident position which are 1st lane (EXP 18) and 2nd lane (EXP 21) as shown in Figure (4.55). Provided that all other variables are the same, when only different incident positions are used, in 2 lanes roads, after 270th second which is the beginning of the incident, EXP 18's queue length leaps up to 92 m until 330th second, decreases to 83 m until 360th second, then leaps up again to 363 m until 570th second. After that it decreases a little bit to 360

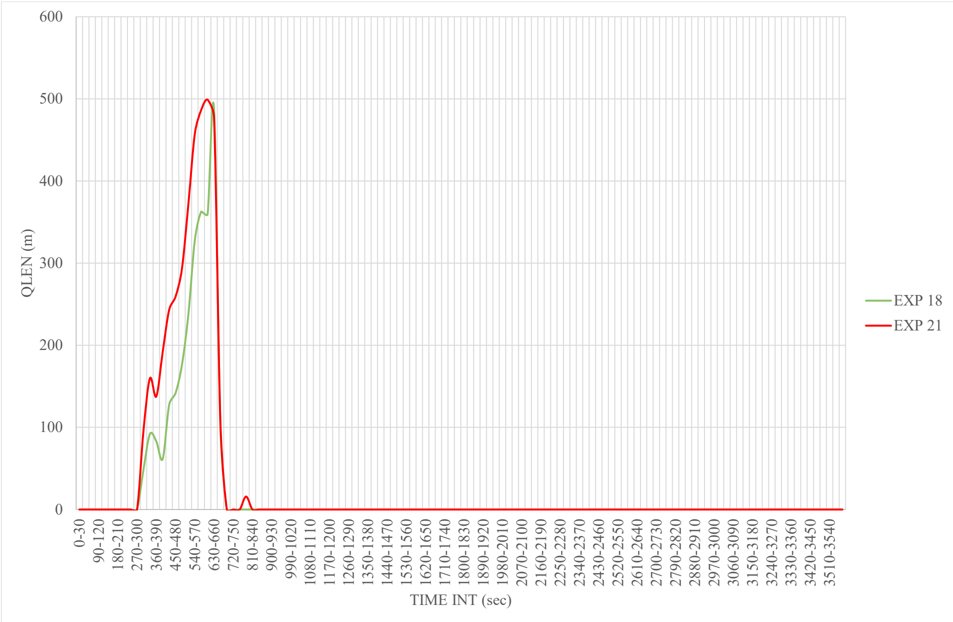

Figure 4.55: QLEN Graph of Incident Position Scenario Group 1.

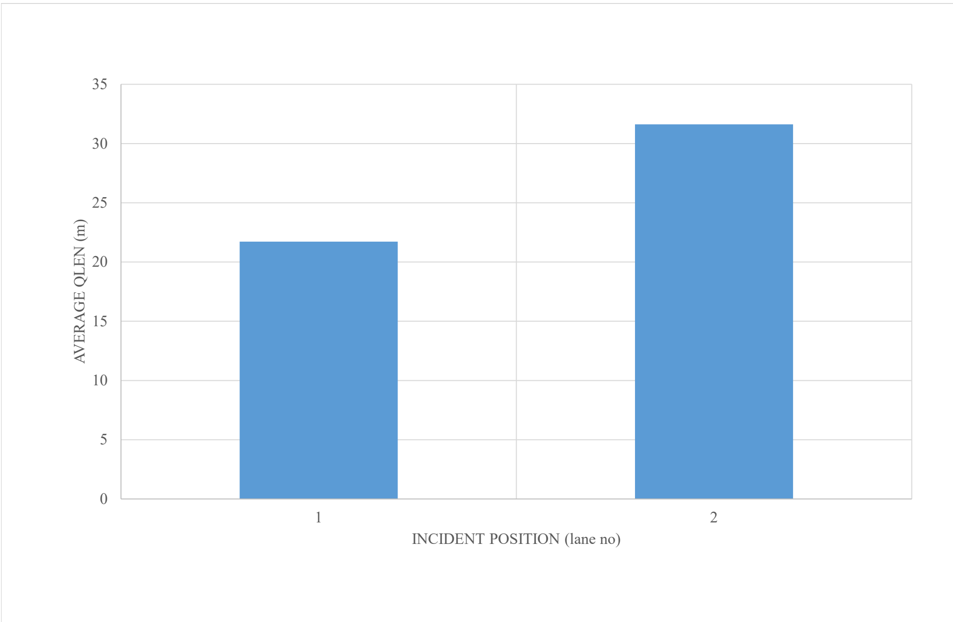

Figure 4.56: AVERAGE QLEN Graph of Incident Position Scenario Group 1.

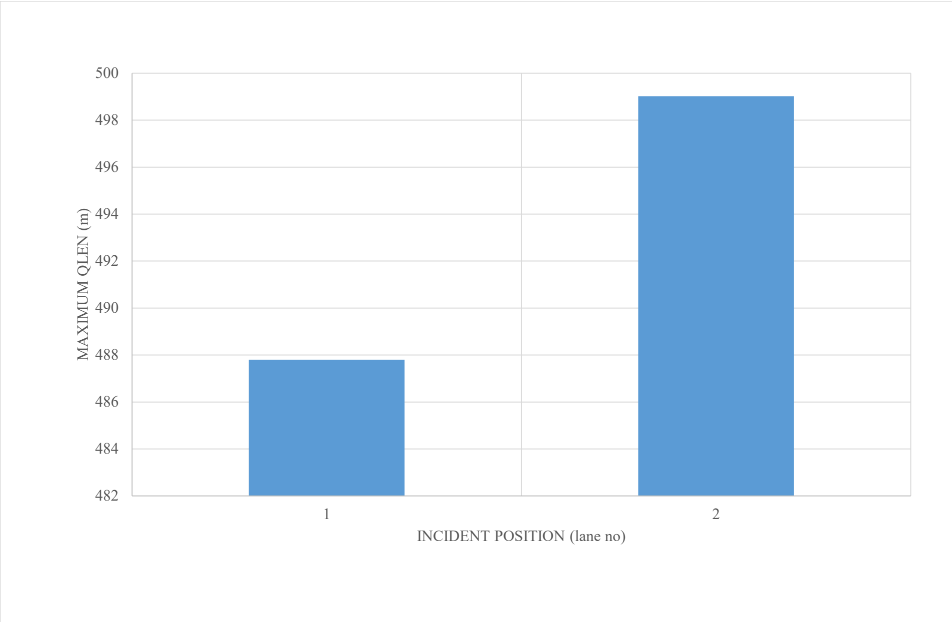

Figure 4.57: MAXIMUM QLEN Graph of Incident Position Scenario Group 1.

m until 600th second and continues to increase to 488 m. It reaches its top point 488 m at 630th second. After 630th second it slumps to zero until 690th second and becomes stable until the end of the simulation.

After 270th second, EXP 21's queue length leaps up to 160 m until 330th second, decreases to 138 m until 360th second, then leaps up again to 499 m until 570th second. It reaches its top point 499 m at 630th second. After 630th second it slumps to zero until 690th second and becomes stable with 1 exception until the end of the simulation. Because it increases to 16 m from 780th second to 810th second and turn back to zero again. When we look at the average queue length's graph in Figure (4.56) and maximum queue length's graph in Figure (4.57); if incident position increases, average queue length and maximum queue length increase.

When an incident whose duration is 15 minutes occurs in a three-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 3 different

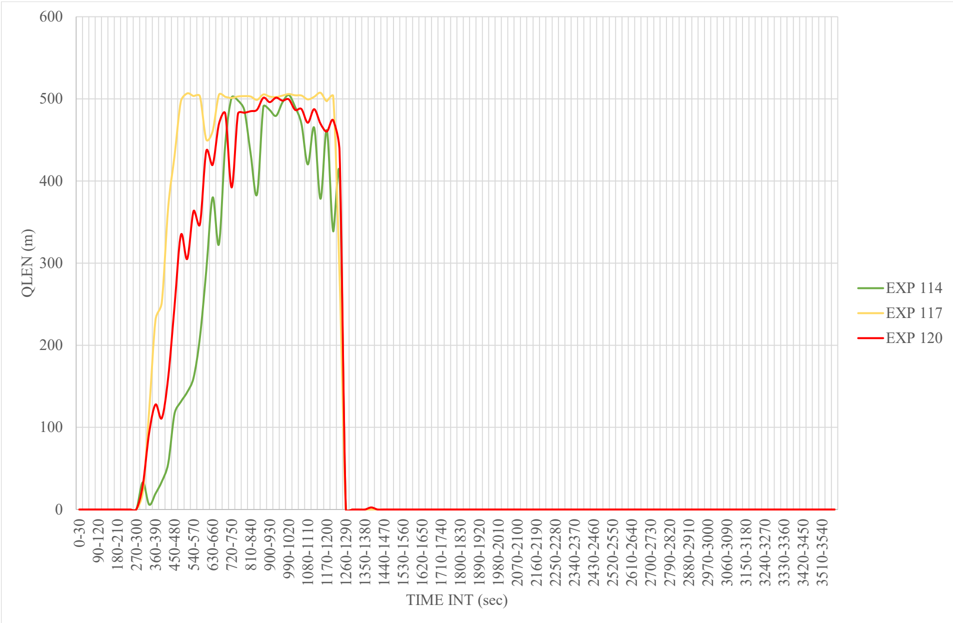

Figure 4.58: QLEN Graph of Incident Position Scenario Group 2.

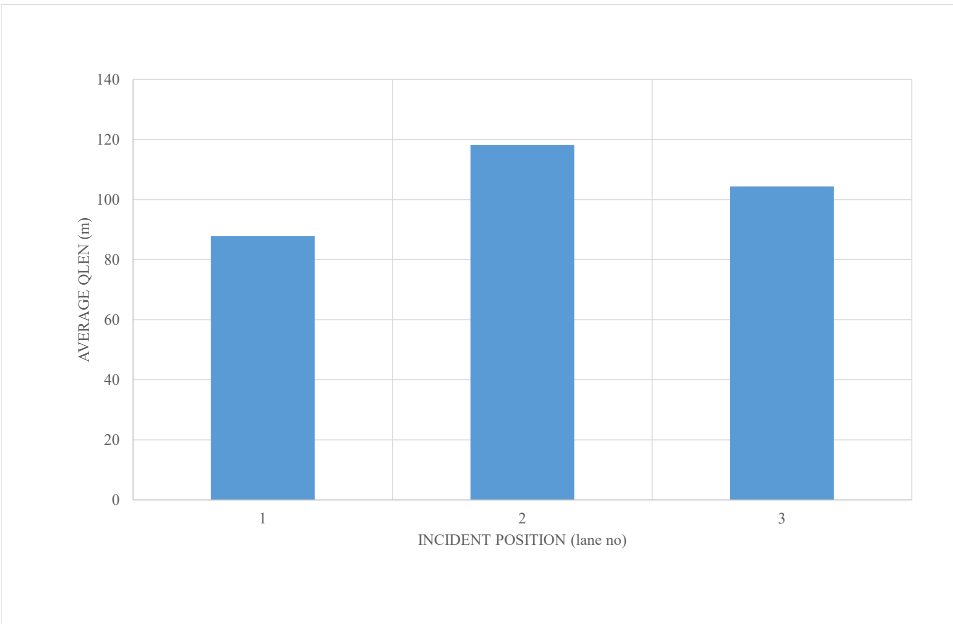

Figure 4.59: AVERAGE QLEN Graph of Incident Position Scenario Group 2.

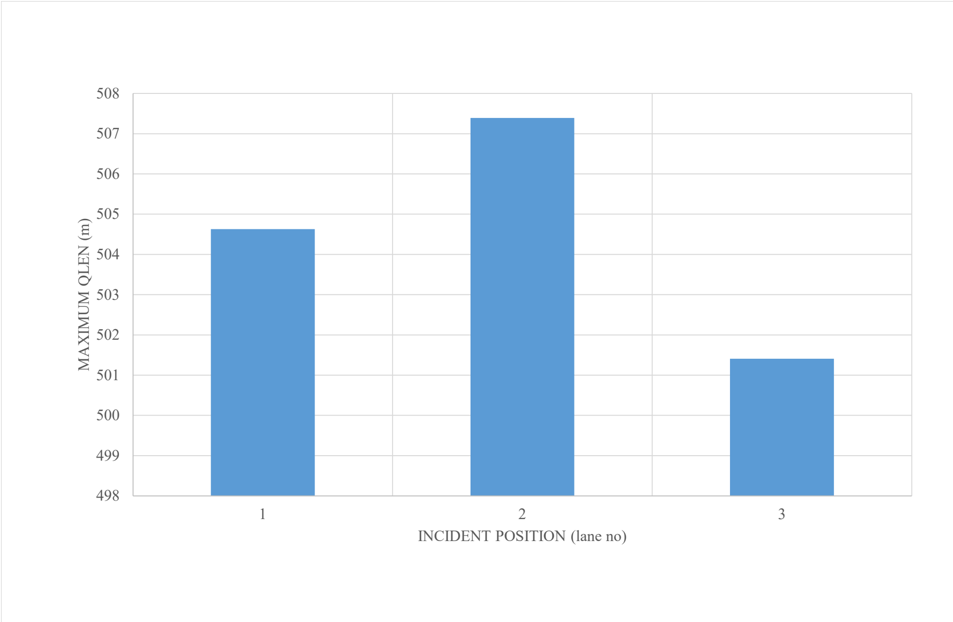

Figure 4.60: MAXIMUM QLEN Graph of Incident Position Scenario Group 2.

experiment scenarios for incident position which are 1st lane (EXP 114), 2nd lane (EXP 117), and 3rd lane (EXP 120) as shown in Figure (4.58). Provided that all other variables are the same, when only different incident positions are used, in 3 lanes roads, after 270th second which is the beginning of the incident, EXP 114's queue length increases to 33 m until 300th second, decreases to 6 m until 330th second, increases to 131 m until 480th second, leaps up to 380 m until 630th second. After that it decreases a little bit to 323 m until 660th second and continues to increase to 505 m. It reaches its top point 505 m at 690th second. After that it decreases to 384 m until 840th second, increases to 491 m until 870th second, fluctuates between 339 m and 505 m until 1230th second, slumps to zero until 1290th second and becomes stable until the end of the simulation.

After 270th second, EXP 117's queue length leaps up to 507 m which is its top point until 510th second, and becomes almost stable until 540th second. After that it decreases to 460 m until 630th second, increases to 502 m until 690th second, and then becomes almost stable until 1170th second. After 1170th second it slumps to zero until 1290th second and becomes stable until the end of the simulation.

After 270th second, EXP 120's queue length increases to 128 m until 360th second, decreases to 111 m until 390th second, then leaps up to 334 m until 480th second. After that it continues to increase to 470 m with some fluctuations until 660th second. After that it decreases to 392 m until 720th second, slumps to 483m until 780th second, and then continues to increase to 501 m which is its top point until 870th second. After that it starts to decrease to 460 m with some fluctuations until 1170th second. After 1170th second it slumps to zero until 1290th second and becomes stable until the end of the simulation. When we look at the average queue length's graph in Figure (4.59) and maximum queue length's graph in Figure (4.60); the sort of average queue length from the highest to the lowest is 2 > 3 >1 and the sort of maximum queue length from the highest to the lowest is 2 >1 >3.

4.1.14 Impact of Incident Position on Number of Vehicles

When the same examples are examined, as shown in Figure (4.61), in 2 lanes roads all experiments' numbers of vehicles have same value except for between 270th-570th, 630th-690th, and 750th-840th seconds. They start from 3 vehicles and leap up to 26 vehicles until 30th second. After that they fluctuate between 29 vehicles and 21 vehicles until 270th second which is the beginning of the incident. After 270th second EXP 18's number of vehicles decreases to 13 vehicles until 330th second, increases 16 vehicles until 450th second, and then fluctuates between 14 vehicles and 17 vehicles until 510th second. After 510th second it decreases to 13 vehicles until 570th second which is the end of the incident. After 570th second EXP 18's number of vehicles leaps up to 45 vehicles until 630th second, decreases 44 vehicles until 690th second, increases 50 vehicles until 720th second, slumps to 26 vehicles until 780th second. After that it fluctuates between 21 vehicles and 35 vehicles until 1260th second, between 11 vehicles and 32 vehicles from 1260th

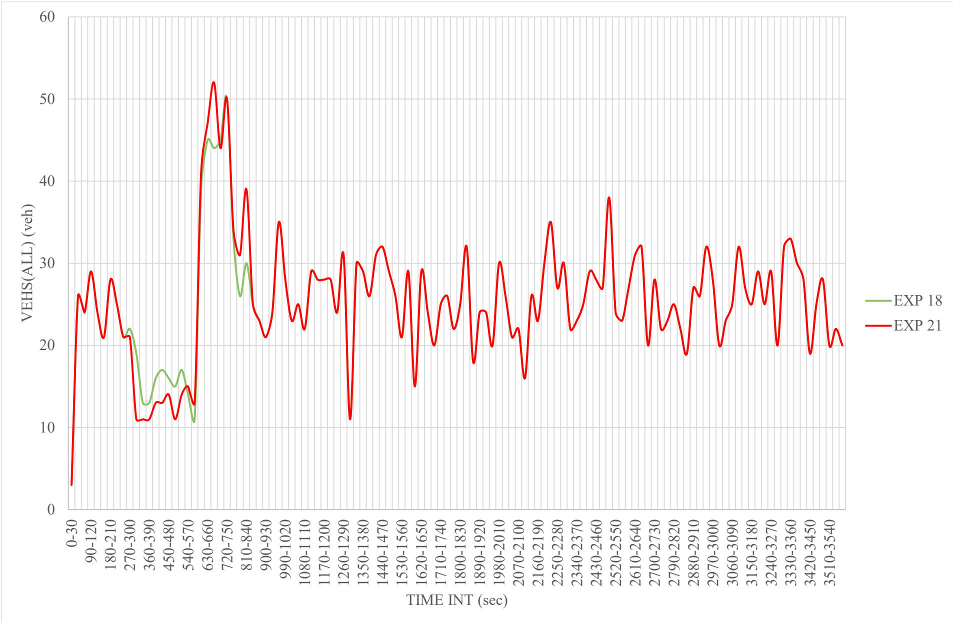

Figure 4.61: VEHS(ALL) Graph of Incident Position Scenario Group 1.

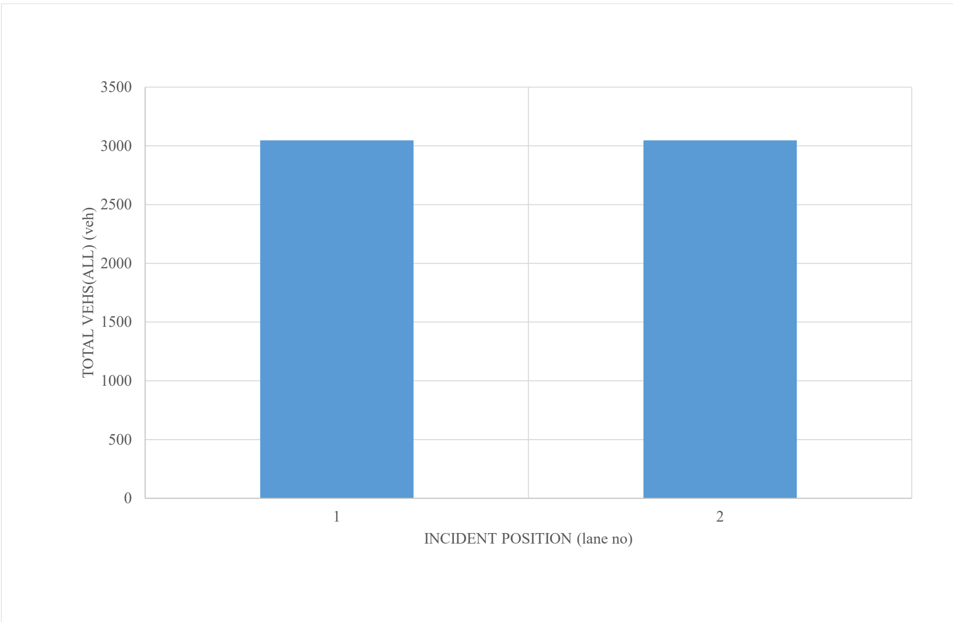

Figure 4.62: TOTAL VEHS(ALL) Graph of Incident Position Scenario Group 1.

second to 2160th second, between 20 vehicles and 38 vehicles from 2160th second to 2670th second, and between 19 vehicles and 32 vehicles from 2670th second to end of the simulation.

The difference of the EXP 21's number of vehicles is after 270th second it decreases 11 vehicles until 330th second and becomes stable until 360th second. After 360th second it fluctuates between 11 vehicles and 14 vehicles until 570th second. After 570th second it leaps up from 13 vehicles to 52 vehicles until 660th second, decreases to 44 vehicles until 690th second, increases to 50 vehicles until 720th second, and then slumps to 31 vehicles until 780th second. After 780th second it increases 39 vehicles until 810th second and decreases to 25 vehicles until 840th second. After 840th second everything is same with EXP 18's number of vehicles until the end of the simulation. When we look at the total number of vehicles' graph in Figure (4.62); if incident position increases, total number of vehicles does not change. It is same for both 2 experiments.

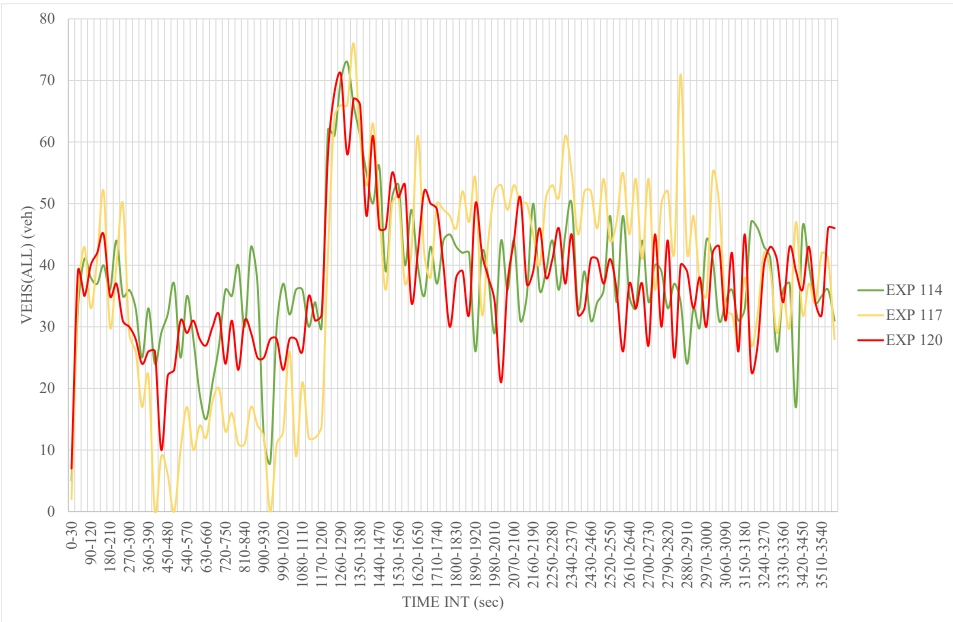

Figure 4.63: VEHS(ALL) Graph of Incident Position Scenario Group 2.

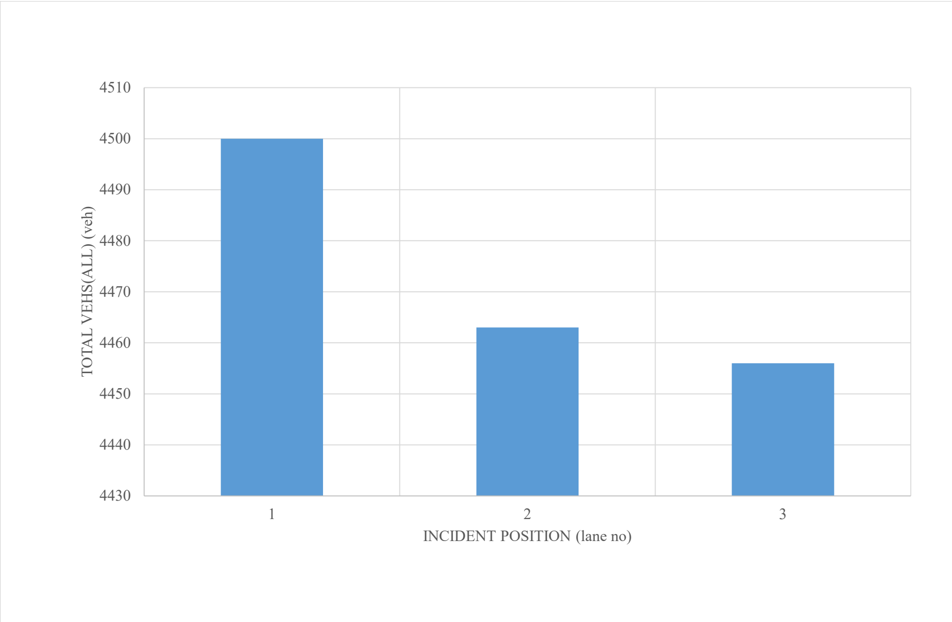

Figure 4.64: TOTAL VEHS(ALL) Graph of Incident Position Scenario Group 2.

When the same examples are examined, as shown in Figure (4.63), in 3 lanes roads, EXP 114's number of vehicles leaps up to 42 vehicles until 90th second, then fluctuates between 38 vehicles and 44 vehicles until 210th second. After that it decreases to 37 vehicles until 270th second which is the beginning of the incident. After that it decreases to 26 vehicles until 330th second, increases to 33 vehicles until 360th second, decreases to 26 vehicles 390th second, increases to 37 vehicles until 480th second, decreases to 25 vehicles until 510th second, increases to 35 vehicles until 540th second, slumps to 15 vehicles 630th second, leaps up to 36 vehicles 720th second, decreases a little bit to 35 vehicles until 750th second, increases to 40 vehicles until 780th second, decreases to 30 vehicles until 810th second, increases to 43 vehicles until 840th second, slumps to 8 vehicles until 930th second, leaps up to 37 vehicles until 990th second, and fluctuates between 30 vehicles and 37 vehicles until 1170th second which is the end of the incident. After that it leaps up to 62 vehicles until 1200th second, decreases a little bit to 61 vehicles until 1230th second, increases to 73 vehicles which is its top point until 1290th second. After that it starts to decrease to 35 vehicles with some big fluctuations until 1650th second. After 1650th second it fluctuates between 17 vehicles and 50 vehicles until the end of the simulation.

EXP 117's number of vehicles leaps up to 43 vehicles until 60th second, then fluctuates between 30 vehicles and 52 vehicles until 270th second. After that it decreases to 17 vehicles until 330th second, increases a little bit to 22 vehicles until 360th second, and then slumps to zero until 390th second. After that it increases to 10 vehicles until 420th second, then slumps to zero again until 480th second. After that it leaps up to 17 vehicles until 540th second and fluctuates between 11 vehicles and 20 vehicles until 900th second. After that it slumps to zero again until 930th second. After 930th second it leaps up to 26 vehicles until 1020th second, decreases to 9 vehicles until 1050th second, increases to 21 vehicles until 1080th second, decreases to 12 vehicles until 1140th second and increases a little bit to 14 until 1170th second. After 1170th second it leaps up to 68 vehicles until 1230th second and continues to increase to 76 vehicles which is its top point until 1320th second. After that it starts to decrease to 36 vehicles with some big fluctuations until 1470th second. After 1470th second it fluctuates between 27 vehicles and 71 vehicles until the end of the simulation.

EXP 120's number of vehicles leaps up to 39 vehicles until 30th second, decreases to 35 vehicles until 60th second and increases to 45 vehicles until 150th second. After that it starts to decrease to 30 vehicles with some fluctuations until 270th second. After that it decreases to 24 vehicles until 330th second, increases a little bit to 26 vehicles until 360th second, and then slumps to 10 vehicles until 420th second. After 420th second it leaps up to 22 vehicles until 450th second, and continues to increase to 23 until 480th second. After that it leaps up to 31 vehicles until 510th second, and fluctuates between 23 vehicles and 35 vehicles until 1170th second. After 1170th second it leaps up to 71 vehicles which is its top point until 1260th second. After that it starts to decrease to 30 vehicles with some big fluctuations until 1770th second. After 1770th second it fluctuates between 21 vehicles and 51 vehicles until the end of the simulation. When we look at the total number of vehicles' graph in Figure (4.64); if incident position increases, total number of vehicles decreases.

4.1.15 Impact of Incident Position on Travel Time

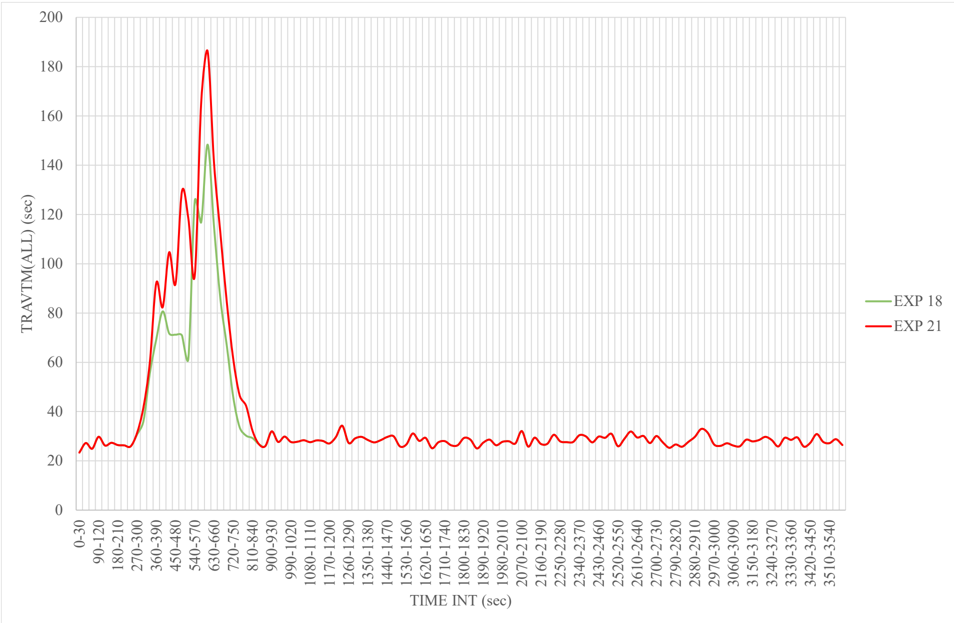

Figure 4.65: TRAVTM(ALL) Graph of Incident Position Scenario Group 1.

When the same examples are examined, as shown in Figure (4.65), in 2 lanes roads all experiments' travel times have same value until 330th second. They fluctuate between 26 seconds and 30 seconds from the beginning of the simulation to 240th second. After that they start to increase to 60 seconds until 330th second. After 330th second EXP 18's travel time and EXP 21's travel time show different values from each other until 810th second. After 330th second EXP 18's travel time increases to 81 seconds until 390th second, decreases to 71 seconds until 420th second and becomes stable until 480th second. After 480th second it continues to decrease to 62 seconds until 510th second. After that it leaps up to 125 seconds until 540th second, decreases to 117 seconds until 570th second, and increases to

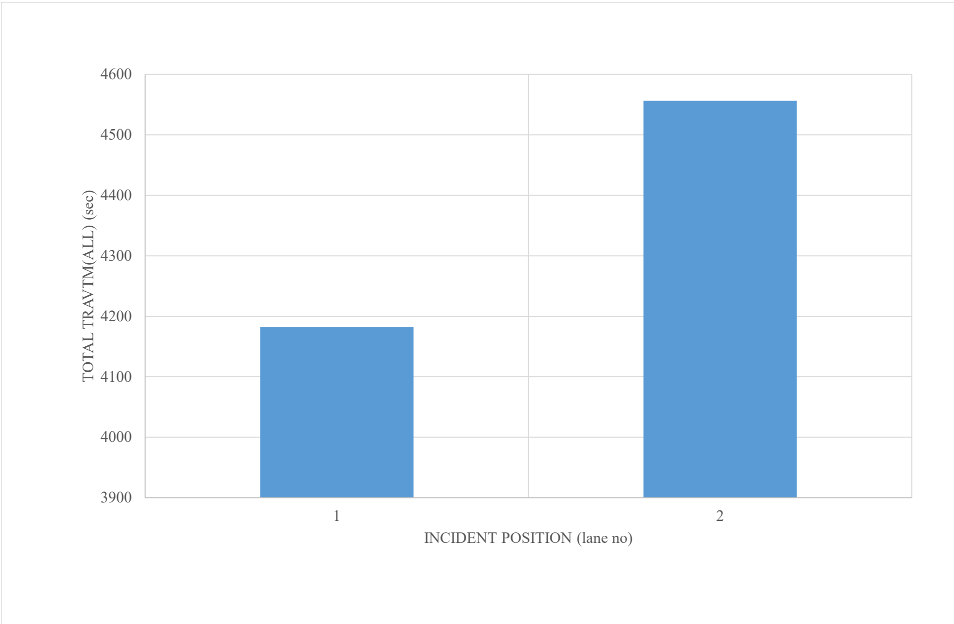

Figure 4.66: TOTAL TRAVTM(ALL) Graph of Incident Position Scenario Group 1.

148 seconds which is its top point until 600th second which is a few minutes after the end of the incident. After that it slumps to 32 seconds until 810th second and starts to fluctuate between 26 seconds and 34 seconds until the end of the simulation.

After 330th second EXP 21's travel time increases to 92 seconds until 360th second, decreases to 82 seconds until 390th second, increases to 105 seconds until 420th second, decreases to 92 seconds until 450th second, increases to 129 seconds until 480th second, decreases to 95 seconds until 540th second, and leaps up to 186 seconds which is its top point until 600th second which is a few minutes after the end of the incident. After that it slumps to 32 seconds until 810th second and starts to fluctuate between 26 seconds and 34 seconds until the end of the simulation. When we look at the total travel time's graph in Figure (4.66); if incident position increases, total travel time increases.

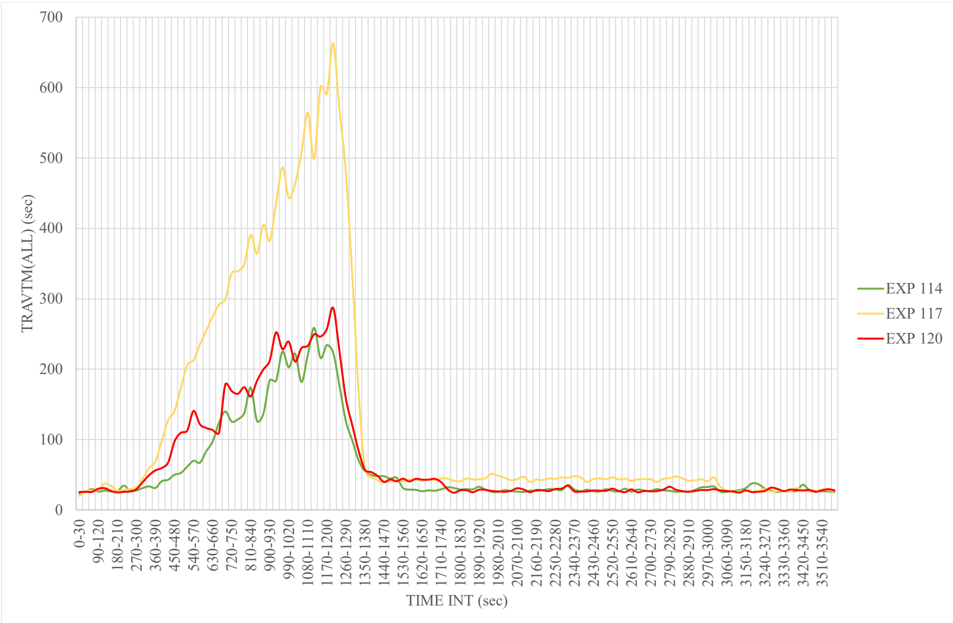

Figure 4.67: TRAVTM(ALL) Graph of Incident Position Scenario Group 2.

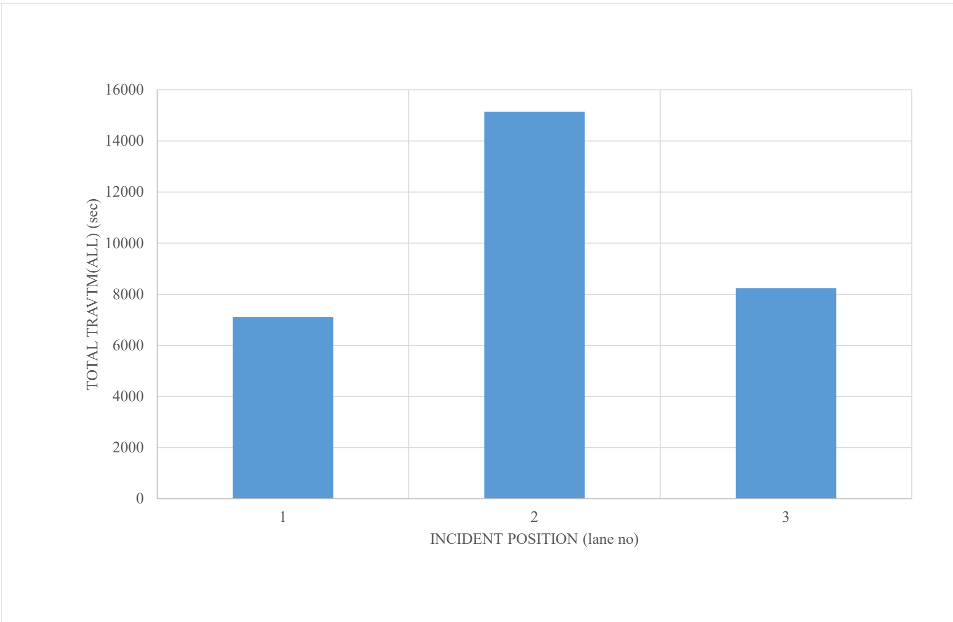

Figure 4.68: TOTAL TRAVTM(ALL) Graph of Incident Position Scenario Group 2.

When the same examples are examined, as shown in Figure (4.67), in 2 lanes roads all experiments' travel times have same value until 330th second. They fluctuate between 26 seconds and 30 seconds from the beginning of the simulation to 240th second. After that they show different values from each other. After 240th second EXP 114's travel time increases to 126 seconds until 720th second. After that it decreases to 129 seconds until 750th second, increases to 184 seconds until 840th second, decreases to 137 seconds until 870th second, increases to 184 seconds until 900th second. After that it starts to fluctuate between 181 seconds and 259 seconds which is its top point until 1110th second. After that it decreases to 216 seconds until 1140th second, increases to 234 seconds until 1170th second which is the end of the incident. After that it slumps to 54 seconds until 1380th second and fluctuates between 29 seconds and 38 seconds until the end of the simulation.

After 240th second EXP 117's travel time continuously increases to 391 seconds until 810th second. After 810th second it decreases to 364 seconds until 840th second, increases to 405 seconds until 870th second, and decreases to 382 seconds until 900th second, increases to 487 seconds until 960th second, decreases 443 seconds until 990th second, increases to 564 seconds until 1080th second, decreases to 499 seconds until 1110th second, increases to 601 seconds until 1140th second, decreases to 591 seconds until 1170th second, and increases to 663 seconds which is its top point until 1200th second. After that it slumps to 54 seconds until 1380th second, then fluctuates between 48 seconds and 51 seconds until 3000th second and between 29 seconds and 32 seconds from 3000th second to the end of the simulation.

After 240th second EXP 120's travel time increases to 141 seconds until 540th second. After that it decreases to 110 seconds until 660th second, increases to 178 seconds until 690th second. After that it fluctuates between 161 seconds and 178 seconds until 810th second. After 810th second it increases to 252 seconds until 930th second, decreases to 228 seconds until 960th second, increases to 239 seconds until 990th second, decreases to 211 seconds until 1020th second. After that it increases to 287 seconds which is its top point until 1200th second.

After 1200th second it slumps to 54 seconds until 1380th second, then fluctuates between 43 seconds and 45 seconds until 1680th second and between 24 seconds and 26 seconds from 1680th second to the end of the simulation. When we look at the total travel time's graph in Figure (4.68); the sort of total travel time from the highest to the lowest is 2 > 3 >1.

4.1.16 Impact of Incident Position on Speed

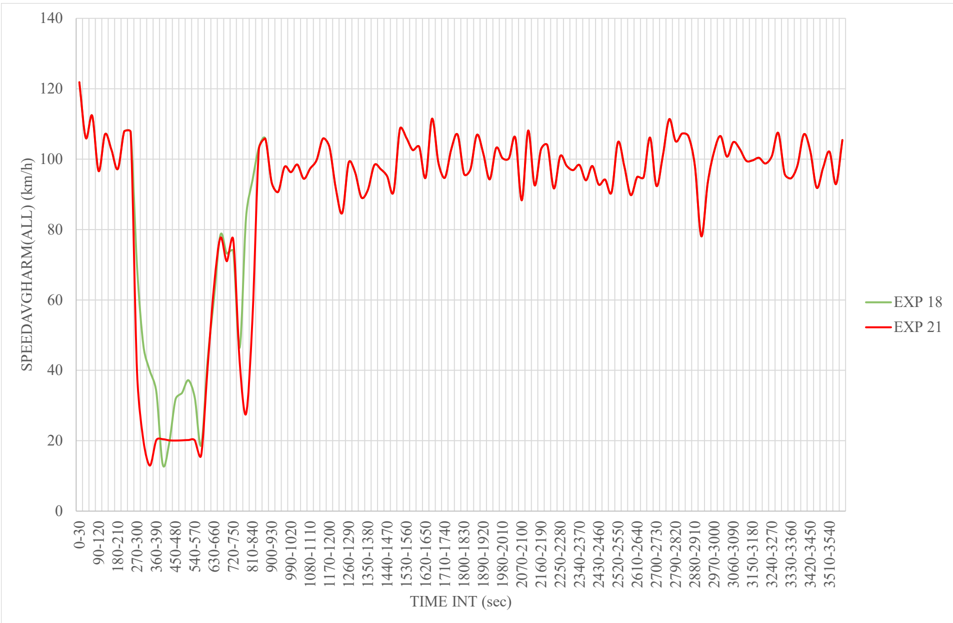

Figure 4.69: SPEEDAVGHARM(ALL) Graph of Incident Position Scenario Group 1.

When the same examples are examined, as shown in Figure (4.69), in 2 lanes roads all experiments' speeds have same value except for between 240th-570th seconds and 750th-840th seconds. They start from 122 km/h and decrease to 106 km/h until 30th second. After that they fluctuate between 97 km/h and 112 km/h until 240th second. After 240th second EXP 18's speed slumps to 40 km/h until 330th second and continues to decrease to 13 km/h until 390th second. After that it leaps up to 34 km/h until 480th second and continues to increase to 37

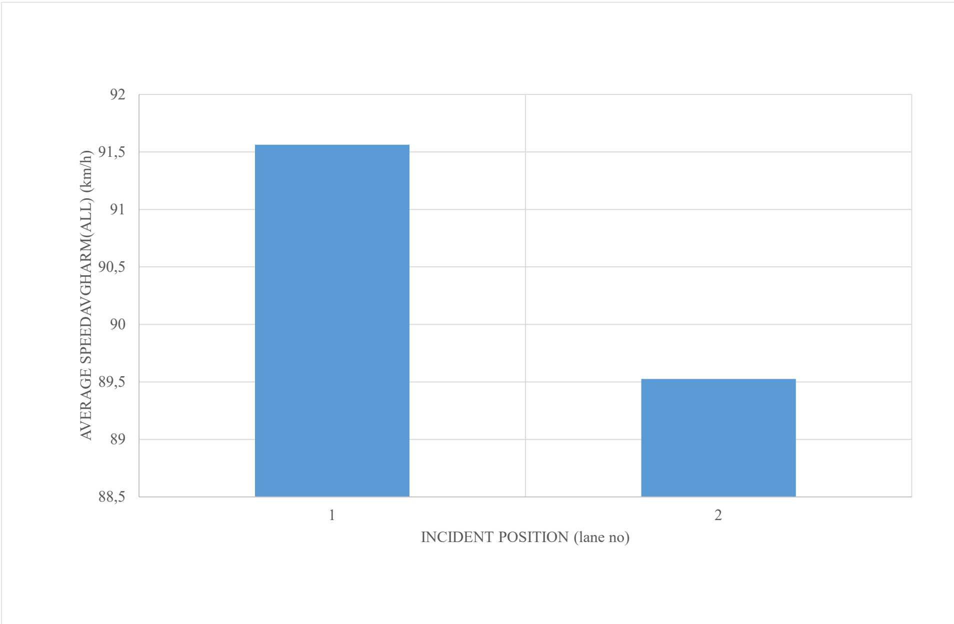

Figure 4.70: AVERAGE SPEEDAVGHARM(ALL) Graph of Incident Position Scenario Group 1.

km/h until 510th second. After that it decreases to 20 km/h until 570th second and it leaps up to 78 km/h until 660th second, decreases to 71 km/h until 690th second, increases to 77 km/h until 720th second, and then slumps to 46 km/h until 750th second. After that it leaps up to 106 km/h until 870th second. After 870th second it starts to fluctuate between 78 km/h and 111 km/h until the end of the simulation.

After 240th second EXP 21's speed slumps to 13 km/h until 330th second. After that it increases to 20 km/h until 360th second, becomes stable until 540th second, decreases to 16 km/h until 570th second, and then leaps up to 78 km/h until 660th second. After that it decreases to 71 km/h until 690th second, increases to 77 km/h until 720th second, and then slumps to 28 km/h until 780th second. After that it leaps up to 106 km/h until 870th second. After 870th second it starts to fluctuate between 78 km/h and 111 km/h until the end of the simulation.

When we look at the average speed's graph in Figure (4.70); if incident position increases, average speed decreases.

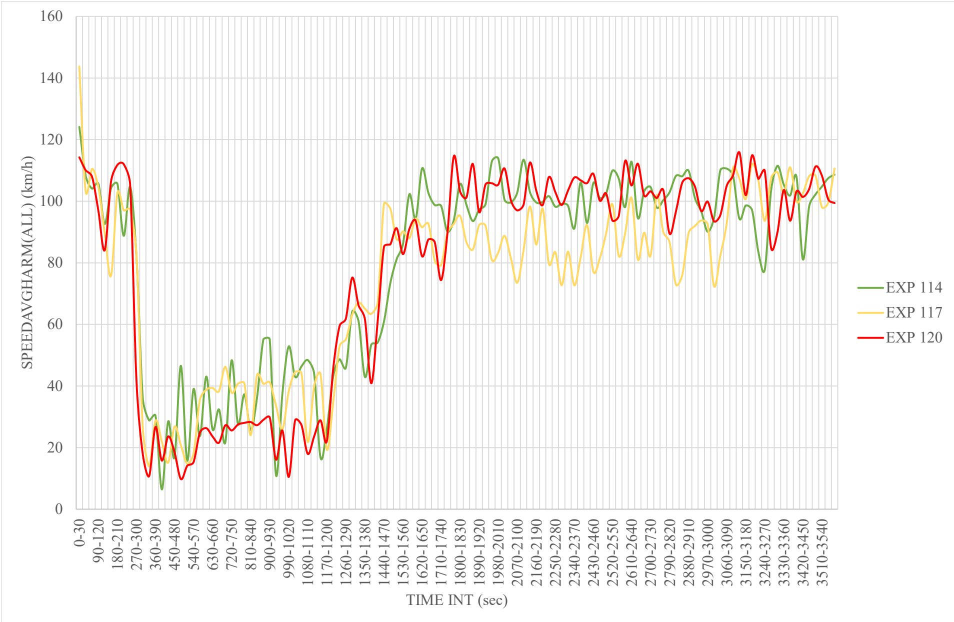

Figure 4.71: SPEEDAVGHARM(ALL) Graph of Incident Position Scenario Group 2.

When the same examples are examined, as shown in Figure (4.71), in 2 lanes roads EXP 114's speed starts from 124 km/h and decreases to 110 km/h until 30th second. After that it fluctuates between 89 km/h and 112 km/h until 240th second which is the beginning of the incident. After 240th second it slumps to 28 km/h until 300th second, increases a little bit to 30 km/h until 360th second, and then slumps to 6 km/h until 390th second. After 390th second it increases to 29 km/h until 420th second, decreases to 19 km/h until 450th second, and then fluctuates between 11 km/h and 55 km/h until 1170th second which is the end of the incident. After 1170th second it increases from 22 km/h to 46 km/h until 1200th second, decreases to 49 km/h until 1230th second, increases to 62 km/h until 1290th second, decreases to 43 km/h until 1350th second. After 1350th second it starts to increase to 102 km/h until 1560th second with some

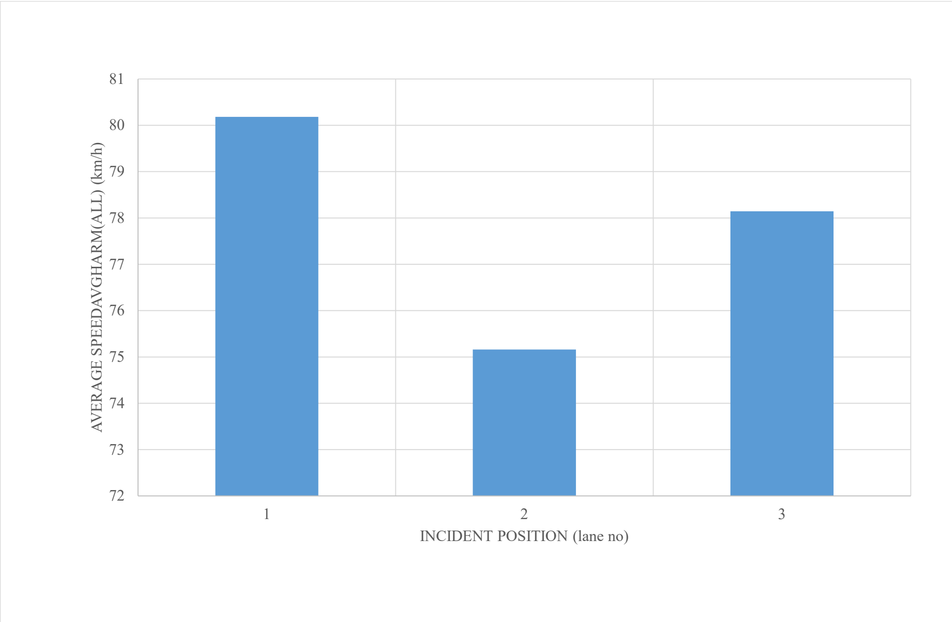

Figure 4.72: AVERAGE SPEEDAVGHARM(ALL) Graph of Incident Position Scenario Group 2.

fluctuation. After that it fluctuates between 91 km/h and 113 km/h until 3030th second, and after 3030th second between 78 km/h and 111 km/h until the end of the simulation.

EXP 117's speed starts from 144 km/h and decreases to 103 km/h until 30th second. After that it increases to 111 km/h until 60th second, decreases to 76 km/h until 150th second, increases to 103 km/h until 180th second, decreases to 97 km/h until 240th second, and becomes stable until 270th second. After 270th second it slumps to 18 km/h until 300th second, increases to 29 km/h until 360th second, decreases to 15 km/h until 420th second, increases to 27 km/h until 450th second, decreases to 15 km/h until 510th second, increases to 36 km/h until 570th second. After that it increases to 39 km/h until 630th second, and continues to increase to 46 km/h until 690th second, decreases to 38 km/h until 720th second, increases to 41 km/h until 750th second, and then slumps to 24 km/h until 810th second. After 810th second it increases to 44 km/h until 840th second, decreases to 41 km/h until 870th second. It fluctuates between 19 km/h and 44 km/h from 870th second to 1170th second. It leaps up from 19 km/h to 55 km/h from 1170th second to 1260th second, and continues to increase to 66 km/h until 1320th second. After that it decreases to 62 km/h until 1350th second, and leaps up to 98 km/h until 1470th second. After that it fluctuates between 72 km/h and 101 km/h until 3060th second, and after 3060th second between 94 km/h and 112 km/h until the end of the simulation.

EXP 120's speed starts from 110 km/h and decreases to 84 km/h until 120th second, increases to 112 km/h until 210th second, and then slumps to 11 km/h until 330th second. After 330th second it fluctuates between 10 km/h and 25 km/h until 570th second, between 22 km/h and 29 km/h from 570th second 870th second, between 10 km/h and 29 km/h from 870th second 1170th second. After 1170th second it leaps up to 59 km/h until 1230th second, and continues to increase to 75 km/h until 1290th second. After that it decreases to 66 km/h until 1320th second, and continues to decrease to 41 km/h until 1380th second. After that it leaps up to 86 km/h until 1470th second, and then fluctuates between 74 km/h and 91 km/h until 1710th second. After 1710th second it leaps up from 74 to 115 km/h until 1770th second, and then fluctuates between 89 km/h and 116 km/h until 3120th second, and after 3120th second between 85 km/h and 116 km/h until the end of the simulation. When we look at the average speed's graph in Figure (4.72); the sort of average speed from the highest to the lowest is $1 > 3 > 2$.

4.1.17 Impact of Lane Width on Queue Length

When an incident whose duration is 5 minutes occurs in the 1st lane of a two-lane road whose vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for lane width which are 3.00 m (EXP 1), 3.25 m (EXP 2), and 3.50 m (EXP 3) as shown in Figure (4.73). Provided that all other variables are the same, when only different lane widths are used, in 2 lanes roads, after 270th

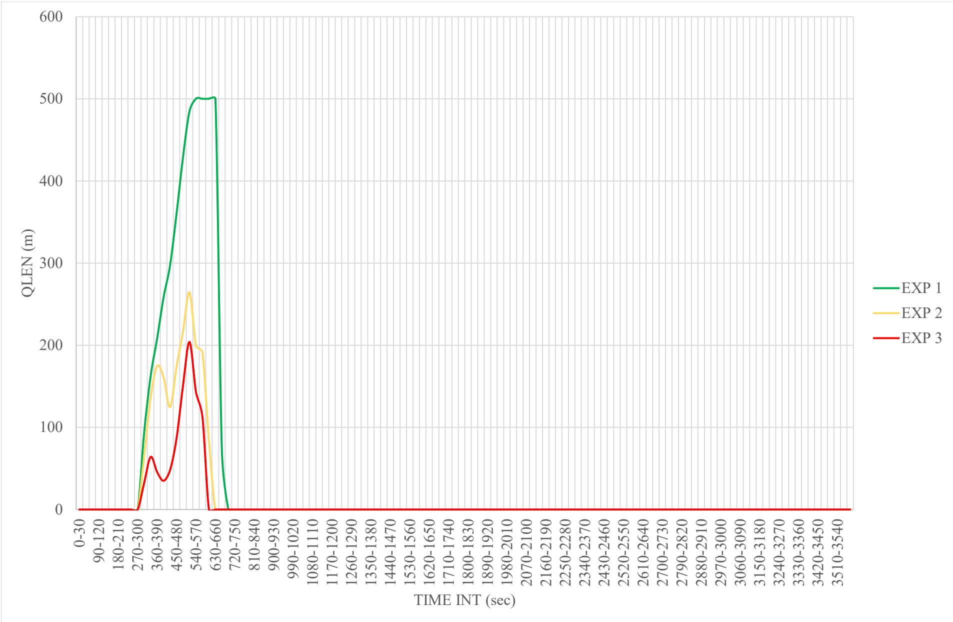

Figure 4.73: QLEN Graph of Lane Width Scenario Group 1.

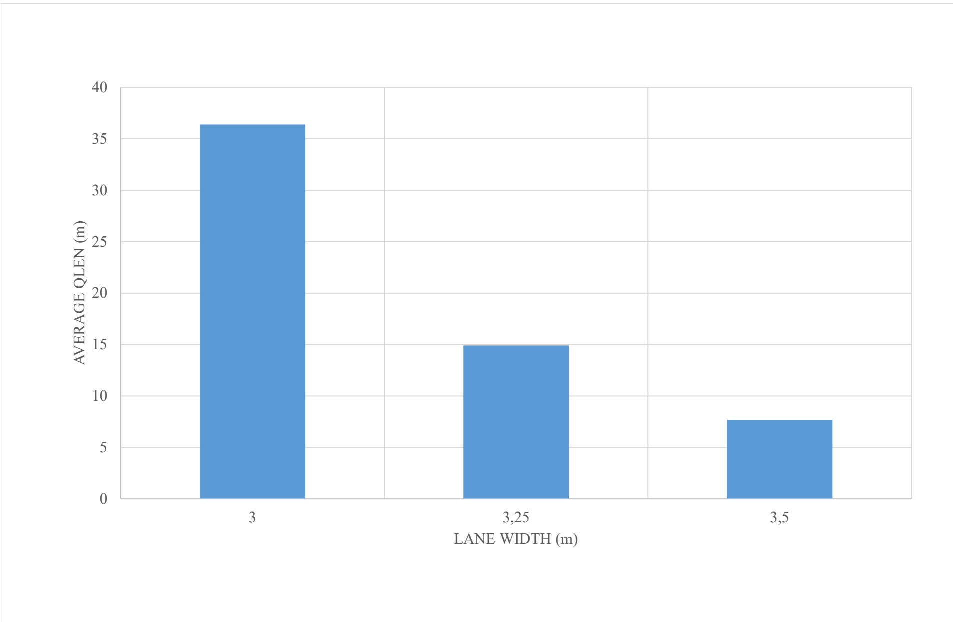

Figure 4.74: AVERAGE QLEN Graph of Lane Width Scenario Group 1.

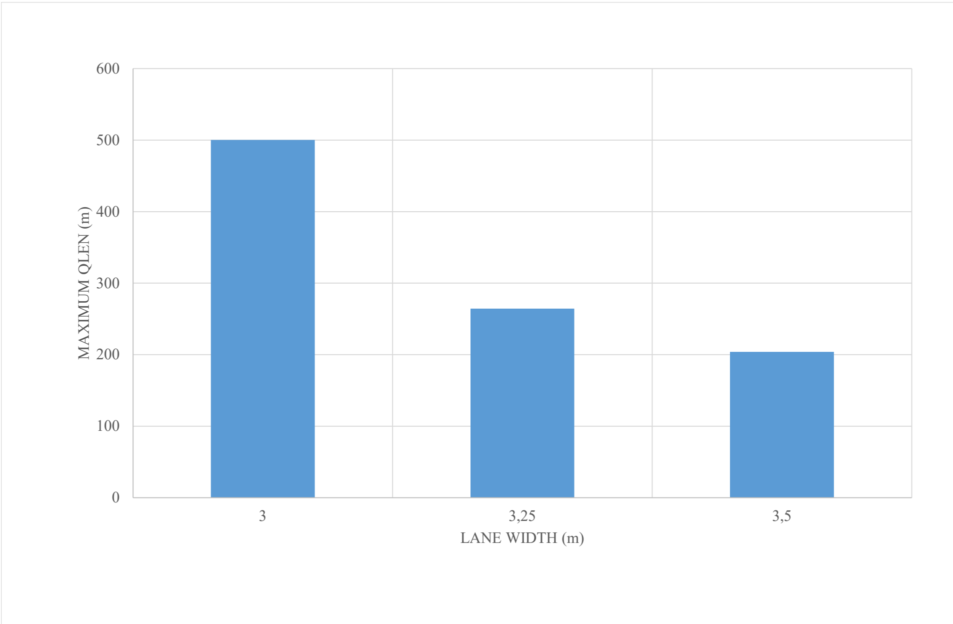

Figure 4.75: MAXIMUM QLEN Graph of Lane Width Scenario Group 1.

second which is the beginning of the incident, EXP 1's queue length leaps up from zero to 500 m which is its top point until 570th second which is the end of the incident, and becomes stable until 630th second. After that it slumps to zero until 720th second, and becomes stable until the end of the simulation.

After 270th second EXP 2's queue length leaps up from zero to 175 m until 360th second, decreases to 125 m until 420th second, increases to 264 m which is its top point until 510th second, decreases to 199 m until 540th second, and continues to decrease to 191 m until 570th second. After 570th second it slumps to zero until 660th second, and becomes stable until the end of the simulation.

After 270th second EXP 3's queue length increases from zero to 64 m until 330th second, decreases to 35 m until 390th second, leaps up to 204 m which is its top point until 510th second, decreases to 143 m until 540th second, and continues to decrease to 112 m until 570th second. After 570th second it slumps to zero until 600th second, and becomes stable until the end of the simulation. When we look at the average queue length's graph in Figure (4.74) and maximum queue length's graph in Figure (4.75); if lane width increases, average queue length and maximum queue length decrease.

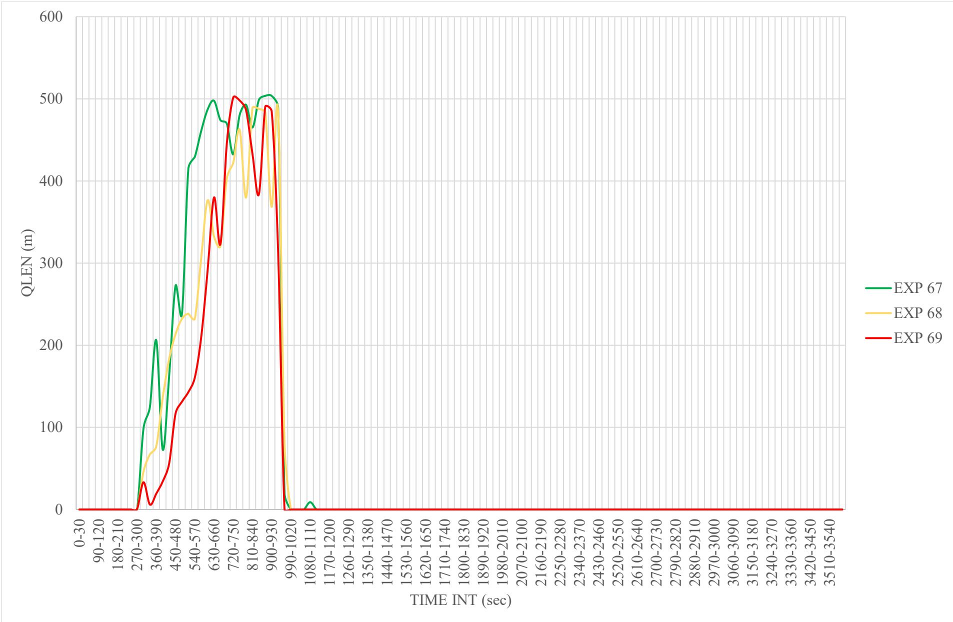

Figure 4.76: QLEN Graph of Lane Width Scenario Group 2.

When an incident whose duration is 10 minutes occurs in the 1st lane of a three-lane road whose vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for lane width which are 3.00 m (EXP 67), 3.25 m (EXP 68), and 3.50 m (EXP 69) as shown in Figure (4.76). When the same examples are examined, in 3 lanes roads after 270th second which is the beginning of the incident, EXP 67's queue length leaps up from zero to 98 m until 300th second, continues to increase to 125 m until 330th second, and to 206 m until 360th second. After that it slumps to 73 m until 390th second, leaps up to 272 m until 450th second, decreases to 238 m until 480th second, leaps up to 429 m until 540th second, and continues to increase to 498 m until 630th second. After that it decreases to 474 m until 660th second, continues to decrease to 446 m until 690th second, increases to 498 m until 750th second, decreases to 465 m until 810th second, increases to

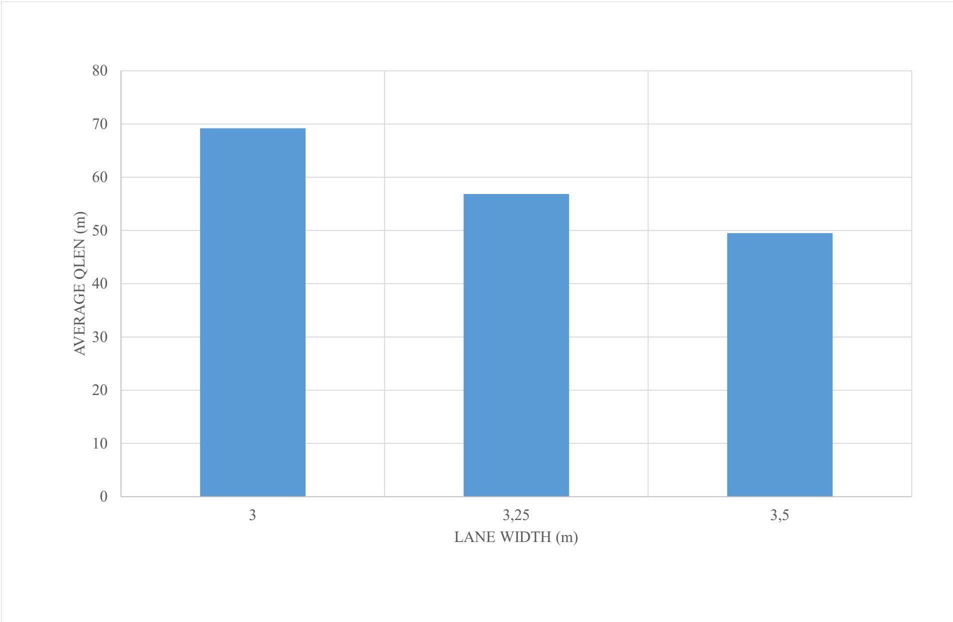

Figure 4.77: AVERAGE QLEN Graph of Lane Width Scenario Group 2.

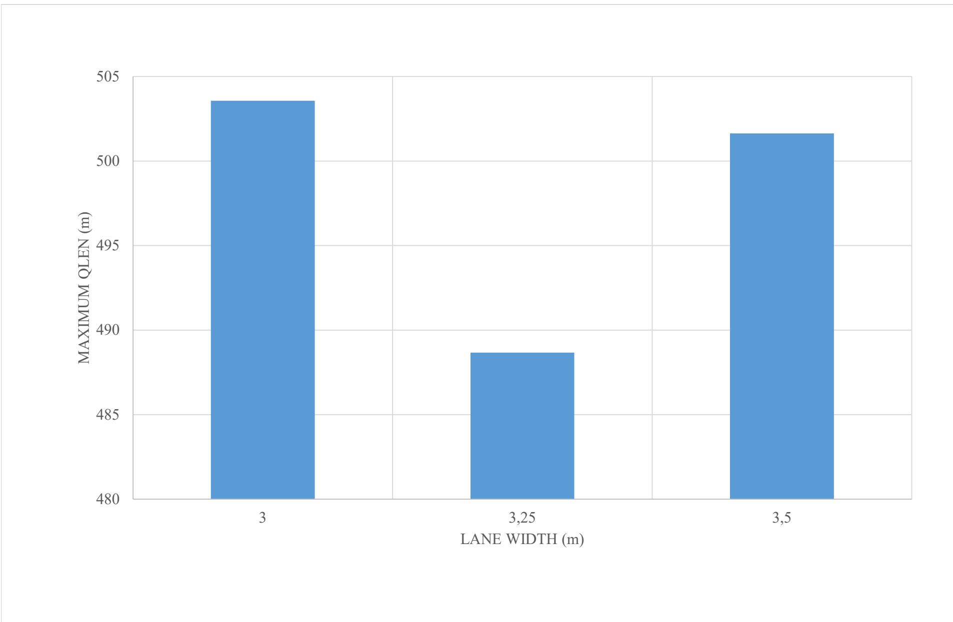

Figure 4.78: MAXIMUM QLEN Graph of Lane Width Scenario Group 2.

504 m which is its top point until 870th second which is the end of the incident, and becomes stable until 900th second. After 900th second it slumps to zero until 960th second, and becomes stable until 1080th second. At 1080th second it increases to 9 m for a while and becomes zero again. After 1080th second it is zero until the end of the simulation.

After 270th second, EXP 68's queue length increases from zero to 67 m until 330th second, leaps up to 238 m until 510th second, decreases to 232 m until 540th second, leaps up to 377 m until 600th second, decreases to 321 m until 660th second, increases to 403 m until 690th second, continues to increase to 462 m until 750th second, decreases to 380 m until 780th second, increases to 488 m which is its top point until 810th second, and becomes stable until 840th second. After that it decreases to 368 m until 900th second, increases to 485 m until 930th second. After 930th second it slumps to zero until 990th second, and becomes stable until the end of the simulation.

After 270th second, EXP 69's queue length increases from zero to 33 m until 300th second, decreases to 6 m until 330th second, increases to 56 m until 420th second, to 117 m until 450th second, to 143 m until 510th second, leaps up to 380 m until 630th second, decreases to 323 m until 660th second, leaps up to 502 m which is its top point until 720th second, decreases to 498 m until 750th second, continues to decrease to 384 m until 840th second, increases to 491 m until 870th second, decreases to 485 m until 900th second. After 900th second it slumps to zero until 960th second, and becomes stable until the end of the simulation. When we look at the average queue length's graph in Figure (4.77) and maximum queue length's graph in Figure (4.78); the sort of average queue length from the highest to the lowest is 3.00 > 3.25 > 3.50 and the sort of maximum queue length from the highest to the lowest is 3.00 > 3.50 > 3.25.

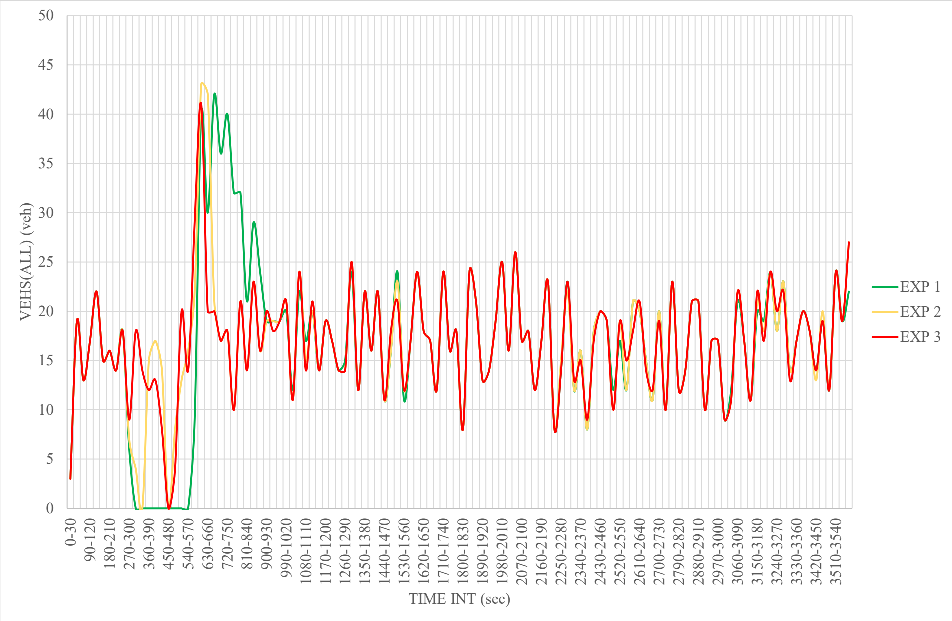

Figure 4.79: VEHS(ALL) Graph of Lane Width Scenario Group 1.

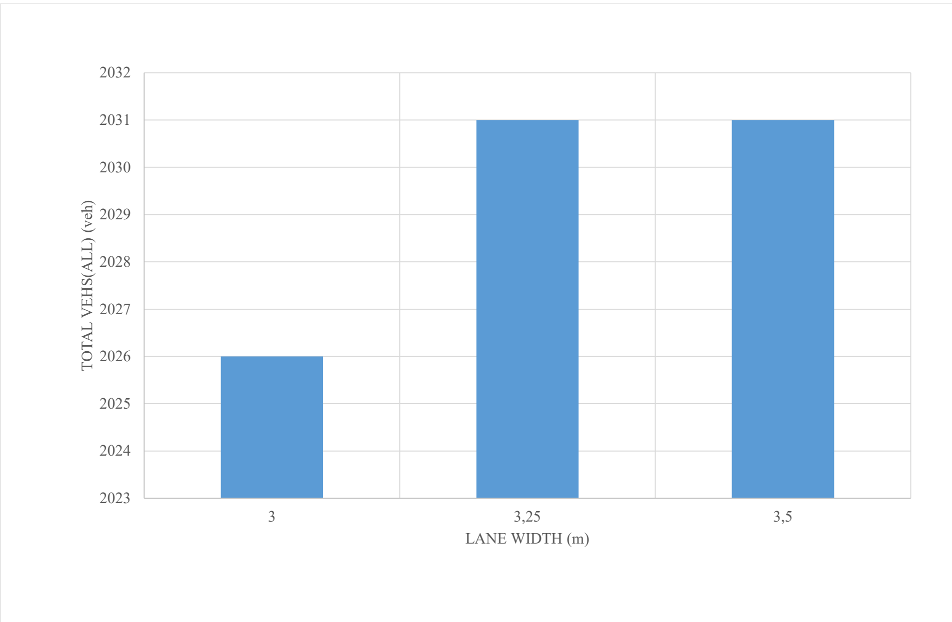

Figure 4.80: TOTAL VEHS(ALL) Graph of Lane Width Scenario Group 1.

4.1.18 Impact of Lane Width on Number of Vehicles

When the same examples are examined, as shown in Figure (4.79), in 2 lanes roads all experiments' numbers of vehicles have same value except for between 270th-900th. The differences between 1500th-1560th, 2310th-2700th, 3210th-3300th, 3420th-3480th, and 3540th-3600th seconds can be ignored. They start from 3 vehicles and leap up to 19 vehicles until 30th second. After that they fluctuate between 13 vehicles and 22 vehicles until 270th second which is the beginning of the incident. After 270th second EXP 1's number of vehicles slumps to zero until 300th second, and becomes stable until 540th second which is the end of the incident. After 540th second it leaps up to 41 vehicles until 600th second, decreases to 30 vehicles until 630th second, increases to 42 vehicles which is its top point until 660th second, decreases to 36 vehicles until 690th second, increases to 40 vehicles until 720th second, decreases to 32 vehicles until 750th second, and becomes stable until 780th second. After that it decreases to 21 vehicles until 810th second, increases to 29 vehicles until 840th second, decreases to 19 vehicles until 900th second. After 900th second it fluctuates between 8 vehicles and 27 vehicles until the end of the simulation.

After 270th second EXP 2's number of vehicles slumps to zero until 330th second, leaps up to 17 vehicles until 390th second, slumps to zero until 450th second, leaps up to 43 vehicles until 600th second which is the end of the incident. After that it slumps to 20 vehicles until 660th second, and then fluctuates between 8 vehicles and 27 vehicles until the end of the simulation.

After 270th second EXP 3's number of vehicles increases to 18 vehicles until 300th second, decreases to 12 vehicles until 360th second, increases to 13 vehicles until 390th second, slumps to zero until 450th second, leaps up to 20 vehicles until 510th second, decreases to 14 until 540th second, leaps up to 41 vehicles until 600th second which is the end of the incident. After that it slumps to 20 vehicles until 630th second, and then fluctuates between 8 vehicles and 27 vehicles until the end of the simulation. When we look at the total number of vehicles' graph in

Figure (4.80); the sort of total number of vehicles from the highest to the lowest is 3.25 = 3.50 > 3.00.

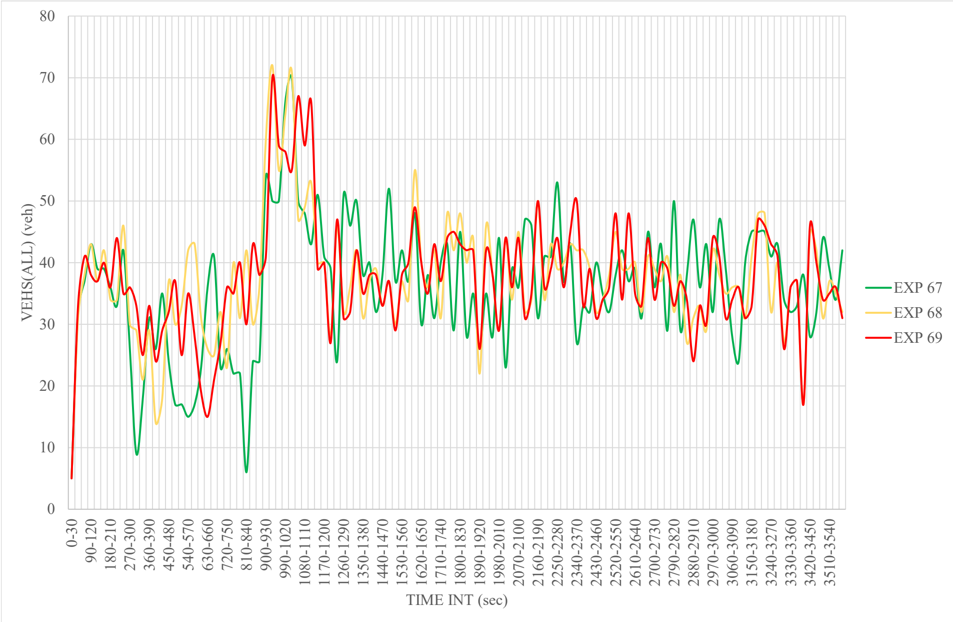

Figure 4.81: VEHS(ALL) Graph of Lane Width Scenario Group 2.

When the same examples are examined, as shown in Figure (4.81), in 3 lanes roads EXP 67's number of vehicles starts from 5 vehicles and leap up to 43 vehicles until 90th second. After that it fluctuates between 33 vehicles and 43 vehicles until 270th second which is the beginning of the incident. After 270th second it slumps to 9 vehicles until 300th second, increases to 30 vehicles until 360th second, decreases to 26 vehicles until 390th second, increases to 35 vehicles until 420th second, slumps to 17 vehicles until 480th second, becomes stable until 510th second, and continues to decrease to 15 vehicles until 540th second. After 540th second it leaps up to 41 vehicles until 660th second, decreases to 23 vehicles until 690th second, increases to 26 vehicles until 720th second, decreases to 22 vehicles until 750th second, becomes stable until 780th second, slumps to 6 vehicles until 810th second, leaps up to 24 vehicles until 840th second, and becomes stable until 870th second which is the end of the incident. After 870th

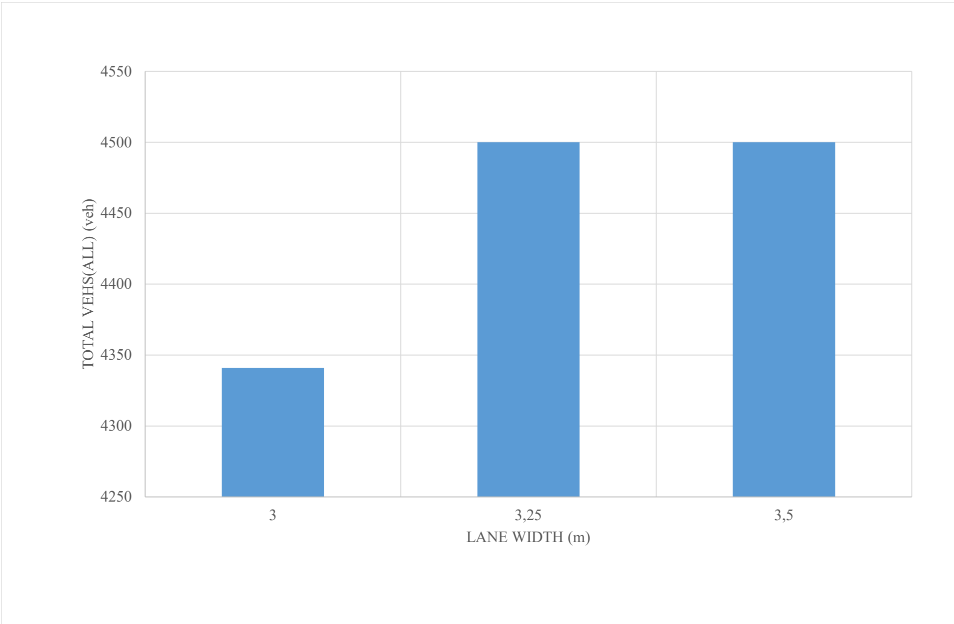

Figure 4.82: TOTAL VEHS(ALL) Graph of Lane Width Scenario Group 2.

second it leaps up to 54 vehicles until 900th second, decreases to 50 vehicles until 960th second, increases to 70 vehicles until 1020th second, decreases to 49 vehicles until 1080th second, to 43 vehicles until 1110th second. After that it starts to fluctuate between 23 vehicles and 53 vehicles until the end of the simulation.

EXP 68's number of vehicles starts from 5 vehicles and leap up to 43 vehicles until 90th second. After that it fluctuates between 34 vehicles and 46 vehicles until 240th second. After 240th second it decreases to 30 vehicles until 270th second, to 29 vehicles until 300th second, to 21 vehicles until 330th second, increases to 30 vehicles until 360th second, slumps to 14 vehicles until 390th second, leaps up to 37 vehicles until 450th second, decreases to 30 vehicles until 480th second, increases to 42 vehicles until 540th second, decreases to 26 vehicles until 630th second, increases to 32 vehicles until 690th second, decreases to 23 vehicles until 720th second, and leaps up to 40 vehicles until 750th second. After 750th second it fluctuates between 30 vehicles and 42 vehicles until 840th second. After 840th second it leaps up to 72 vehicles until 930th second, decreases to 55 vehicles until 960th second, increases to 71 vehicles until 1020th second, decreases to 47 vehicles until 1050th second, increases to 53 vehicles until 1110th second, and then decreases to 39 vehicles until 1140th second. After that it starts to fluctuate between 22 vehicles and 55 vehicles until the end of the simulation.

EXP 69's number of vehicles starts from 5 vehicles and leap up to 41 vehicles until 60th second. After that it fluctuates between 36 vehicles and 44 vehicles until 270th second. After 270th second it decreases to 25 vehicles until 330th second, and fluctuates between 24 vehicles and 37 vehicles until 570th second. After that it slumps to 15 vehicles until 630th second, leaps up to 36 vehicles until 720th second, decreases to 35 vehicles until 750th second, increases to 40 vehicles until 780th second, decreases to 30 vehicles until 810th second, increases to 43 vehicles until 840th second, and then decreases to 38 vehicles until 870th second. After 870th second it leaps up to 70 vehicles until 930th second, decreases to 59 vehicles until 960th second, to 58 vehicles until 990th second, to 55 vehicles until 1020th second, increases to 67 vehicles until 1050th second, decreases to 59 vehicles until 1080th second, increases to 66 vehicles until 1110th second, slumps to 40 vehicles until 1170th second. After that it starts to fluctuate between 24 vehicles and 50 vehicles until 3330th second. After that it slumps to 17 vehicles until 3390th second, leaps up to 46 vehicles until 3420th second, decreases to 35 vehicles until 3510th second, increases to 36 vehicles until 3540th second, and then decreases to 31 vehicles until the end of the simulation. When we look at the total number of vehicles' graph in Figure (4.82); the sort of total number of vehicles from the highest to the lowest is $3.25 = 3.50 > 3.00$.

4.1.19 Impact of Lane Width on Travel Time

When the same examples are examined, as shown in Figure (4.83), in 2 lanes roads all experiments' travel times have same value except for between 270th-870th seconds. They start from 26 seconds and become stable until 270th second which is the beginning of the incident. After 270th second EXP 1's travel time

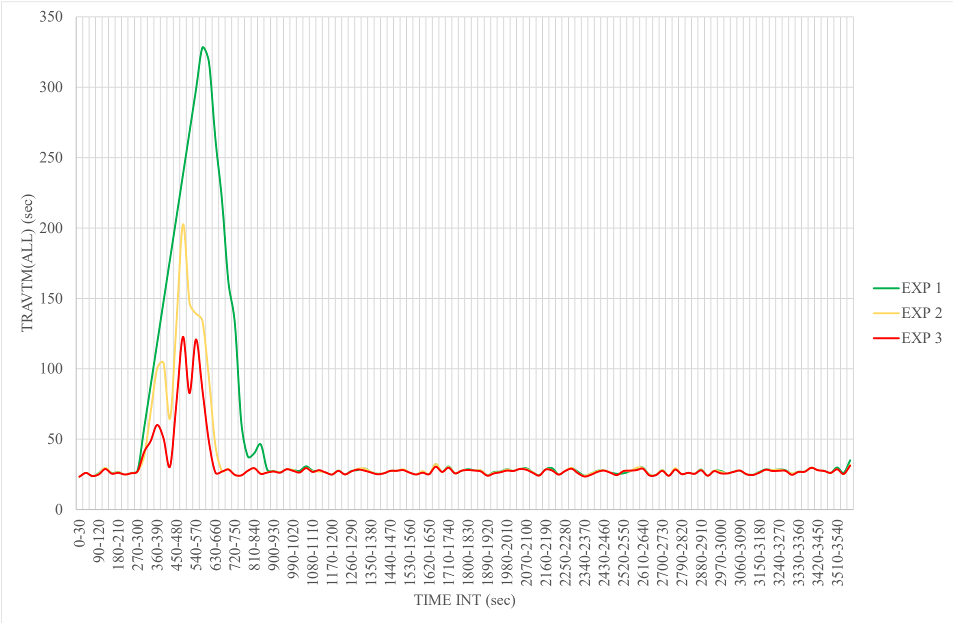

Figure 4.83: TRAVTM(ALL) Graph of Lane Width Scenario Group 1.

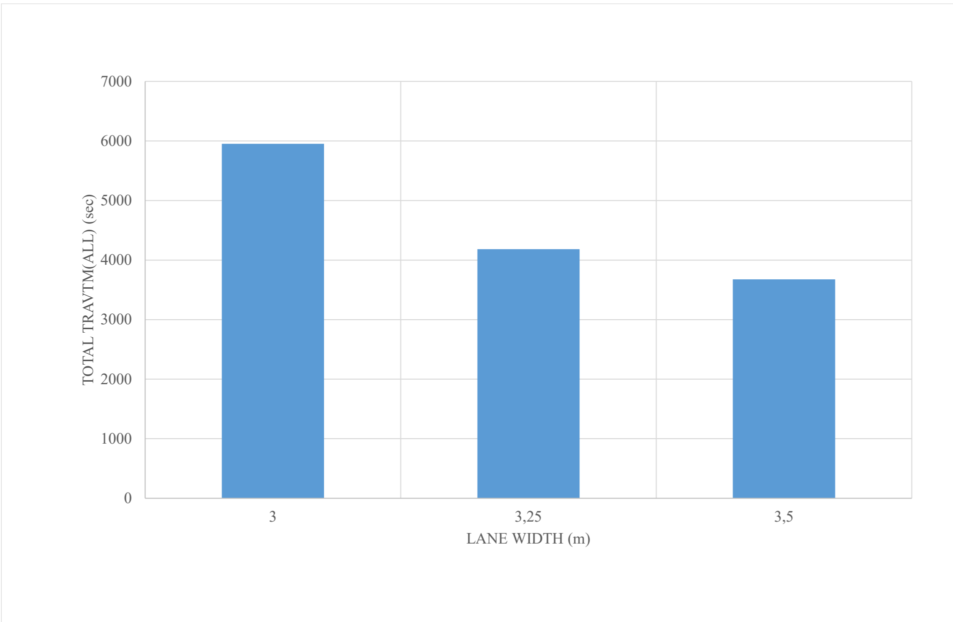

Figure 4.84: TOTAL TRAVTM(ALL) Graph of Lane Width Scenario Group 1.

leaps up from 27 seconds to 328 seconds until 570th second which is the end of the incident. After 570th second EXP 1's travel time slumps from 328 seconds to 38 seconds until 780th second, increases to 40 seconds until 810th second, decreases to 27 seconds until 900th second, and becomes stable except for some little fluctuations until the end of the simulation.

After 270th second EXP 2's travel time leaps up from 26 seconds to 104 seconds until 390th second. After 390th second EXP 2's travel time decreases to 65 seconds until 420th second, and then leaps up to 203 seconds until 480th second. After 480th second EXP 2's travel time decreases from 203 seconds to 147 seconds until 510th second, to 134 seconds until 570th second, slumps to 28 seconds until 690th second, and becomes stable except for some little fluctuations until the end of the simulation.

After 270th second EXP 3's travel time increases to 60 seconds until 360th second, decreases to 31 seconds until 420th second, and then leaps up to 123 seconds until 480th second. After 480th second EXP 3's travel time decreases from 123 seconds to 83 seconds until 510th second, increases to 121 seconds until 540th second, slumps to 26 seconds until 630th second, and becomes stable except for some little fluctuations until the end of the simulation. When we look at the total travel time's graph in Figure (4.84); if lane width increases, total travel time decreases.

When the same examples are examined, as shown in Figure (4.85), in 3 lanes roads all experiments' travel times have same value until 210th second. After 1110th second EXP 68's travel time and EXP 69's travel time have same value until the end of the incident. They start from 26 seconds and become stable until 210th second. After 210th second EXP 67's travel time increases to 39 seconds until 240th second, decreases to 29 seconds until 270th second, increases to 88 seconds until 390th second, decreases to 74 seconds until 450th second, increases to 108 seconds until 480th second, decreases to 106 seconds until 510th second, leaps up to 176 seconds until 600th second, decreases to 162 seconds until 660th second,

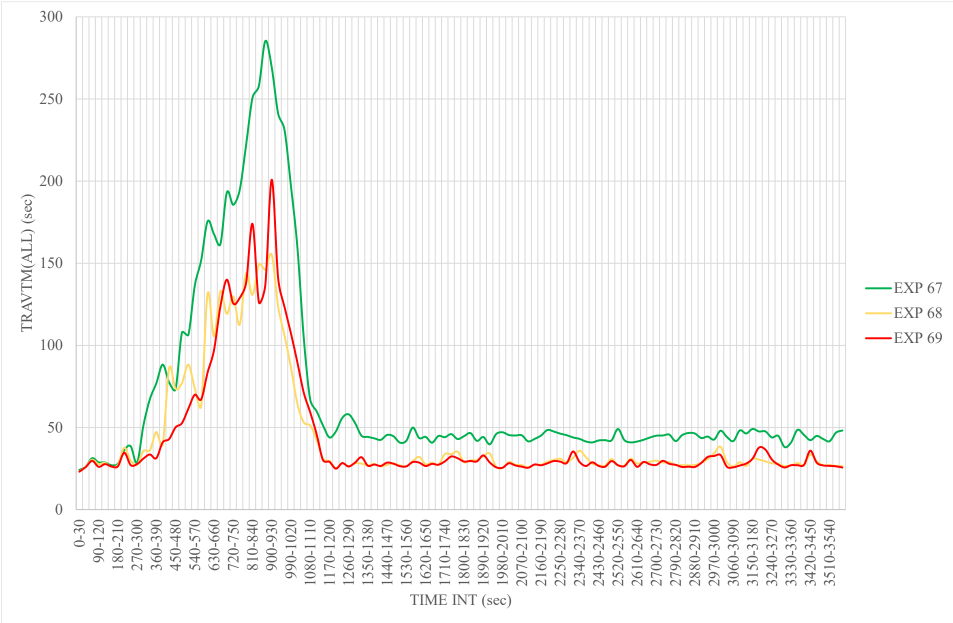

Figure 4.85: TRAVTM(ALL) Graph of Lane Width Scenario Group 2.

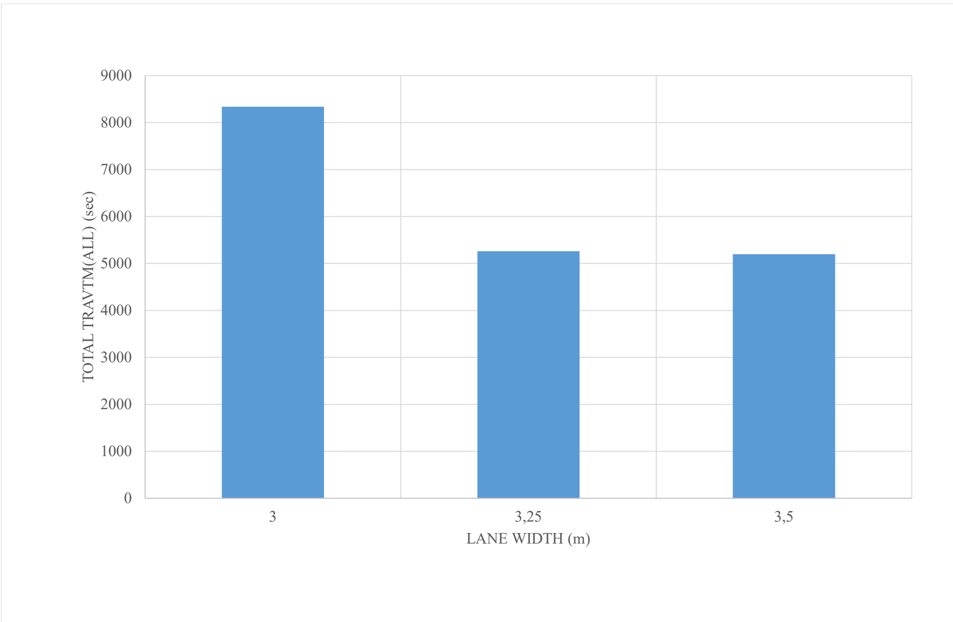

Figure 4.86: TOTAL TRAVTM(ALL) Graph of Lane Width Scenario Group 2.

increases to 193 seconds until 690th second, decreases to 186 seconds until 720th second, leaps up to 258 seconds until 840th second, and continues to increase to 285 seconds which is its top point until 870th second which is the end of the incident. After that it decreases to 241 seconds until 930th second, slumps to 67 seconds until 1080th second, continues to decrease to 44 seconds until 1170th second, increases to 56 seconds until 1230th second, decreases to 45 seconds until 1320th second, and becomes stable except for some little fluctuations until the end of the simulation.

After 210th second EXP 68's travel time increases to 38 seconds until 240th second, decreases to 28 seconds until 270th second, increases to 47 seconds with some fluctuations until 360th second, decreases to 41 seconds until 390th second, increases to 86 seconds until 420th second, decreases to 74 seconds until 450th second, increases to 88 seconds until 510th second, decreases to 63 seconds until 570th second, leaps up to 131 seconds until 600th second. After that it fluctuates between 105 seconds and 155 seconds and reaches to 155 seconds which is its top point at 900th second. After 900th second it slumps to 53 seconds until 1050th second, and continues to decrease to 29 seconds until 1170th second, and becomes stable except for some little fluctuations until the end of the simulation.

After 210th second EXP 69's travel time increases to 28 seconds until 240th second, decreases to 27 seconds until 270th second, and starts to increase to 140 seconds with some little fluctuations until 690th second. After 690th second it decreases to 129 seconds until 750th second, increases to 174 seconds until 810th second, decreases to 126 seconds until 840th second, increases to 201 seconds which is its top point until 900th second. After that it decreases to 141 seconds until 930th second, slumps to 29 seconds until 1170th second, and becomes stable except for some little fluctuations until the end of the simulation. When we look at the total travel time's graph in Figure (4.86); if lane width increases, total travel time decreases.

4.1.20 Impact of Lane Width on Speed

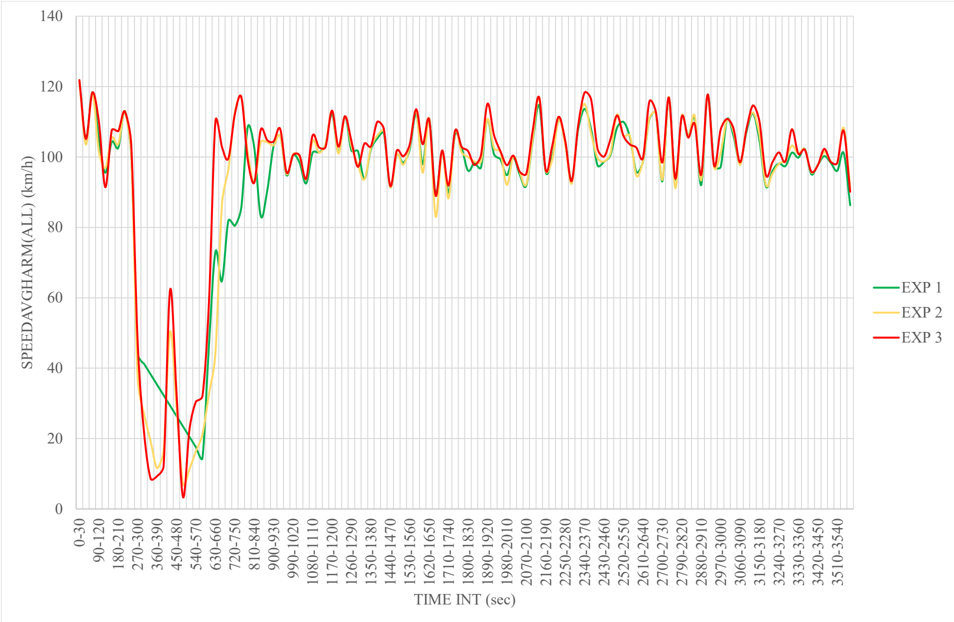

Figure 4.87: SPEEDAVGHARM(ALL) Graph of Lane Width Scenario Group 1.

When the same examples are examined, as shown in Figure (4.87), in 2 lanes roads all experiments' speeds have same value except for between 300th-930th seconds. After 930th second they are almost same. They start from 122 km/h, decrease to 105 km/h until 30th second, increase to 118 km/h until 60th second, decrease to 91 km/h until 120th second, increase to 113 km/h with some fluctuations until 210th second. After 210th second which is a few seconds before the incident, EXP 1's speed slumps to 41 km/h until 300th second, and continues to decrease to 15 km/h until 570th second. After 570th second which is the end of the incident EXP 1's speed starts from 15 km/h and leaps up to 75 km/h until 630th second, decreases to 65 km/h until 660th second, increases to 82 km/h until 690th second, decreases to 80 km/h until 720th second, increases to 109 km/h which is its top point until 780th second, decreases to 83 km/h until 840th second, increases to 108 km/h until 930th second, and then fluctuates between 86 km/h and 118 km/h until the end of the simulation.

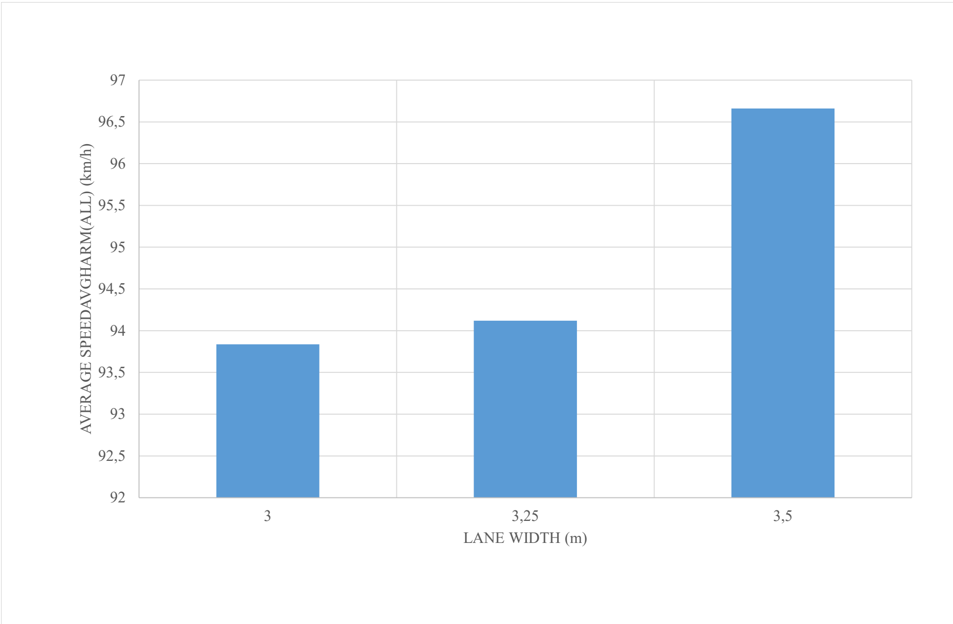

Figure 4.88: AVERAGE SPEEDAVGHARM(ALL) Graph of Lane Width Scenario Group 1.

After 210th second which is a few seconds before the incident EXP 2's speed and EXP 3's speed slump to 9 km/h until 330th second, increase to 12 km/h until 390th second, leap up to 62 km/h until 420th second, and slumps to 3 km/h until 480th second. After 480th second EXP 2's speed leaps up to 117 km/h which is its top point with some fluctuations until 750th second, and then fluctuates between 83 km/h and 117 km/h until the end of the simulation.

After 480th second EXP 3's speed starts from 3 km/h and increases to 31 km/h until 540th second, continues to increases to 32 km/h until 570th second, leaps up to 110 km/h until 630th second, decreases to 103 km/h until 660th second, and increases to 117 km/h which is its top point until 750th second. After that it fluctuates between 92 km/h and 117 km/h until the end of the simulation. When we look at the average speed's graph in Figure (4.88); if lane width increases, average speed increases.

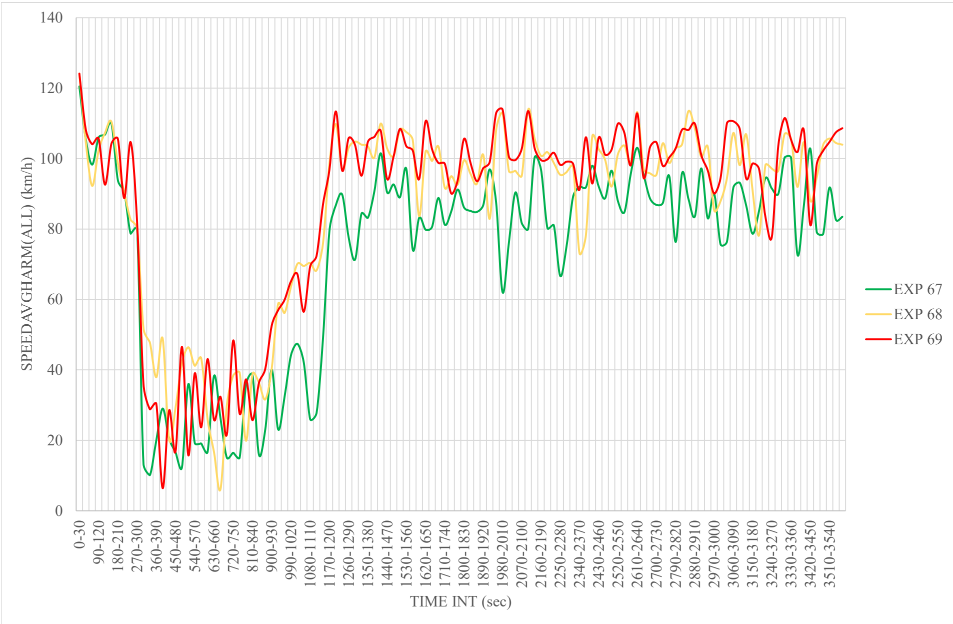

Figure 4.89: SPEEDAVGHARM(ALL) Graph of Lane Width Scenario Group 2.

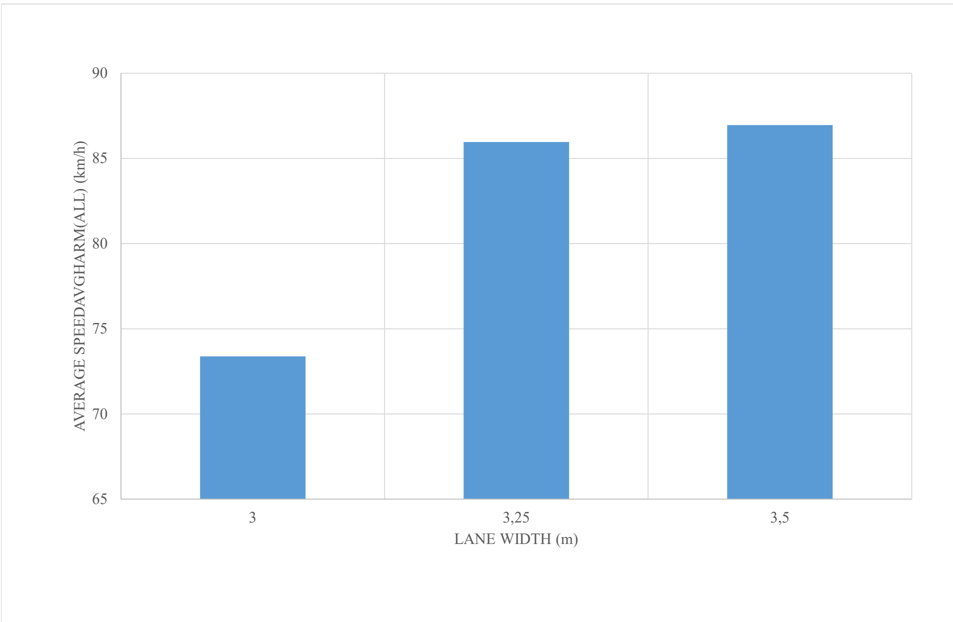

Figure 4.90: AVERAGE SPEEDAVGHARM(ALL) Graph of Lane Width Scenario Group 2.

When the same examples are examined, as shown in Figure (4.89), in 3 lanes roads EXP 67's speed starts from 120 km/h, decrease to 100 km/h until 60th second, increase to 107 km/h until 90th second, decrease to 79 km/h with some fluctuations until 240th second, increase to 82 km/h until 270th second which is the beginning of the incident. After 270th second it slumps to 13 km/h until 300th second, and then fluctuates between 12 km/h and 38 km/h until 870th second which is the end of the incident. After 870th second it increases from 16 km/h to 40 km/h until 900th second, decreases to 23 km/h until 930th second, increases to 47 km/h until 1020th second, decreases to 28 km/h until 1110th second, leaps up to 97 km/h until 1230th second, decreases to 71 km/h until 1290th second, increases to 84 km/h until 1320th second, decreases to 83 km/h until 1350th second, and increases to 106 km/h which is its top point until 1380th second. After that it fluctuates between 74 km/h and 105 km/h until 1920th second, after 1920th second between 62 km/h and 106 km/h until 2310th second, after 2310th second between 73 km/h and 103 km/h until the end of the simulation.

EXP 68's speed starts from 120 km/h, decrease to 92 km/h until 60th second, increase to 110 km/h until 150th second, decrease to 82 km/h until 270th second. After 270th second it slumps to 48 km/h until 330th second, continues to decrease to 38 km/h until 360th second, increases to 49 km/h until 390th second, decreases to 20 km/h until 420th second, increases to 46 km/h until 510th second, decreases to 40 km/h until 540th second, increases to 43 km/h until 570th second, slumps to 6 km/h until 660th second. After 660th second it increases to 39 km/h until 750th second, decreases to 20 km/h until 780th second, increases to 39 km/h until 810th second, decreases to 32 km/h until 870th second, increases to 59 km/h until 930th second, decreases to 56 km/h until 960th second, increases to 70 km/h until 1020th second, decreases to 68 km/h until 1110th second, and leaps up to 113 km/h which is its top point until 1200th second. After that it fluctuates between 78 km/h and 113 km/h until the end of the simulation.

EXP 69's speed starts from 124 km/h, decrease to 104 km/h until 60th second, and then fluctuates between 89 km/h and 106 km/h until 240th second. After

240th second it slumps to 29 km/h until 330th second, increases to 30 km/h until 360th second, decrease to 6 km/h until 390th second, increases to 29 km/h until 420th second. After 420th second it fluctuates between 16 km/h and 48 km/h until 840th second. After 840th second it leaps up to 65 km/h until 990th second, decreases to 57 km/h until 1050th second, slumps to 114 km/h which is its top point until 1200th second. After that it fluctuates between 78 km/h and 113 km/h until the end of the simulation. When we look at the average speed's graph in Figure (4.90); if lane width increases, average speed increases.

4.2 Detailed Analysis on Speed – Discharge Characteristics

As the second part of our analysis we focused on the changes of the speed in only incident period and immediately after incident period. We created some other graphs to see and comment discharge. To better interpret discharge in the graphics in this section, we added trendlines, equations of these trendlines, and R-square equations.

4.2.1 Impact of Incident Duration on Speed – Discharge Characteristics

When an incident occurs in the 1st lane of a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for incident duration which are 5 minutes (EXP 18), 10 minutes (EXP 63), and 15 minutes (EXP 108) as shown in Figure (4.91). If we compare the average SPEEDAVGHARM(ALL) of discharge in Figure (4.92), we deduce that 5 min > 10 min > 15 min. If we compare the SPEEDAVGHARM(ALL) difference of discharge between maximum and minimum in Figure (4.93), we deduce that 10 min > 5 min > 15 min. If incident duration increases, average speed decreases. The reason why 10 min's speed difference is greater than 5 min's speed difference

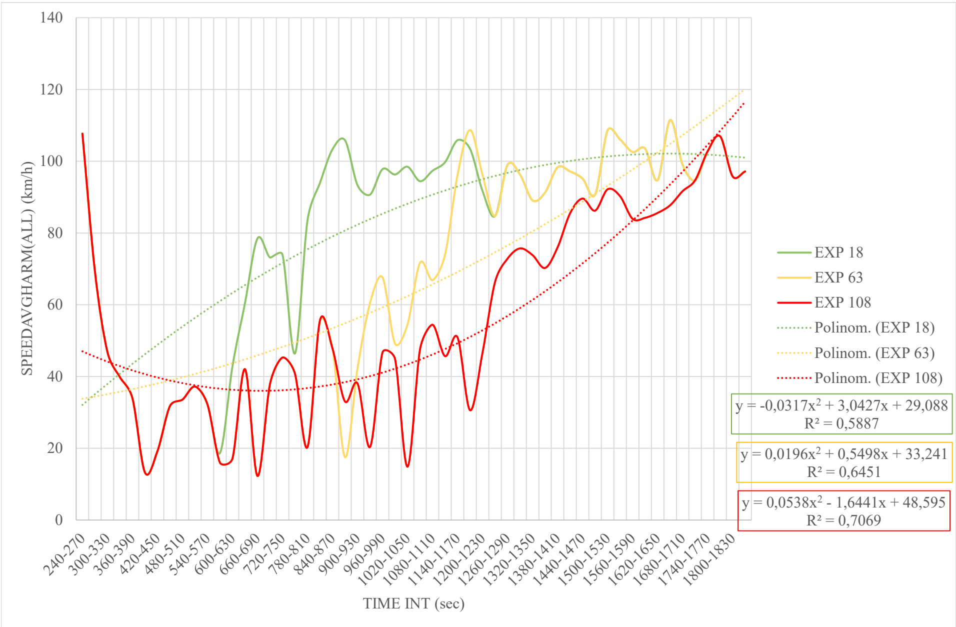

Figure 4.91: SPEEDAVGHARM(ALL) of Discharge Graph of Incident Duration Scenario Group 1.

is that there is momentarily a high point in the graph. This exception does not affect the overall simulation.

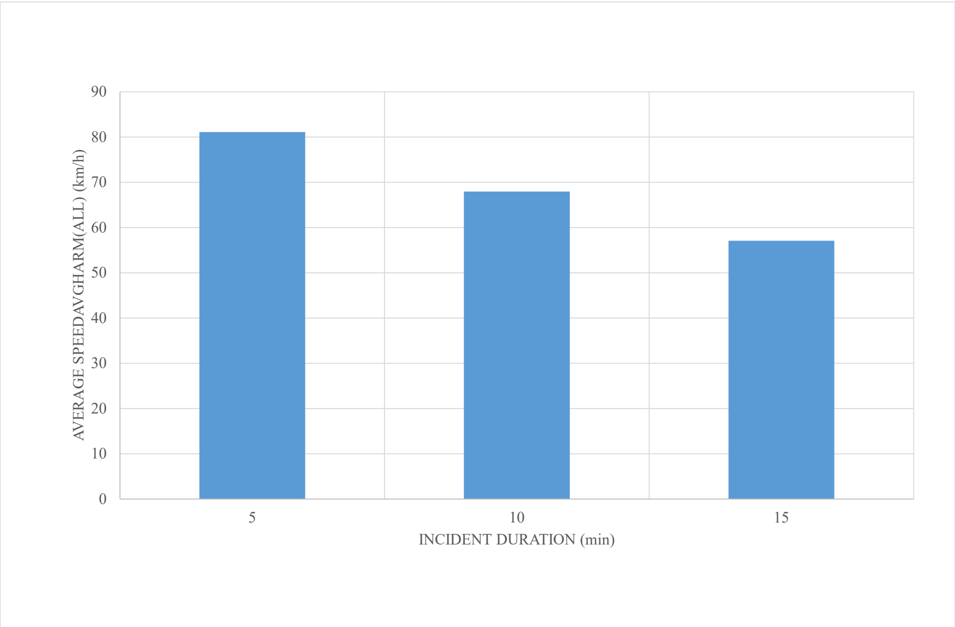

Figure 4.92: AVERAGE SPEEDAVGHARM(ALL) of Discharge Graph of Incident Duration Scenario Group 1.

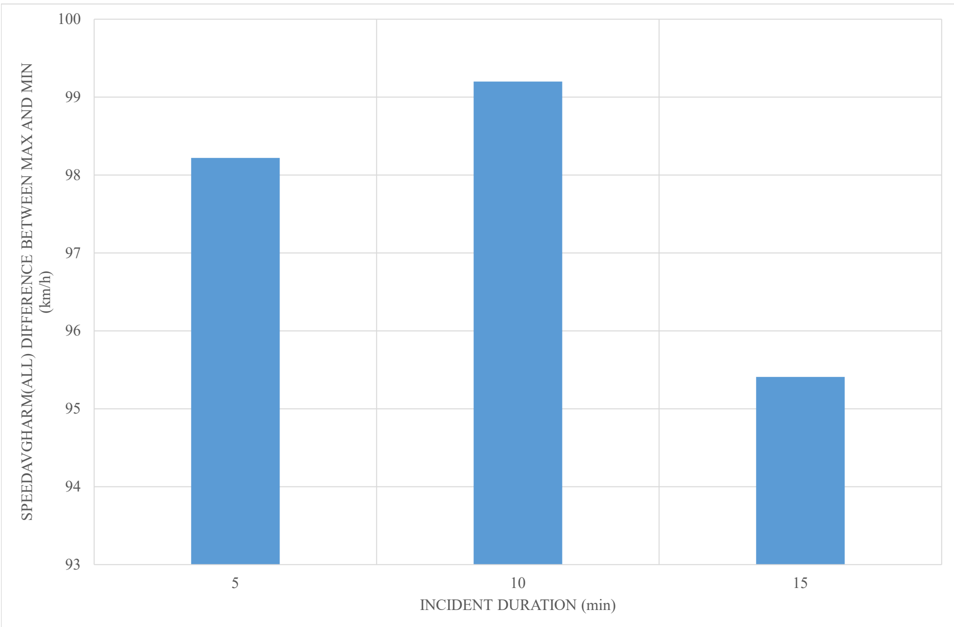

Figure 4.93: SPEEDAVGHARM(ALL) DIFFERENCE BETWEEN MAX AND MIN of Discharge Graph of Incident Duration Scenario Group 1.

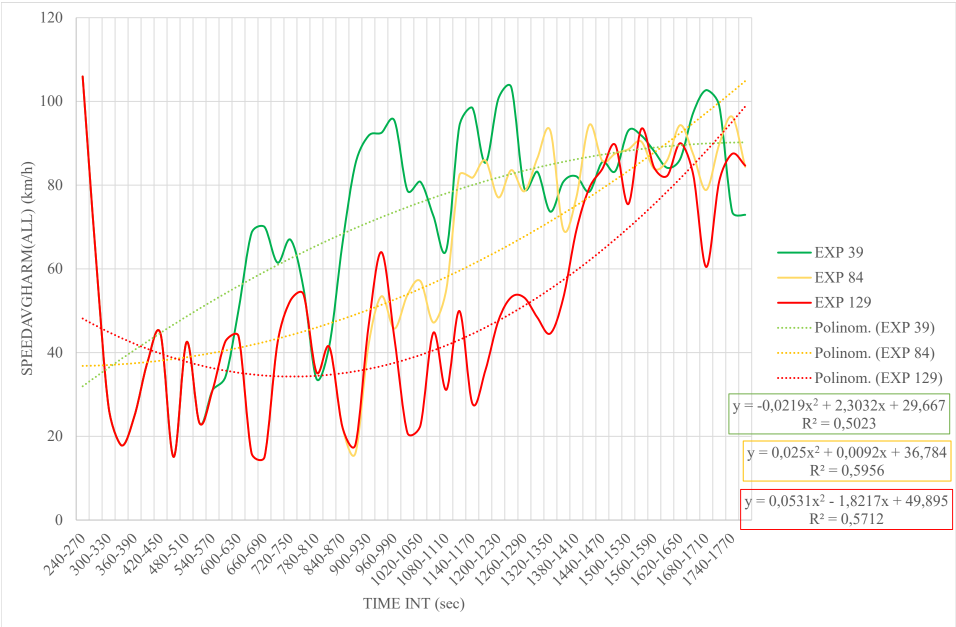

Figure 4.94: SPEEDAVGHARM(ALL) of Discharge Graph of Incident Duration Scenario Group 2.

When an incident occurs in the 1st lane of a three-lane road whose lane width is 3,50 m and vehicle input is 2000 veh/lane, we have 3 different experiment scenarios for incident duration which are 5 minutes (EXP 39), 10 minutes (EXP 84), and 15 minutes (EXP 129) as shown in Figure (4.94). If we compare the average SPEEDAVGHARM(ALL) of discharge in Figure (4.95), we deduce that 5 min > 10 min > 15 min. If we compare the SPEEDAVGHARM(ALL) difference of discharge between maximum and minimum in Figure (4.96), we deduce that 10 min = 15 min > 5 min. If incident duration increases, average speed decreases. 10 min's and 15 min's speed differences are greater than 5 min's speed difference. Because 10 min's and 15 min's graphs fluctuate larger areas than 5 min's graph. Therefore, their speed differences are higher. The reason for this is that traffic congestions of 10 min and 15 min are greater than congestion of 5 min and a bigger change occurred in discharges after traffic congestion is opened.

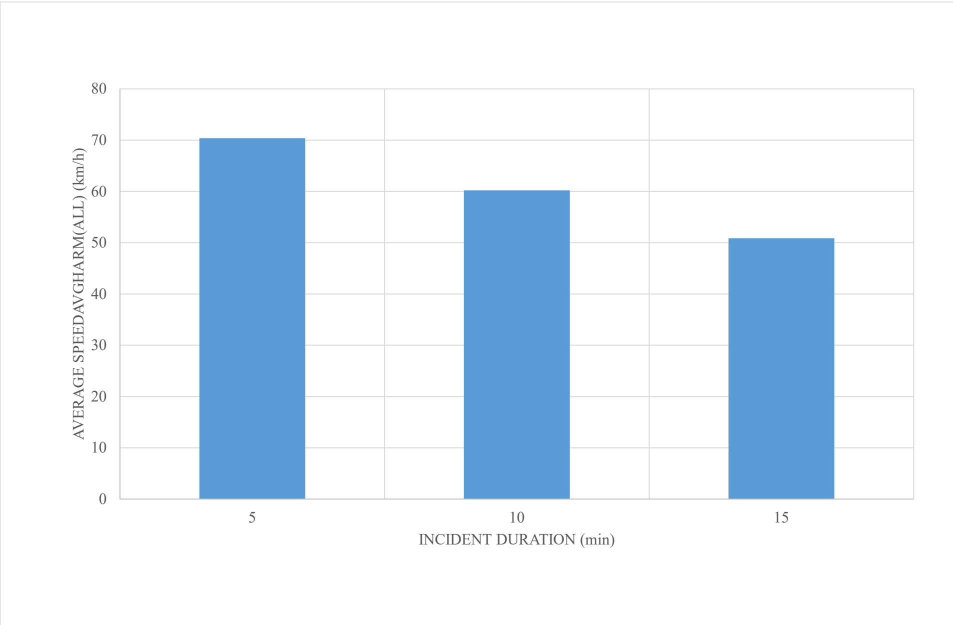

Figure 4.95: AVERAGE SPEEDAVGHARM(ALL) of Discharge Graph of Incident Duration Scenario Group 2.

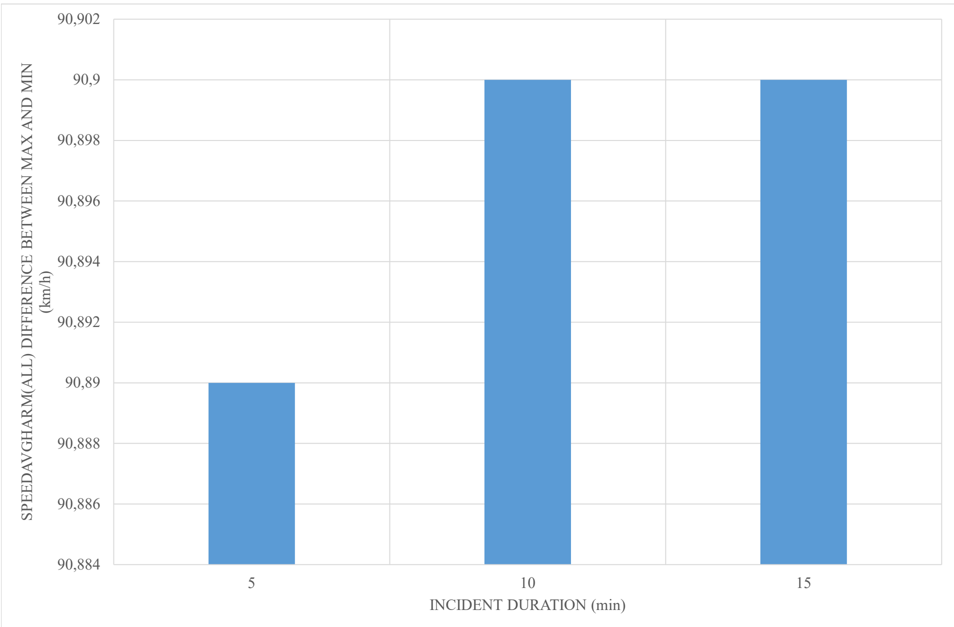

Figure 4.96: SPEEDAVGHARM(ALL) DIFFERENCE BETWEEN MAX AND MIN of Discharge Graph of Incident Duration Scenario Group 2.

4.2.2 Impact of Vehicle Input on Speed – Discharge Characteristics

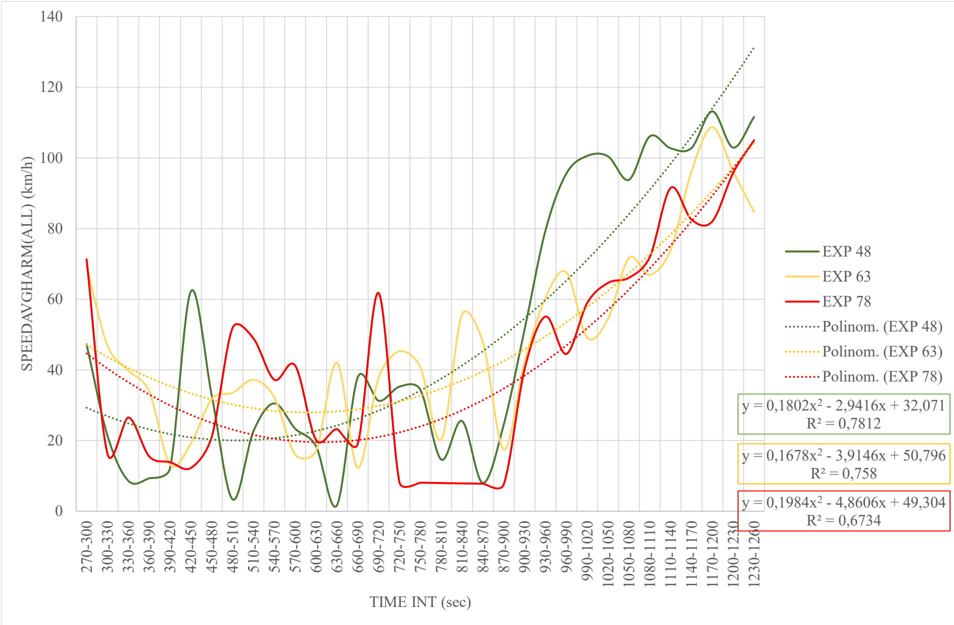

Figure 4.97: SPEEDAVGHARM(ALL) of Discharge Graph of Vehicle Input Scenario Group 1.

When an incident whose duration is 10 minutes occurs in the 1st lane of a two-lane road whose lane width is 3,50 m, we have 3 different experiment scenarios for vehicle input which are 1000 veh/lane (EXP 48), 1500 veh/lane (EXP 63), and 2000 veh/lane (EXP 78) as shown in Figure (4.97). If we compare the average SPEEDAVGHARM(ALL) of discharge in Figure (4.98), we deduce that 1000 veh/lane > 1500 veh/lane > 2000 veh/lane. If we compare the SPEEDAVGHARM(ALL) difference of discharge between maximum and minimum in Figure (4.99), we deduce that 1000 veh/lane > 2000 veh/lane > 1500 veh/lane. Speed differences of 1500 veh/lane and 2000 veh/lane are almost the same. But there is a big difference between speed difference of 1000 veh/lane. If vehicle input increases, average speed decreases. The reason why 2000 veh/lane's speed difference is greater than 1500 veh/lane's speed difference is that there is momentarily a high point in the graph. This exception does not affect the overall simulation. The reason why

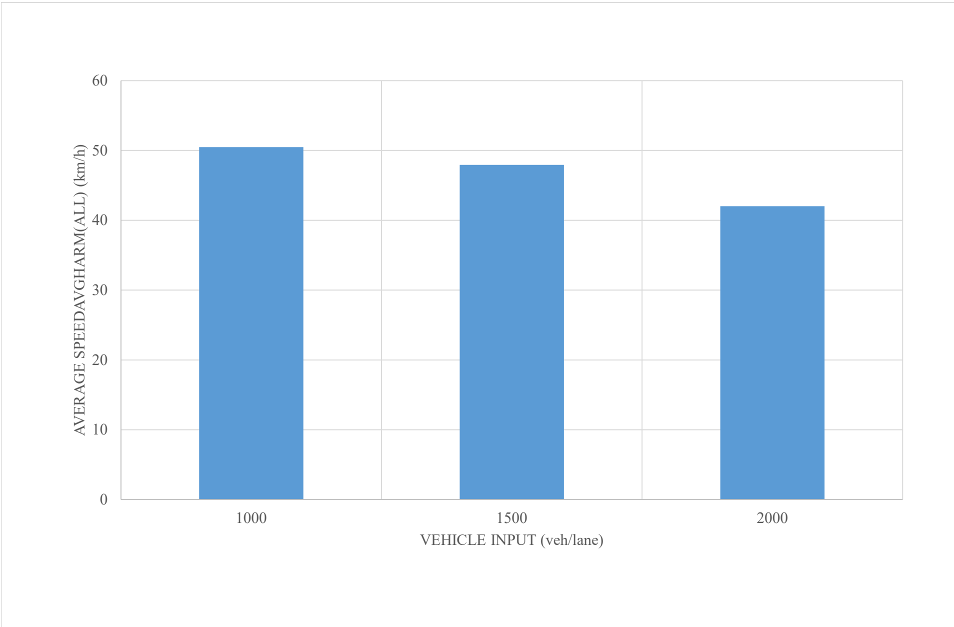

Figure 4.98: AVERAGE SPEEDAVGHARM(ALL) of Discharge Graph of Vehicle Input Scenario Group 1.

1000 veh/lane's average speed and speed difference are the greatest is that it is easy to recover incident when vehicle input is low. As the vehicle input increases, the road can not handle this much vehicle. That's why vehicles can not reach high speeds.

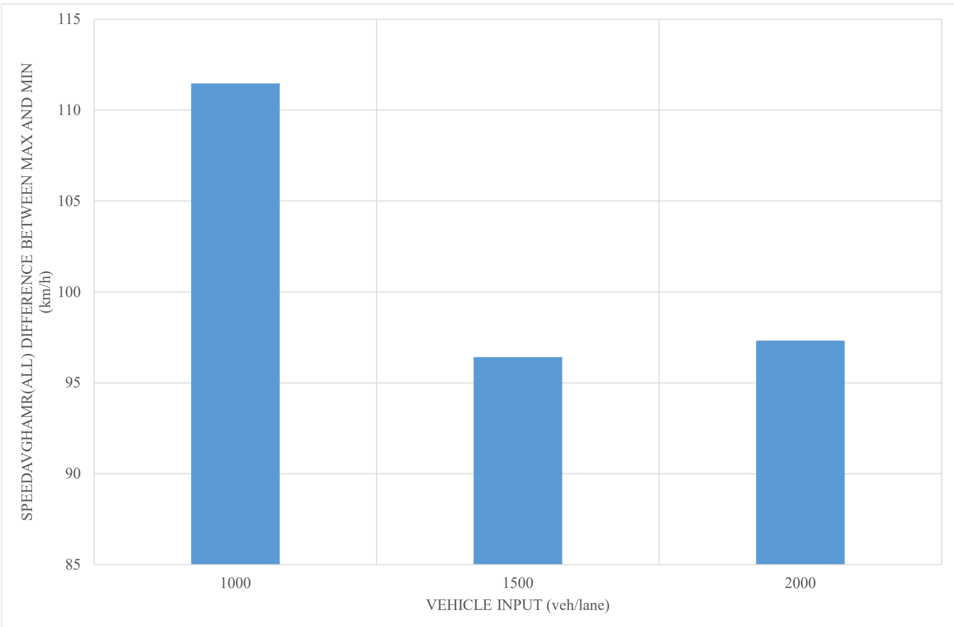

Figure 4.99: SPEEDAVGHARM(ALL) DIFFERENCE BETWEEN MAX AND MIN of Discharge Graph of Vehicle Input Scenario Group 1.

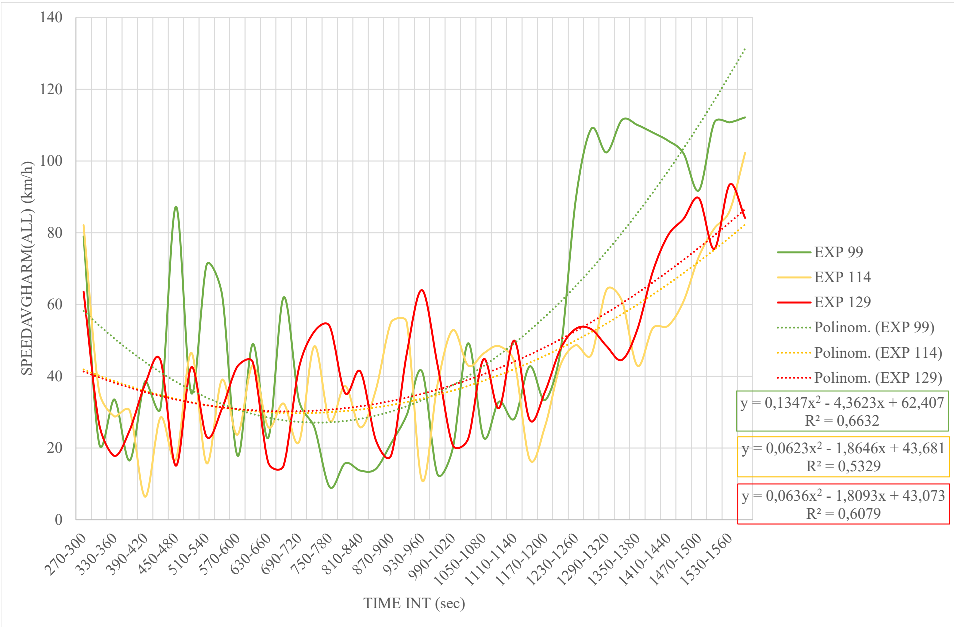

Figure 4.100: SPEEDAVGHARM(ALL) of Discharge Graph of Vehicle Input Scenario Group 2.

When an incident whose duration is 15 minutes occurs in the 1st lane of a three-lane road whose lane width is 3,50 m, we have 3 different experiment scenarios for vehicle input which are 1000 veh/lane (EXP 99), 1500 veh/lane (EXP 114), and 2000 veh/lane (EXP 129) as shown in Figure (4.100). If we compare the average SPEEDAVGHARM(ALL) of discharge in Figure (4.101), we deduce that 1000 veh/lane > 2000 veh/lane > 1500 veh/lane. Average speeds of 1500 veh/lane and 2000 veh/lane are almost the same. If we compare the SPEEDAVGHARM(ALL) difference of discharge between maximum and minimum in Figure (4.102), we deduce that 1000 veh/lane > 1500 veh/lane > 2000 veh/lane. Speed difference of 2000 veh/lane is less than others. If vehicle input increases, average speed decreases. The reason why 2000 veh/lane's average speed is greater than 1500 veh/lane's average speed is that there is momentarily a high point in the graph. This exception does not affect the overall simulation. The reason why 1000 veh/lane's average speed and speed difference are the greatest is that it is easy to

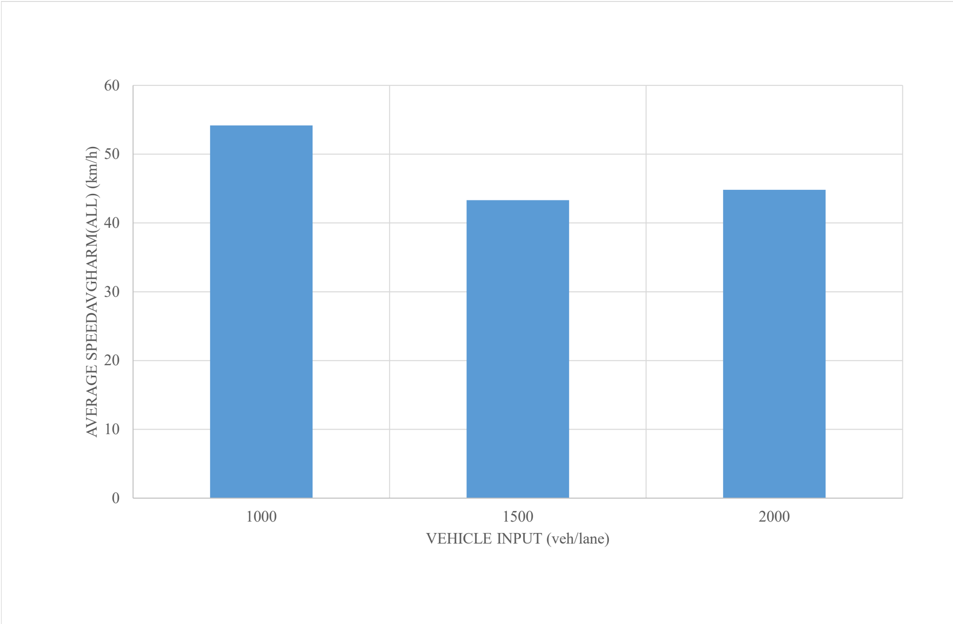

Figure 4.101: AVERAGE SPEEDAVGHARM(ALL) of Discharge Graph of Vehicle Input Scenario Group 2.

recover incident when vehicle input is low. As the vehicle input increases, the road can not handle this much vehicle. That's why vehicles can not reach high speeds. Consequently 1000 veh/lane's average speed and speed difference values are the highest.

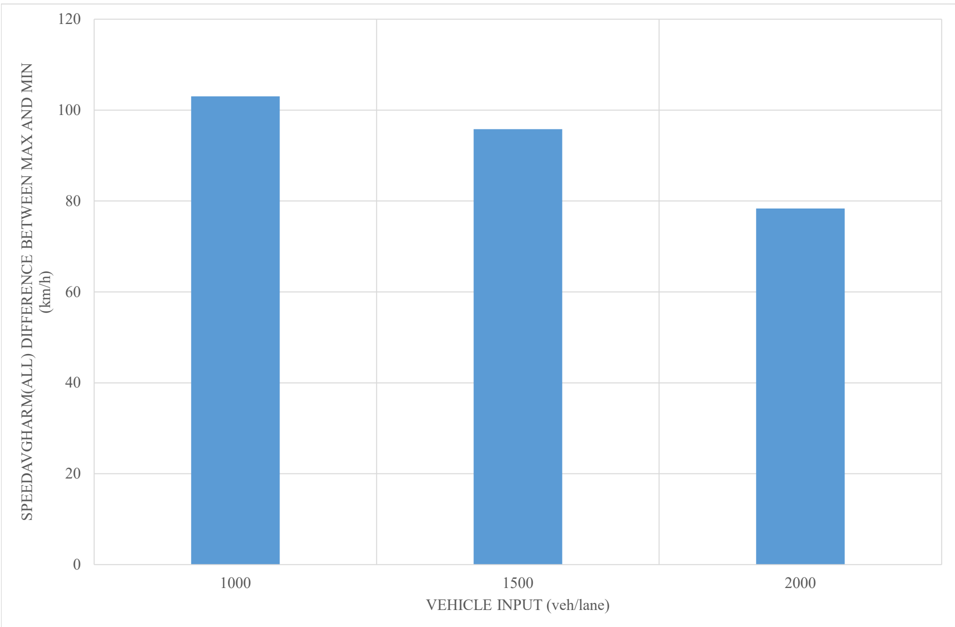

Figure 4.102: SPEEDAVGHARM(ALL) DIFFERENCE BETWEEN MAX AND MIN of Discharge Graph of Vehicle Input Scenario Group 2.

4.2.3 Impact of Number of Lane on Speed – Discharge Characteristics

Figure 4.103: SPEEDAVGHARM(ALL) of Discharge Graph of Number of Lane Scenario Group 1.

When an incident whose duration is 5 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 2 different experiment scenarios for number of lane which are 2 lanes (EXP 18) and 3 lanes (EXP 24) as shown in Figure (4.103). If we compare the average SPEEDAVGHARM(ALL) of discharge in Figure (4.104), we deduce that 2 lanes > 3 lanes. If we compare the SPEEDAVGHARM(ALL) difference of discharge between maximum and minimum in Figure (4.105), we deduce that 3 lanes > 2 lanes. If number of lanes increases, vehicle input increases. Therefore, higher average speed values will be seen on a two-lane road than a three-lane road. The reason why an opposite situation was observed in speed differences is that when the vehicle input is more, a higher increase in speed occurs during discharge. So three-lane roads have higher differences than two-lane roads.

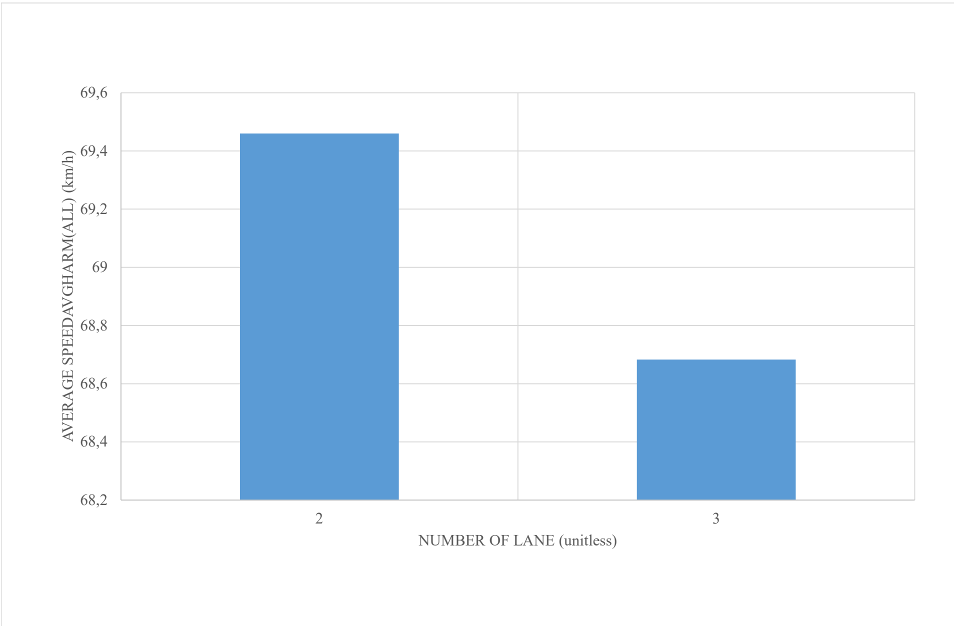

Figure 4.104: AVERAGE SPEEDAVGHARM(ALL) of Discharge Graph of Number of Lane Scenario Group 1.

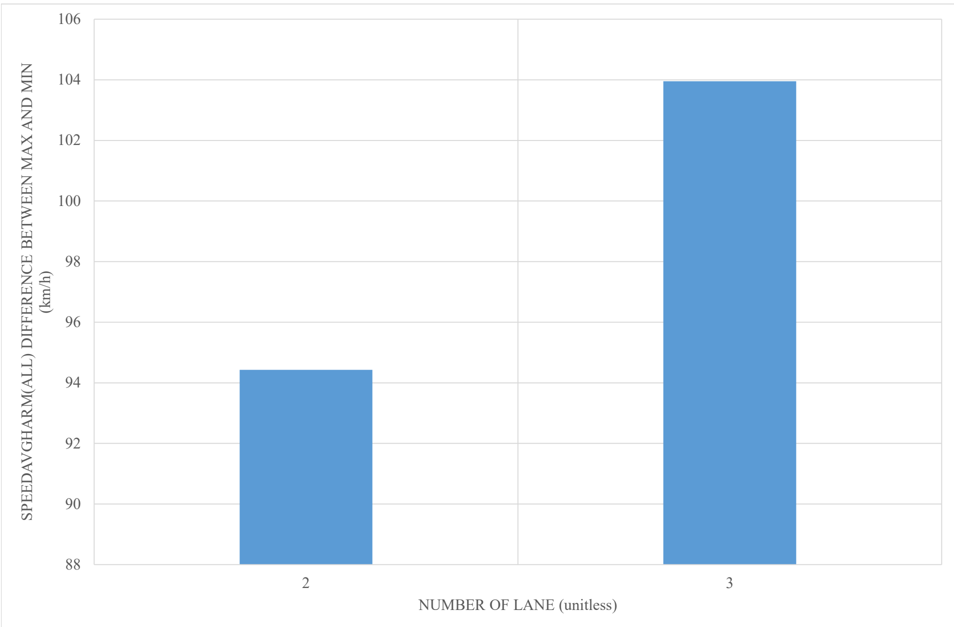

Figure 4.105: SPEEDAVGHARM(ALL) DIFFERENCE BETWEEN MAX AND MIN of Discharge Graph of Number of Lane Scenario Group 1.

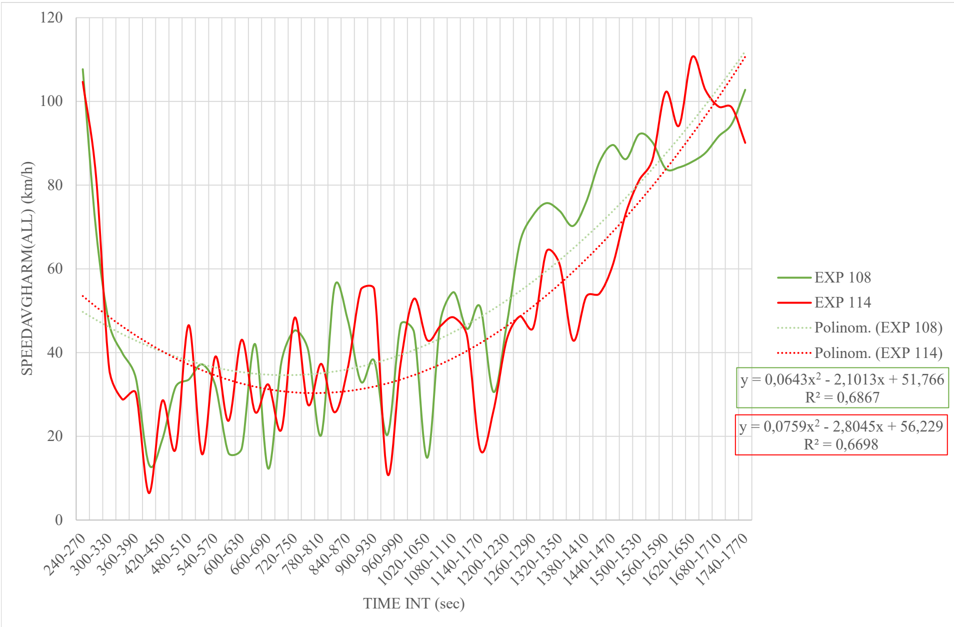

Figure 4.106: SPEEDAVGHARM(ALL) of Discharge Graph of Number of Lane Scenario Group 2.

When an incident whose duration is 15 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 2 different experiment scenarios for number of lane which are 2 lanes (EXP 108) and 3 lanes (EXP 114) as shown in Figure (4.106). If we compare the average SPEEDAVGHARM(ALL) of discharge in Figure (4.107), we deduce that 2 lanes > 3 lanes. If we compare the SPEEDAVGHARM(ALL) difference of discharge between maximum and minimum in Figure (4.108), we deduce that 3 lanes > 2 lanes. If number of lanes increases, vehicle input increases. Therefore, higher average speed values will be seen on a two-lane road than a three-lane road. The reason why an opposite situation was observed in speed differences is that when the vehicle input is more, a higher increase in speed occurs during discharge. So three-lane roads have higher differences than two-lane roads.

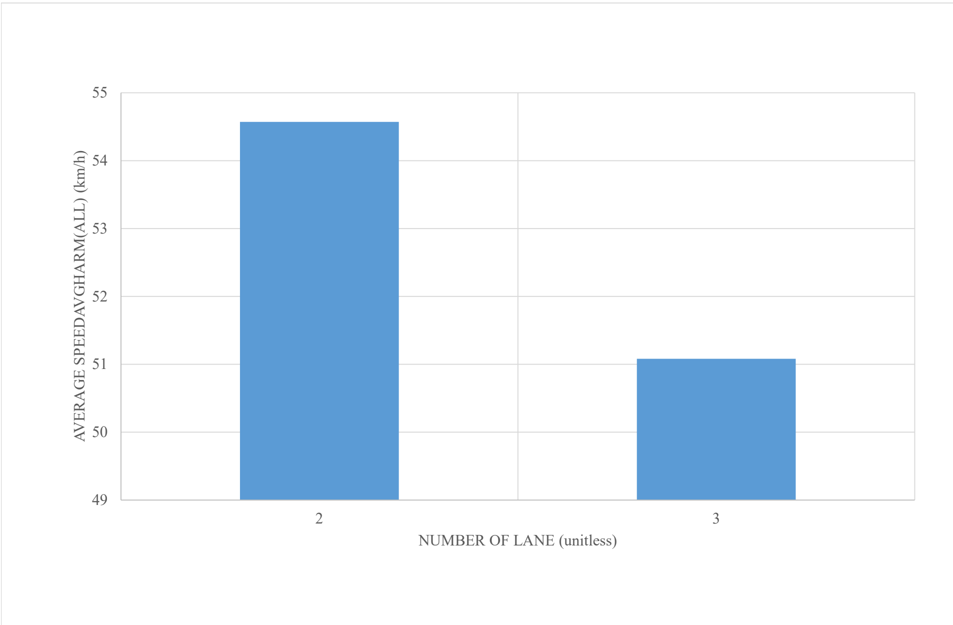

Figure 4.107: AVERAGE SPEEDAVGHARM(ALL) of Discharge Graph of Number of Lane Scenario Group 2.

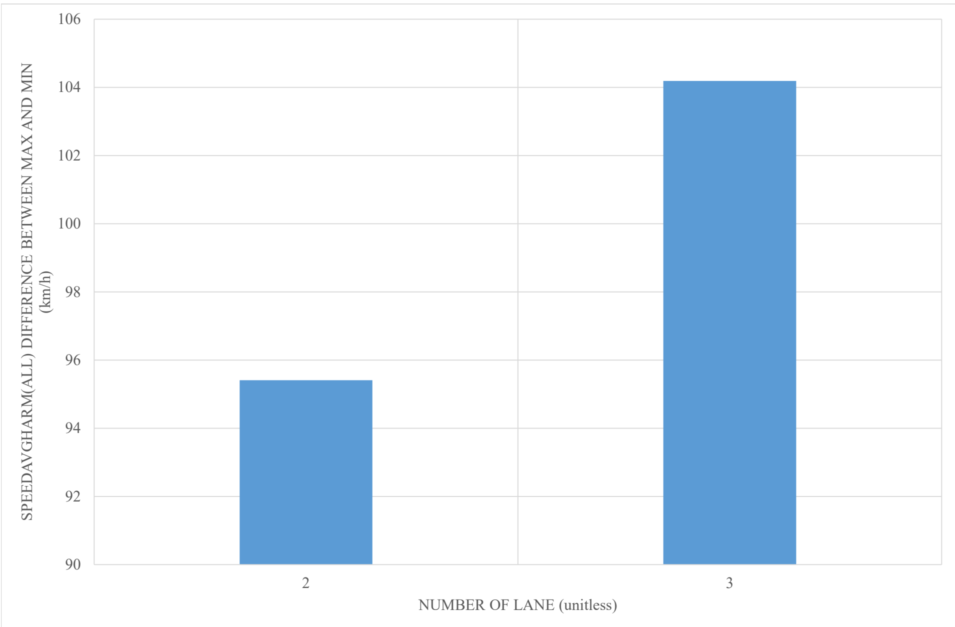

Figure 4.108: SPEEDAVGHARM(ALL) DIFFERENCE BETWEEN MAX AND MIN of Discharge Graph of Number of Lane Scenario Group 2.

4.2.4 Impact of Incident Position on Speed – Discharge Characteristics

Figure 4.109: SPEEDAVGHARM(ALL) of Discharge Graph of Incident Position Scenario Group 1.

When an incident whose duration is 5 minutes occurs in a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 2 different experiment scenarios for incident position which are 1st lane (EXP 18) and 2nd lane (EXP 21) as shown in Figure (4.109). If we compare the average SPEEDAVGHARM(ALL) of discharge in Figure (4.110), we deduce that 1st lane > 2nd lane. If we compare the SPEEDAVGHARM(ALL) difference of discharge between maximum and minimum in Figure (4.111), we deduce that 2nd lane > 1st lane. On a road where traffic flows from the right, the right lane is the slowest lane. Fast vehicles use the left lane. Also, a vehicle passes to the left lane if the vehicle in front of it slows down. Therefore, incident occurrence in 1st lane on a two-lane road is easier to tolerate in terms of traffic flow and other vehicles can adapt themselves into incident more easily. Hence, the average speed values in

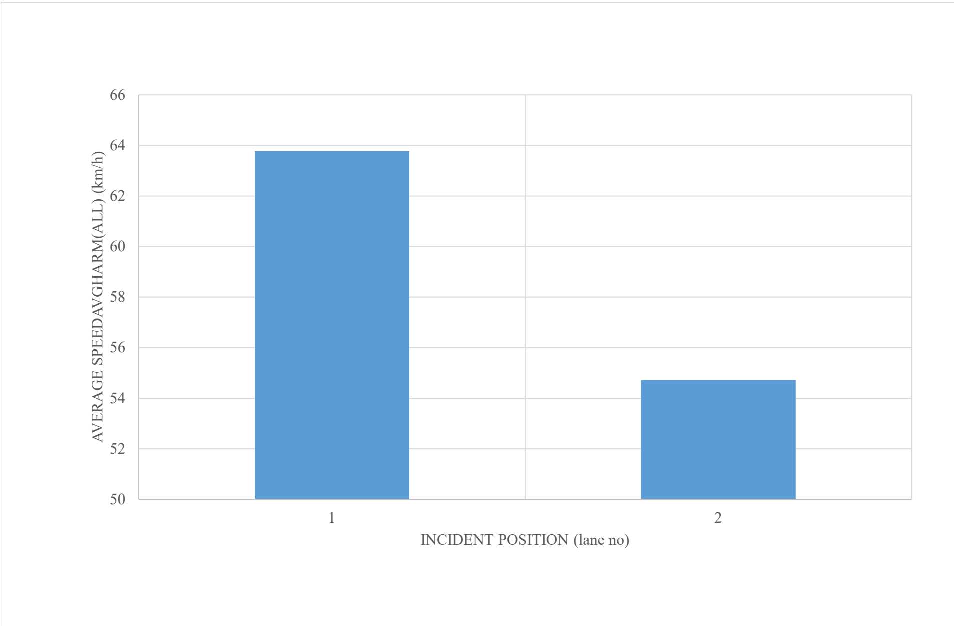

Figure 4.110: AVERAGE SPEEDAVGHARM(ALL) of Discharge Graph of Incident Position Scenario Group 1.

case of the incident being in the 1st lane are higher than in the case of the 2nd lane. The reason why an opposite situation was observed in speed differences is that since there is a lot of congestion when there is an incident in the 2nd lane, a greater increase in speed occurs during discharge. Thus, the differences are higher when the incident is in the 2nd lane than in the 1st lane.

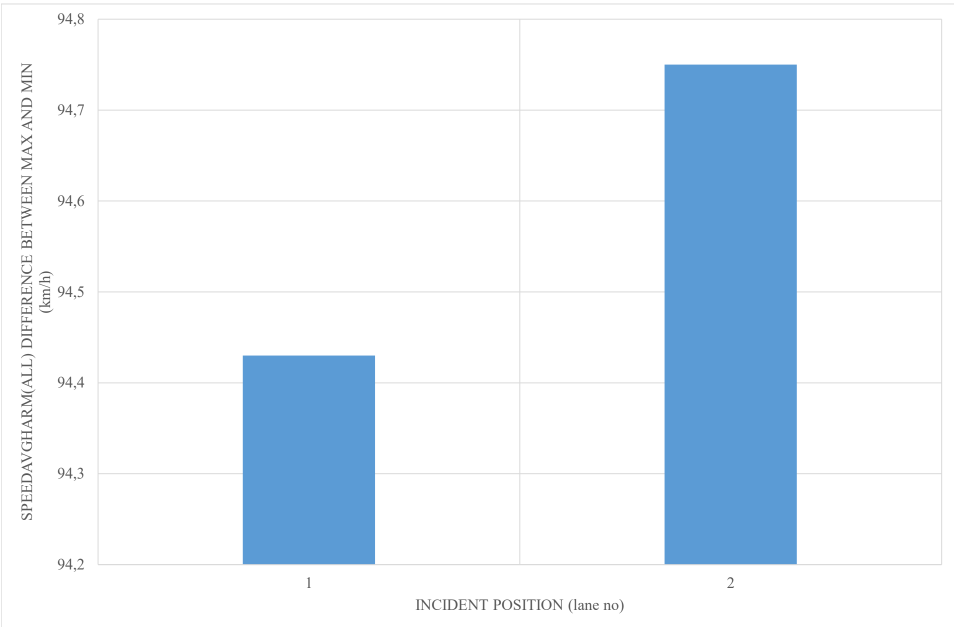

Figure 4.111: SPEEDAVGHARM(ALL) DIFFERENCE BETWEEN MAX AND MIN of Discharge Graph of Incident Position Scenario Group 1.

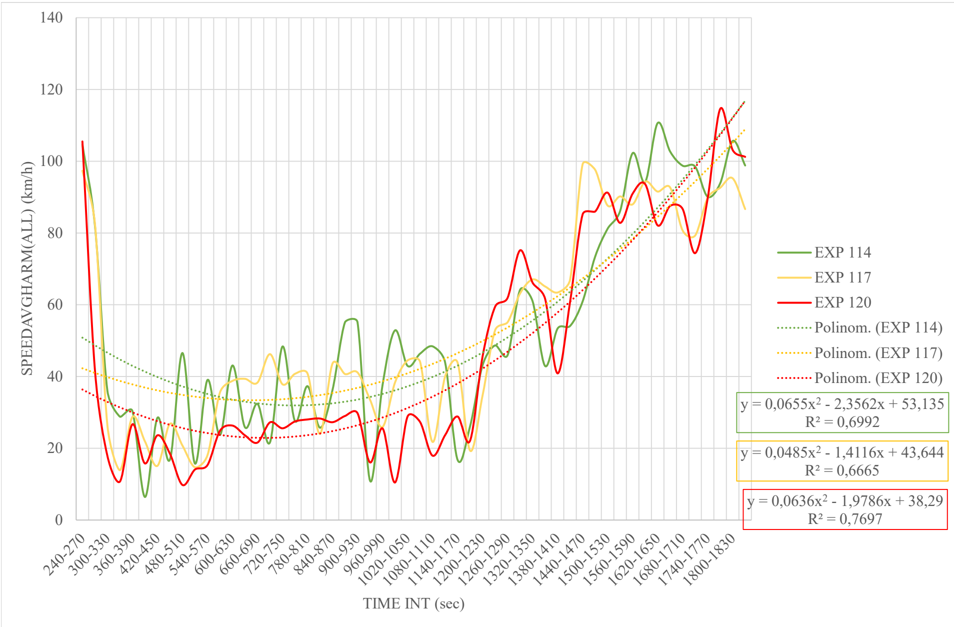

Figure 4.112: SPEEDAVGHARM(ALL) of Discharge Graph of Incident Position Scenario Group 2.

When an incident whose duration is 15 minutes occurs in a three-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for incident position which are 1st lane (EXP 114), 2nd lane (EXP 117), and 3rd lane (EXP 120) as shown in Figure (4.112). If we compare the average SPEEDAVGHARM(ALL) of discharge in Figure (4.113), we deduce that 1st lane > 2nd lane > 3rd lane. 1st lane and 2nd lane have close values. If we compare the SPEEDAVGHARM(ALL) difference of discharge between maximum and minimum in Figure (4.114), we deduce that 3rd lane > 1st lane > 2nd lane. 3rd lane and 1st lane are almost the same. On a road where traffic flows from the right, the right lane is the slowest lane. Fast vehicles use the left lane. Also, a vehicle passes to the left lane if the vehicle in front of it slows down. Therefore, incident occurrence in 1st lane on a three-lane road is easier to tolerate in terms of traffic flow and other vehicles can adapt themselves into incident more easily. Hence, the average speed values in case of the incident being

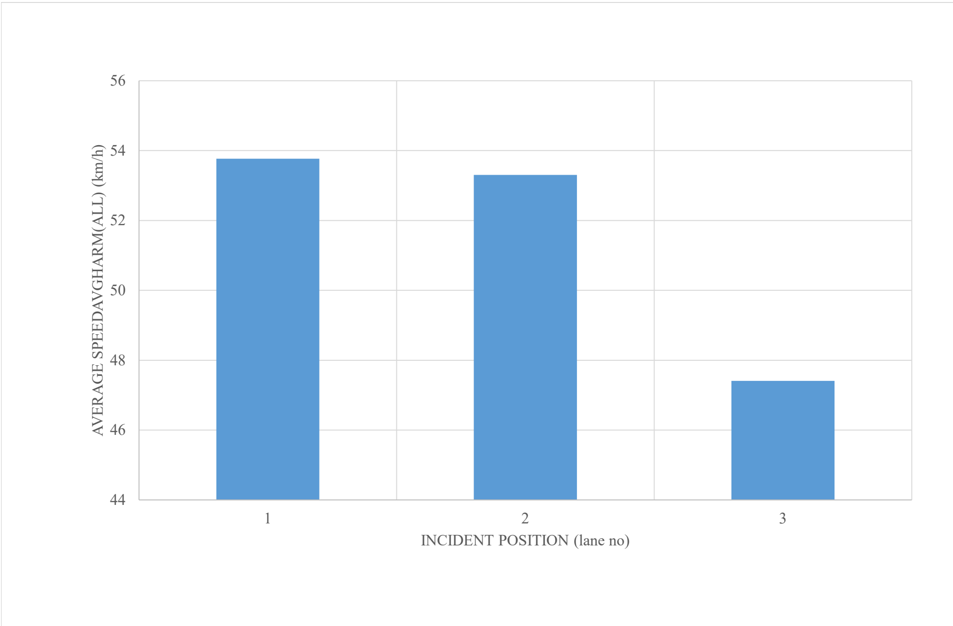

Figure 4.113: AVERAGE SPEEDAVGHARM(ALL) of Discharge Graph of Incident Position Scenario Group 2.

in the 1st lane are the highest. As the 2nd lane is a slower lane than the 3rd lane, occurrence of incident-related congestion is lower in 2nd lane than in 3rd lane. That's why higher average speed values are seen in 2nd lane compared to 3rd lane. However, since 3rd lane is the fastest lane in traffic, the response to congestion is very insufficient here in case of an incident. So, the average speed is the lowest when the incident occurs in the 3rd lane. The reason for the situation in speed differences is that when the incident occurs in the 3rd lane, since the congestion will be higher compared to the 1st lane and the 2nd lane, a greater increase in speed occurs during discharge. Therefore, the speed differences are higher when the incident is in the 3rd lane than in the 1st lane and the 2nd lane. The reason why 1st lane's speed difference is greater than 2nd lane's speed difference is that 1st lane's maximum speed value is higher than 2nd lane's maximum speed value in the graph momentarily. This exception does not affect the overall simulation.

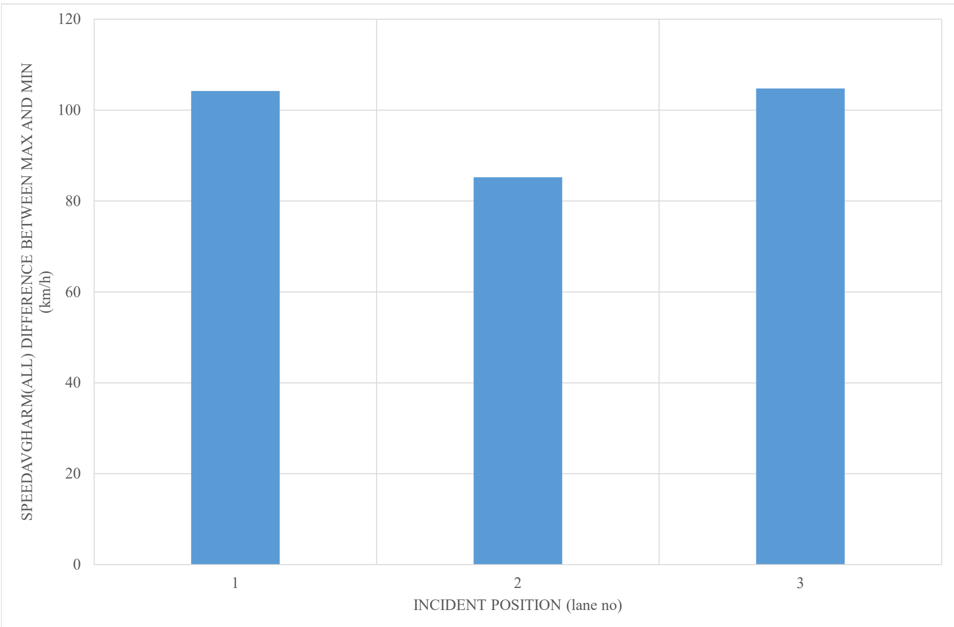

Figure 4.114: SPEEDAVGHARM(ALL) DIFFERENCE BETWEEN MAX AND MIN of Discharge Graph of Incident Position Scenario Group 2.

4.2.5 Impact of Lane Width on Speed – Discharge Characteristics

Figure 4.115: SPEEDAVGHARM(ALL) of Discharge Graph of Lane Width Scenario Group 1.

When an incident whose duration is 5 minutes occurs in the 1st lane of a two-lane road whose vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for lane width which are 3.00 m (EXP 1), 3.25 m (EXP 2), and 3.50 m (EXP 3) as shown in Figure (4.115). If we compare the average SPEEDAVGHARM(ALL) of discharge in Figure (4.116), we deduce that 3.50 m > 3.00 m > 3.25 m. Average speeds of 3.00 m and 3.25 m are almost the same. If we compare the SPEEDAVGHARM(ALL) difference of discharge between maximum and minimum in Figure (4.117), we deduce that 3.50 m > 3.25 m > 3.00 m. As lane width increases, vehicles can change lanes more easily and overcome the congestion during an incident. Also, congestion occurring in one lane on narrow roads may affect the other lanes. Therefore, the highest average speed value was observed on the road where the lane width was 3.50 m compared to other roads. Although the lane width being 3.50 m makes a noticeable difference in terms of

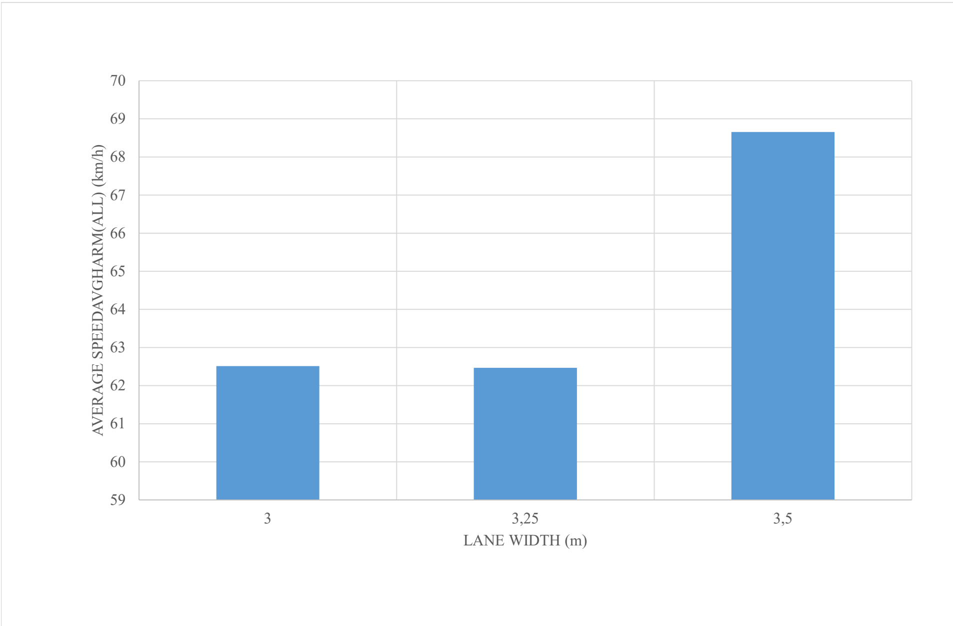

Figure 4.116: AVERAGE SPEEDAVGHARM(ALL) of Discharge Graph of Lane Width Scenario Group 1.

average speed of discharge, there is almost no difference between 3.00 m and 3.25 m. The reason why 3.00 m and 3.25 m are almost the same may be related to the width of the vehicles. Only 3.50 m lane width could be enough for vehicles' widths in terms of discharge. The reason for the situation in speed differences is that the discharge of the incident-related congestion occurring in narrow roads is difficult to take place. Speeds can not easily recover. As the road expands, higher speeds are reached in discharge and the speed difference increases.

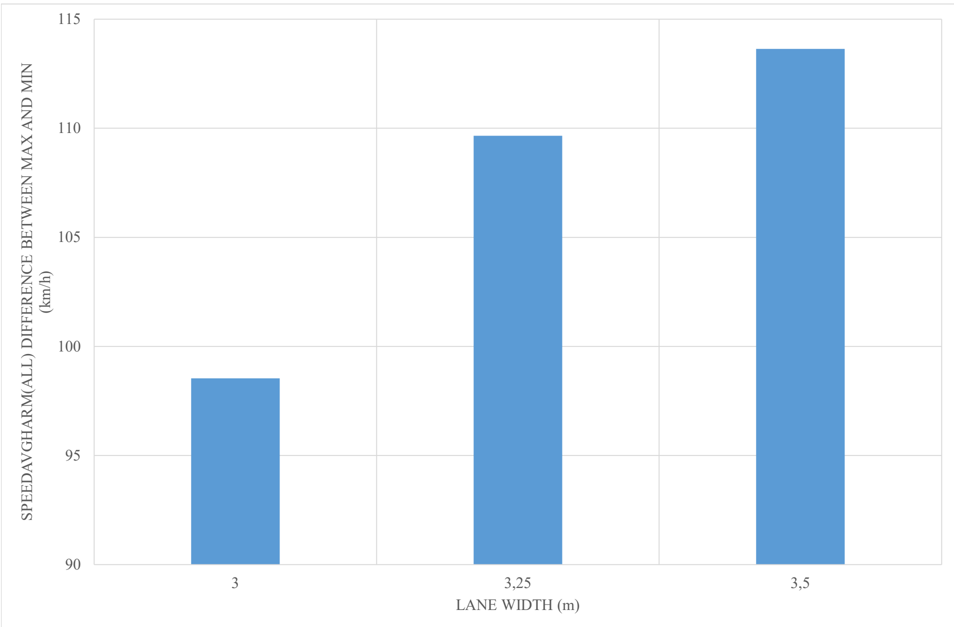

Figure 4.117: SPEEDAVGHARM(ALL) DIFFERENCE BETWEEN MAX AND MIN of Discharge Graph of Lane Width Scenario Group 1.

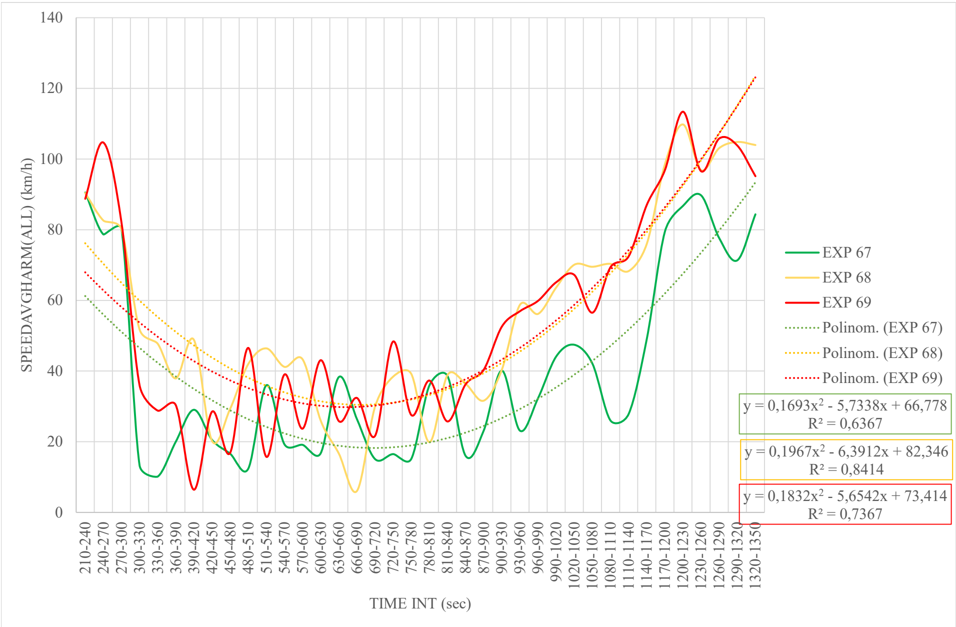

Figure 4.118: SPEEDAVGHARM(ALL) of Discharge Graph of Lane Width Scenario Group 2.

When an incident whose duration is 10 minutes occurs in the 1st lane of a three-lane road whose vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for lane width which are 3.00 m (EXP 67), 3.25 m (EXP 68), and 3.50 m (EXP 69) as shown in Figure (4.118). If we compare the average SPEEDAVGHARM(ALL) of discharge in Figure (4.119), we deduce that 3.25 m > 3.50 m > 3.00 m. Average speeds of 3.25 m and 3.50 m are almost the same. If we compare the SPEEDAVGHARM(ALL) difference of discharge between maximum and minimum in Figure (4.120), we deduce that 3.50 m > 3.25 m > 3.00 m. As lane width increases, vehicles can change lanes more easily and overcome the congestion during an incident. Also, congestion occurring in one lane on narrow roads may affect the other lanes. Therefore, the lowest average speed value was observed on the road where the lane width was 3.00 m compared to other roads. Although the lane width being 3.25 m and 3.50 m makes a noticeable difference compared to 3.00 m in terms of average speed of discharge, there is almost no

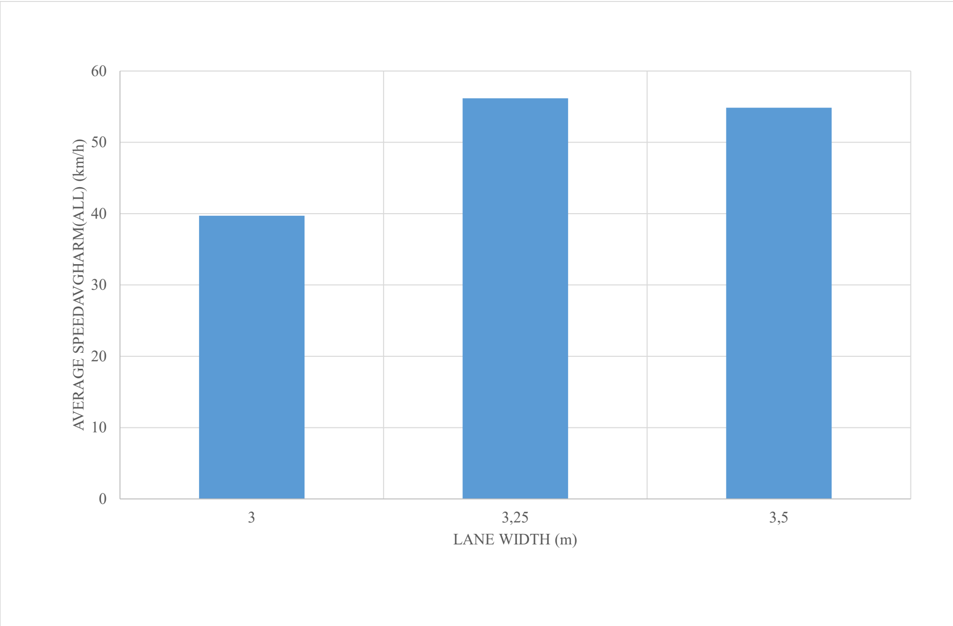

Figure 4.119: AVERAGE SPEEDAVGHARM(ALL) of Discharge Graph of Lane Width Scenario Group 2.

difference between 3.25 m and 3.50 m. There may be two reasons why 3.25 m and 3.50 m are almost the same. One of them may be due to the fact that 3.25 m is more stable without excessive fluctuation. Other reason is that although 3.50 m reaches higher values during discharge, it may be due to the low speed values it has during incident.

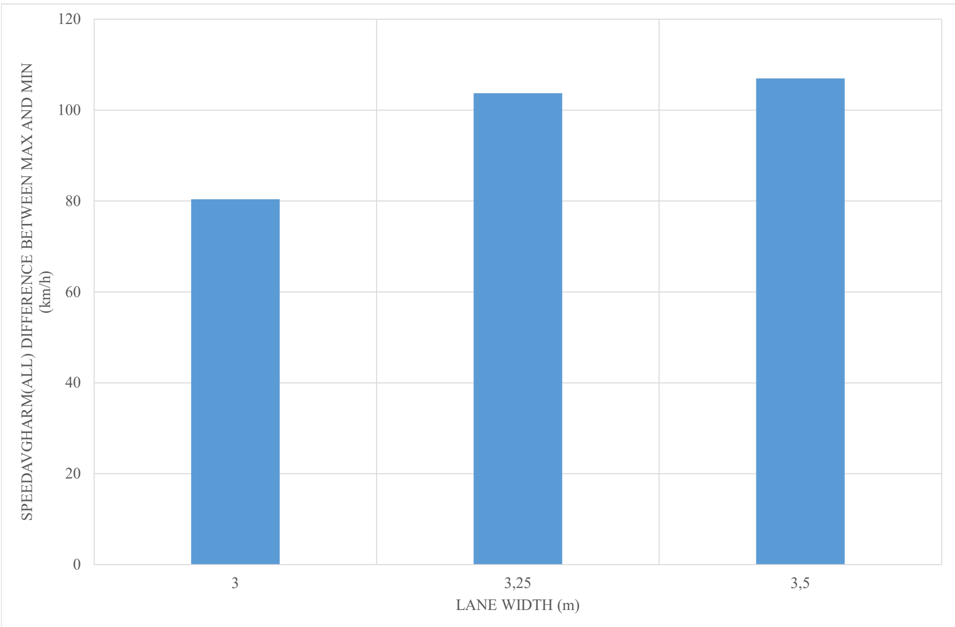

Figure 4.120: SPEEDAVGHARM(ALL) DIFFERENCE BETWEEN MAX AND MIN of Discharge Graph of Lane Width Scenario Group 2.

4.3 Statistical Tests

As it mentioned before, according to our experimental setup table, we have 5 different parameters which affect the incident and we have 2 different example groups for each parameter. That's why we have 10 scenario groups. After plotting their graphs, as the last part of our results, we applied some statistical tests for in depth analysis of speed. Our statistical tests are Anova Single Factor Test and Tukey – Kramer Post Hoc Test. Anova Single Factor Test is a test that tells us whether there is a statistical difference between the experiments we analyzed [64]. But this test has one thing missing. It does not tell us which experiment has statistical difference. Therefore, if there is a difference, we applied the Tukey – Kramer Post Hoc Test after Anova Single Factor Test to find out which experiments are different [65]. We applied these tests for both overall simulation process (3600 seconds) and the discharge process (only incident and post-incident process).

4.3.1 Statistical Tests for Overall Simulation

4.3.1.1 Statistical Tests of the Impact of Incident Duration on Speed for Overall Simulation

When an incident occurs in the 1st lane of a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for incident duration which are 5 minutes (EXP 18), 10 minutes (EXP 63), and 15 minutes (EXP 108). According to Anova Single Factor Test there is a statistically significant difference at least one pair of our groups as shown in Table (4.1). Because F value is greater than F crit value. We applied Tukey – Kramer Post Hoc Test to know which pair is different. According to Tukey – Kramer Post Hoc Test there is a statistically significant difference between EXP 18 and EXP 108 as shown in Table (4.2). Because its q value is greater than its critical value.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 18	120	10987,51	91,56	468,11
EXP 63	120	10278,22	85,65	749,28
EXP 108	120	9691,30	80,76	843,24

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7021,47	2	3510,73	5,1112	0,0065	3,0210
Within Groups	245214,19	357	686,87			
Total	252235,66	359				

Table 4.1: Anova Single Factor Test Results of Incident Duration Scenario Group 1 for Overall Simulation.

Between	Difference	n1	n2	SE	q	critical value	result
EXP 18 - EXP 63	5,91	120	120	2,39	2,471	3,335	no difference
EXP 63 - EXP 108	4,89	120	120	2,39	2,044	3,335	no difference
EXP 18 - EXP 108	10,80	120	120	2,39	4,515	3,335	difference

Table 4.2: Tukey – Kramer Post Hoc Test Results of Incident Duration Scenario Group 1 for Overall Simulation.

When an incident occurs in the 1st lane of a three-lane road whose lane width is 3,50 m and vehicle input is 2000 veh/lane, we have 3 different experiment scenarios for incident duration which are 5 minutes (EXP 39), 10 minutes (EXP 84), and 15 minutes (EXP 129). According to Anova Single Factor Test there is no statistically significant difference between pairs of our groups as shown in Table (4.3). Because F value is smaller than F crit value.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 39	120	9488,24	79,07	383,53
EXP 84	120	9104,83	75,87	550,34
EXP 129	120	8728,37	72,74	672,57

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2405,91	2	1202,96	2,2465	0,1073	3,0210
Within Groups	191166,57	357	535,48			
Total	193572,48	359				

Table 4.3: Anova Single Factor Test Results of Incident Duration Scenario Group 2 for Overall Simulation.

4.3.1.2 Statistical Tests of the Impact of Vehicle Input on Speed for Overall Simulation

When an incident whose duration is 10 minutes occurs in the 1st lane of a two-lane road whose lane width is 3,50 m, we have 3 different experiment scenarios for vehicle input which are 1000 veh/lane (EXP 48), 1500 veh/lane (EXP 63), and 2000 veh/lane (EXP 78). According to Anova Single Factor Test there is a statistically significant difference at least one pair of our groups as shown in Table (4.4). Because F value is greater than F crit value. We applied Tukey – Kramer Post Hoc Test to know which pair is different. According to Tukey – Kramer Post Hoc Test there is a statistically significant difference between EXP 63 and EXP 78, and between EXP 48 and EXP 78 as shown in Table (4.5). Because their q values are greater than critical values.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 48	120	10735,83	89,47	1022,44
EXP 63	120	10278,22	85,65	749,28
EXP 78	120	9052,58	75,44	723,48

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12624,81	2	6312,40	7,5894	0,0006	3,0210
Within Groups	296929,22	357	831,73			
Total	309554,02	359				

Table 4.4: Anova Single Factor Test Results of Vehicle Input Scenario Group 1 for Overall Simulation.

Between	Difference	n1	n2	SE	q	critical value	result
EXP 48 - EXP 63	3,81	120	120	2,63	1,448	3,335	no difference
EXP 63 - EXP 78	10,21	120	120	2,63	3,880	3,335	difference
EXP 48 - EXP 78	14,03	120	120	2,63	5,328	3,335	difference

Table 4.5: Tukey – Kramer Post Hoc Test Results of Vehicle Input Scenario Group 1 for Overall Simulation.

When an incident whose duration is 15 minutes occurs in the 1st lane of a three-lane road whose lane width is 3,50 m, we have 3 different experiment scenarios for vehicle input which are 1000 veh/lane (EXP 99), 1500 veh/lane (EXP 114), and 2000 veh/lane (EXP 129). According to Anova Single Factor Test there is a statistically significant difference at least one pair of our groups as shown in Table (4.6). Because F value is greater than F crit value. We applied Tukey – Kramer Post Hoc Test to know which pair is different. According to Tukey – Kramer Post Hoc Test there is a statistically significant difference between EXP

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 99	120	10662,63	88,86	1193,54
EXP 114	120	9622,01	80,18	986,44
EXP 129	120	8728,37	72,74	672,57

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	15619,01	2	7809,51	8,2132	0,0003	3,0210
Within Groups	339453,89	357	950,85			
Total	355072,90	359				

Table 4.6: Anova Single Factor Test Results of Vehicle Input Scenario Group 2 for Overall Simulation.

Between	Difference	n1	n2	SE	q	critical value	result
EXP 99 - EXP 114	8,67	120	120	2,81	3,081	3,335	no difference
EXP 114 - EXP 129	7,45	120	120	2,81	2,646	3,335	no difference
EXP 99 - EXP 129	16,12	120	120	2,81	5,726	3,335	difference

Table 4.7: Tukey – Kramer Post Hoc Test Results of Vehicle Input Scenario Group 2 for Overall Simulation.

99 and EXP 129 as shown in Table (4.7). Because its q value is greater than its critical value.

4.3.1.3 Statistical Tests of the Impact of Number of Lane on Speed for Overall Simulation

When an incident whose duration is 5 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 2 different experiment scenarios for number of lane which are 2 lanes (EXP 18) and 3 lanes

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 18	120	10987,51	91,56	468,11
EXP 24	120	11151,88	92,93	563,04

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	112,57	1	112,57	0,2183	0,6407	3,8808
Within Groups	122706,87	238	515,58			
Total	122819,44	239				

Table 4.8: Anova Single Factor Test Results of Number of Lane Scenario Group 1 for Overall Simulation.

(EXP 24). According to Anova Single Factor Test there is no statistically significant difference between pairs of our groups as shown in Table (4.8). Because F value is smaller than F crit value.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 108	120	9691,3	80,76	843,24
EXP 114	120	9622,01	80,18	986,44

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20,00	1	20,00	0,0219	0,8826	3,8808
Within Groups	217731,95	238	914,84			
Total	217751,96	239				

Table 4.9: Anova Single Factor Test Results of Number of Lane Scenario Group 2 for Overall Simulation.

When an incident whose duration is 15 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 2 different experiment scenarios for number of lane which are 2 lanes (EXP 108) and 3 lanes (EXP 114). According to Anova Single Factor Test there is no statistically significant difference between pairs of our groups as shown in Table (4.9). Because F value is smaller than F crit value.

4.3.1.4 Statistical Tests of the Impact of Incident Position on Speed for Overall Simulation

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 18	120	10987,51	91,56	468,11
EXP 21	120	10743,03	89,53	653,82

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	249,04	1	249,04	0,4440	0,5059	3,8808
Within Groups	133509,51	238	560,96			
Total	133758,55	239				

Table 4.10: Anova Single Factor Test Results of Incident Position Scenario Group 1 for Overall Simulation.

When an incident whose duration is 5 minutes occurs in a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 2 different experiment scenarios for incident position which are 1st lane (EXP 18) and 2nd lane (EXP 21). According to Anova Single Factor Test there is no statistically significant difference between pairs of our groups as shown in Table (4.10). Because F value is smaller than F crit value.

When an incident whose duration is 15 minutes occurs in a three-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for incident position which are 1st lane (EXP 114), 2nd lane (EXP 117), and 3rd lane (EXP 120). According to Anova Single Factor Test there is no statistically significant difference between pairs of our groups as shown in Table (4.11). Because F value is smaller than F crit value.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 114	120	9622,01	80,18	986,44
EXP 117	120	9019,19	75,16	824,66
EXP 120	120	9377,38	78,14	1248,69

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1532,04	2	766,02	0,7511	0,4726	3,0210
Within Groups	364114,17	357	1019,93			
Total	365646,21	359				

Table 4.11: Anova Single Factor Test Results of Incident Position Scenario Group 2 for Overall Simulation.

4.3.1.5 Statistical Tests of the Impact of Lane Width on Speed for Overall Simulation

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 1	120	11260,11	93,83	530,10
EXP 2	120	11294,34	94,12	655,64
EXP 3	120	11599,15	96,66	602,69

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	580,64	2	290,32	0,4870	0,6149	3,0210
Within Groups	212822,72	357	596,14			
Total	213403,36	359				

Table 4.12: Anova Single Factor Test Results of Lane Width Scenario Group 1 for Overall Simulation.

When an incident whose duration is 5 minutes occurs in the 1st lane of a two-lane road whose vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for lane width which are 3.00 m (EXP 1), 3.25 m (EXP 2), and 3.50 m (EXP

3). According to Anova Single Factor Test there is no statistically significant difference between pairs of our groups as shown in Table (4.12). Because F value is smaller than F crit value.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 67	120	8806,08	73,38	806,20
EXP 68	120	10315,83	85,97	707,73
EXP 69	120	10435,24	86,96	803,60

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13743,79	2	6871,90	8,8956	0,0002	3,0210
Within Groups	275785,15	357	772,51			
Total	289528,95	359				

Table 4.13: Anova Single Factor Test Results of Lane Width Scenario Group 2 for Overall Simulation.

Between	Difference	n1	n2	SE	q	critical value	result
EXP 67 - EXP 68	12,58	120	120	2,54	4,959	3,335	difference
EXP 68 - EXP 69	1,00	120	120	2,54	0,392	3,335	no difference
EXP 67 - EXP 69	13,58	120	120	2,54	5,351	3,335	difference

Table 4.14: Tukey – Kramer Post Hoc Test Results of Lane Width Scenario Group 2 for Overall Simulation.

When an incident whose duration is 10 minutes occurs in the 1st lane of a three-lane road whose vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for lane width which are 3.00 m (EXP 67), 3.25 m (EXP 68), and 3.50 m (EXP 69). According to Anova Single Factor Test there is a statistically significant difference at least one pair of our groups as shown in Table (4.13). Because F value is greater than F crit value. We applied Tukey – Kramer Post

Hoc Test to know which pair is different. According to Tukey – Kramer Post Hoc Test there is a statistically significant difference between EXP 67 and EXP 68, and between EXP 67 and EXP 69 as shown in Table (4.14). Because their q values are greater than their critical values.

4.3.2 Statistical Tests for Discharge Process

4.3.2.1 Statistical Tests of the Impact of Incident Duration on Speed for Discharge Process

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 18	54	4379,23	81,10	792,02
EXP 63	54	3669,94	67,96	1046,52
EXP 108	54	3083,02	57,09	799,50

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	15603,26	2	7801,63	8,8721	0,0002	3,0529
Within Groups	139815,74	159	879,34			
Total	155419,00	161				

Table 4.15: Anova Single Factor Test Results of Incident Duration Scenario Group 1 for the Discharge Process.

Between	Difference	n1	n2	SE	q	critical value	result
EXP 18 - EXP 63	13,14	54	54	4,04	3,255	3,356	no difference
EXP 63 - EXP 108	10,87	54	54	4,04	2,693	3,356	no difference
EXP 18 - EXP 108	24,00	54	54	4,04	5,948	3,356	difference

Table 4.16: Tukey – Kramer Post Hoc Test Results of Incident Duration Scenario Group 1 for the Discharge Process.

When an incident occurs in the 1st lane of a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for incident duration which are 5 minutes (EXP 18), 10 minutes (EXP 63), and 15 minutes (EXP 108). According to Anova Single Factor Test there is a statistically significant difference at least one pair of our groups as shown in Table (4.15). Because F value is greater than F crit value. We applied Tukey – Kramer Post Hoc Test to know which pair is different. According to Tukey – Kramer Post Hoc Test there is a statistically significant difference between EXP 18 and EXP 108 as shown in Table (4.16). Because its q value is greater than its critical value.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 39	52	3660,32	70,39	636,31
EXP 84	52	3131,1	60,21	729,70
EXP 129	52	2645,99	50,88	600,94

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9899,17	2	4949,59	7,5491	0,0007	3,0552
Within Groups	100314,53	153	655,65			
Total	110213,70	155				

Table 4.17: Anova Single Factor Test Results of Incident Duration Scenario Group 2 for the Discharge Process.

When an incident occurs in the 1st lane of a three-lane road whose lane width is 3,50 m and vehicle input is 2000 veh/lane, we have 3 different experiment scenarios for incident duration which are 5 minutes (EXP 39), 10 minutes (EXP 84), and 15 minutes (EXP 129). According to Anova Single Factor Test there is a statistically significant difference at least one pair of our groups as shown in Table (4.17). Because F value is greater than F crit value. We applied Tukey – Kramer Post Hoc Test to know which pair is different. According to Tukey – Kramer Post Hoc Test there is a statistically significant difference between EXP

Between	Difference	n1	n2	SE	q	critical value	result
EXP 39 - EXP 84	10,18	52	52	3,55	2,866	3,356	no difference
EXP 84 - EXP 129	9,33	52	52	3,55	2,627	3,356	no difference
EXP 39 - EXP 129	19,51	52	52	3,55	5,493	3,356	difference

Table 4.18: Tukey – Kramer Post Hoc Test Results of Incident Duration Scenario Group 2 for the Discharge Process.

39 and EXP 129 as shown in Table (4.18). Because its q value is greater than its critical value.

4.3.2.2 Statistical Tests of the Impact of Vehicle Input on Speed for Discharge Process

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 48	33	1666,08	50,49	1495,98
EXP 63	33	1582,12	47,94	646,12
EXP 78	33	1386,47	42,01	889,55

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1247,58	2	623,79	0,6173	0,5415	3,0912
Within Groups	97012,47	96	1010,55			
Total	98260,05	98				

Table 4.19: Anova Single Factor Test Results of Vehicle Input Scenario Group 1 for the Discharge Process.

When an incident whose duration is 10 minutes occurs in the 1st lane of a two-lane road whose lane width is 3,50 m, we have 3 different experiment scenarios for vehicle input which are 1000 veh/lane (EXP 48), 1500 veh/lane (EXP 63), and 2000 veh/lane (EXP 78). According to Anova Single Factor Test there is no statistically significant difference between pairs of our groups as shown in Table (4.19). Because F value is smaller than F crit value.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 99	44	2384,26	54,19	1301,16
EXP 114	44	1905,63	43,31	427,55
EXP 129	44	1971,78	44,81	441,99

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3057,59	2	1528,80	2,1129	0,1251	3,0664
Within Groups	93340,37	129	723,57			
Total	96397,96	131				

Table 4.20: Anova Single Factor Test Results of Vehicle Input Scenario Group 2 for the Discharge Process.

When an incident whose duration is 15 minutes occurs in the 1st lane of a three-lane road whose lane width is 3,50 m, we have 3 different experiment scenarios for vehicle input which are 1000 veh/lane (EXP 99), 1500 veh/lane (EXP 114), and 2000 veh/lane (EXP 129). According to Anova Single Factor Test there is no statistically significant difference between pairs of our groups as shown in Table (4.20). Because F value is smaller than F crit value.

4.3.2.3 Statistical Tests of the Impact of Number of Lane on Speed for Discharge Process

When an incident whose duration is 5 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 2 different experiment scenarios for number of lane which are 2 lanes (EXP 18) and 3 lanes

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 18	32	2222,72	69,46	980,40
EXP 24	32	2197,86	68,68	1174,45

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9,66	1	9,66	0,0090	0,9249	3,9959
Within Groups	66800,28	62	1077,42			
Total	66809,94	63				

Table 4.21: Anova Single Factor Test Results of Number of Lane Scenario Group 1 for the Discharge Process.

(EXP 24). According to Anova Single Factor Test there is no statistically significant difference between pairs of our groups as shown in Table (4.21). Because F value is smaller than F crit value.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 108	51	2783,17	54,57	729,30
EXP 114	51	2605,16	51,08	760,50

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	310,66	1	310,66	0,4171	0,5199	3,9361
Within Groups	74489,86	100	744,90			
Total	74800,52	101				

Table 4.22: Anova Single Factor Test Results of Vehicle Input Scenario Group 2 for the Discharge Process.

When an incident whose duration is 15 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 2 different experiment scenarios for number of lane which are 2 lanes (EXP 108) and 3 lanes

(EXP 114). According to Anova Single Factor Test there is no statistically significant difference between pairs of our groups as shown in Table (4.22). Because F value is smaller than F crit value.

4.3.2.4 Statistical Tests of the Impact of Incident Position on Speed for Discharge Process

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 18	27	1721,93	63,78	950,91
EXP 21	27	1477,45	54,72	1212,35

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1106,86	1	1106,86	1,0233	0,3164	4,0266
Within Groups	56244,84	52	1081,63			
Total	57351,70	53				

Table 4.23: Anova Single Factor Test Results of Incident Position Scenario Group 1 for the Discharge Process.

When an incident whose duration is 5 minutes occurs in a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 2 different experiment scenarios for incident position which are 1st lane (EXP 18) and 2nd lane (EXP 21). According to Anova Single Factor Test there is no statistically significant difference between pairs of our groups as shown in Table (4.23). Because F value is smaller than F crit value.

When an incident whose duration is 15 minutes occurs in a three-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for incident position which are 1st lane (EXP 114), 2nd lane (EXP 117), and 3rd lane (EXP 120). According to Anova Single Factor Test there is no statistically significant difference between pairs of our groups as shown in Table (4.24). Because F value is smaller than F crit value.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 114	54	2903,41	53,77	843,67
EXP 117	54	2878,52	53,31	756,56
EXP 120	54	2560,04	47,41	993,75

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1357,73	2	678,86	0,7851	0,4578	3,0529
Within Groups	137480,81	159	864,66			
Total	138838,54	161				

Table 4.24: Anova Single Factor Test Results of Incident Position Scenario Group 2 for the Discharge Process.

4.3.2.5 Statistical Tests of the Impact of Lane Width on Speed for Discharge Process

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 1	25	1562,76	62,51	1132,23
EXP 2	25	1561,63	62,47	1715,10
EXP 3	25	1716,38	68,66	1751,47

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	633,97	2	316,99	0,2068	0,8137	3,1239
Within Groups	110371,36	72	1532,94			
Total	111005,33	74				

Table 4.25: Anova Single Factor Test Results of Lane Width Scenario Group 1 for the Discharge Process.

When an incident whose duration is 5 minutes occurs in the 1st lane of a two-lane road whose vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for lane width which are 3.00 m (EXP 1), 3.25 m (EXP 2), and 3.50 m (EXP

3). According to Anova Single Factor Test there is no statistically significant difference between pairs of our groups as shown in Table (4.25). Because F value is smaller than F crit value.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 67	38	1509,00	39,71	680,47
EXP 68	38	2134,96	56,18	786,35
EXP 69	38	2084,66	54,86	913,12

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6366,14	2	3183,07	4,0124	0,0208	3,0781
Within Groups	88057,85	111	793,31			
Total	94423,99	113				

Table 4.26: Anova Single Factor Test Results of Lane Width Scenario Group 2 for the Discharge Process.

Between	Difference	n1	n2	SE	q	critical value	result
EXP 67 - EXP 68	16,47	38	38	4,57	3,605	3,377	difference
EXP 68 - EXP 69	1,32	38	38	4,57	0,290	3,377	no difference
EXP 67 - EXP 69	15,15	38	38	4,57	3,316	3,377	no difference

Table 4.27: Tukey – Kramer Post Hoc Test Results of Lane Width Scenario Group 2 for the Discharge Process.

When an incident whose duration is 10 minutes occurs in the 1st lane of a three-lane road whose vehicle input is 1500 veh/lane, we have 3 different experiment scenarios for lane width which are 3.00 m (EXP 67), 3.25 m (EXP 68), and 3.50 m (EXP 69). According to Anova Single Factor Test there is a statistically significant difference at least one pair of our groups as shown in Table (4.26). Because F value is greater than F crit value. We applied Tukey – Kramer Post

Hoc Test to know which pair is different. According to Tukey – Kramer Post Hoc Test there is a statistically significant difference between EXP 67 and EXP 68 as shown in Table (4.27). Because its q value is greater than its critical value.

Chapter 5

Conclusion and Further Studies

The general outcomes we obtained as a result of overall simulations are presented below as items.

1. When an incident occurs in the 1st lane of a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident durations are identified, if incident duration increases from 5 minutes to 10 minutes, average queue length increases by 176,4% and maximum queue length increases by 1,3%. If incident duration increases from 10 minutes to 15 minutes, average queue length increases by 64,9% and maximum queue length increases by 1,8%. If incident duration increases from 5 minutes to 15 minutes, average queue length increases by 355,9% and maximum queue length increases by 3,1%.

2. When an incident occurs in the 1st lane of a three-lane road whose lane width is 3,50 m and vehicle input is 2000 veh/lane; provided that all other variables are the same, when only different incident durations are identified, if incident duration increases from 5 minutes to 10 minutes, average queue length increases by 130,5% and maximum queue length is the same. If incident duration increases from 10 minutes to 15 minutes, average queue length increases by 54,8% and maximum queue length is the same. If incident duration increases from 5 minutes to 15 minutes, average queue length increases by 256,7% and maximum queue length is the same.

3. When an incident occurs in the 1st lane of a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident durations are identified, if incident duration increases from 5 minutes to 10 minutes, total number of vehicles is the same. If incident duration increases from 10 minutes to 15 minutes, total number of vehicles is the same. If incident duration increases from 5 minutes to 15 minutes, total number of vehicles is the same.

4. When an incident occurs in the 1st lane of a three-lane road whose lane width is 3,50 m and vehicle input is 2000 veh/lane; provided that all other variables are the same, when only different incident durations are identified, if incident duration increases from 5 minutes to 10 minutes, total number of vehicles decreases by 1,9%. If incident duration increases from 10 minutes to 15 minutes, total number of vehicles decreases by 4,6%. If incident duration increases from 5 minutes to 15 minutes, total number of vehicles decreases by 6,4%.

5. When an incident occurs in the 1st lane of a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident durations are identified, if incident duration increases from 5 minutes to 10 minutes, total travel time increases by 48,3%. If incident duration increases from 10 minutes to 15 minutes, total travel time increases by 40,3%. If incident duration increases from 5 minutes to 15 minutes, total travel time increases by 108,1%.

6. When an incident occurs in the 1st lane of a three-lane road whose lane width is 3,50 m and vehicle input is 2000 veh/lane; provided that all other variables are the same, when only different incident durations are identified, if incident duration increases from 5 minutes to 10 minutes, total travel time increases by 23,7%. If incident duration increases from 10 minutes to 15 minutes, total travel time increases by 20,8%. If incident duration increases from 5 minutes to 15 minutes, total travel time increases by 49,5%.

7. When an incident occurs in the 1st lane of a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident durations are identified, if incident duration increases from 5 minutes to 10 minutes, average speed decreases by 6,5%. If incident duration increases from 10 minutes to 15 minutes, average speed decreases by 5,7%. If incident duration increases from 5 minutes to 15 minutes, average speed decreases by 11,8%.

8. When an incident occurs in the 1st lane of a three-lane road whose lane width is 3,50 m and vehicle input is 2000 veh/lane; provided that all other variables are the same, when only different incident durations are identified, if incident duration increases from 5 minutes to 10 minutes, average speed decreases by 4,0%. If incident duration increases from 10 minutes to 15 minutes, average speed decreases by 4,1%. If incident duration increases from 5 minutes to 15 minutes, average speed decreases by 8,0%.

9. When an incident whose duration is 10 minutes occurs in the 1st lane of a two-lane road whose lane width is 3,50 m; provided that all other variables are the same, when only different vehicle inputs are used, if vehicle input increases from 1000 veh/lane to 1500 veh/lane, average queue length increases by 182,6% and maximum queue length increases by 142,3%. If vehicle input increases from 1500 veh/lane to 2000 veh/lane, average queue length increases by 28,6% and maximum queue length increases by 3,4%. If vehicle input increases from 1000 veh/lane to 2000 veh/lane, average queue length increases by 263,5% and maximum queue length increases by 150,6%.

10. When an incident whose duration is 15 minutes occurs in the 1st lane of a three-lane road whose lane width is 3,50 m; provided that all other variables are the same, when only different vehicle inputs are used, if vehicle input increases from 1000 veh/lane to 1500 veh/lane, average queue length increases by 397,9% and maximum queue length increases by 182,7%. If vehicle input increases from 1500 veh/lane to 2000 veh/lane, average queue

length increases by 17,0% and maximum queue length decreases by 0,9%. If vehicle input increases from 1000 veh/lane to 2000 veh/lane, average queue length increases by 482,5% and maximum queue length increases by 180,2%.

11. When an incident whose duration is 10 minutes occurs in the 1st lane of a two-lane road whose lane width is 3,50 m; provided that all other variables are the same, when only different vehicle inputs are used, if vehicle input increases from 1000 veh/lane to 1500 veh/lane, total number of vehicles increases by 50,0%. If vehicle input increases from 1500 veh/lane to 2000 veh/lane, total number of vehicles increases by 25,8%. If vehicle input increases from 1000 veh/lane to 2000 veh/lane, total number of vehicles increases by 88,8%.

12. When an incident whose duration is 15 minutes occurs in the 1st lane of a three-lane road whose lane width is 3,50 m; provided that all other variables are the same, when only different vehicle inputs are used, if vehicle input increases from 1000 veh/lane to 1500 veh/lane, total number of vehicles increases by 47,6%. If vehicle input increases from 1500 veh/lane to 2000 veh/lane, total number of vehicles increases by 17,3%. if vehicle input increases from 1000 veh/lane to 2000 veh/lane, total number of vehicles increases by 73,1%.

13. When an incident whose duration is 10 minutes occurs in the 1st lane of a two-lane road whose lane width is 3,50 m; provided that all other variables are the same, when only different vehicle inputs are used, if vehicle input increases from 1000 veh/lane to 1500 veh/lane, total travel time increases by 42,2%. If vehicle input increases from 1500 veh/lane to 2000 veh/lane, total travel time increases by 60,4%. If vehicle input increases from 1000 veh/lane to 2000 veh/lane, total travel time increases by 128,1%.

14. When an incident whose duration is 15 minutes occurs in the 1st lane of a three-lane road whose lane width is 3,50 m; provided that all other variables are the same, when only different vehicle inputs are used, if vehicle input

increases from 1000 veh/lane to 1500 veh/lane, total travel time increases by 84,2%. If vehicle input increases from 1500 veh/lane to 2000 veh/lane, total travel time increases by 24,9%. If vehicle input increases from 1000 veh/lane to 2000 veh/lane, total travel time increases by 130,1%.

15. When an incident whose duration is 10 minutes occurs in the 1st lane of a two-lane road whose lane width is 3,50 m; provided that all other variables are the same, when only different vehicle inputs are used, if vehicle input increases from 1000 veh/lane to 1500 veh/lane, average speed decreases by 4,3%. If vehicle input increases from 1500 veh/lane to 2000 veh/lane, average speed decreases by 11,9%. If vehicle input increases from 1000 veh/lane to 2000 veh/lane, average speed decreases by 15,7%.

16. When an incident whose duration is 15 minutes occurs in the 1st lane of a three-lane road whose lane width is 3,50 m; provided that all other variables are the same, when only different vehicle inputs are used, if vehicle input increases from 1000 veh/lane to 1500 veh/lane, average speed decreases by 9,8%. If vehicle input increases from 1500 veh/lane to 2000 veh/lane, average speed decreases by 9,3%. If vehicle input increases from 1000 veh/lane to 2000 veh/lane, average speed decreases by 18,1%.

17. When an incident whose duration is 5 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different numbers of lane are used, if number of lane increases from 2 lanes to 3 lanes, average queue length decreases by 52,1% and maximum queue length decreases by 36,9%.

18. When an incident whose duration is 15 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different numbers of lane are used, if number of lane increases from 2 lanes to 3 lanes, average queue length decreases by 11,3% and maximum queue length increases by 0,3%.

19. When an incident whose duration is 5 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different numbers of lane are used, if number of lane increases from 2 lanes to 3 lanes, total number of vehicles increases by 47,7%.

20. When an incident whose duration is 15 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different numbers of lane are used, if number of lane increases from 2 lanes to 3 lanes, total number of vehicles increases by 47,7%.

21. When an incident whose duration is 5 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different numbers of lane are used, if number of lane increases from 2 lanes to 3 lanes, total travel time decreases by 10,7%.

22. When an incident whose duration is 15 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different numbers of lane are used, if number of lane increases from 2 lanes to 3 lanes, total travel time decreases by 18,2%.

23. When an incident whose duration is 5 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different numbers of lane are used, if number of lane increases from 2 lanes to 3 lanes, average speed increases by 1,5%.

24. When an incident whose duration is 15 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different numbers of lane

are used, if number of lane increases from 2 lanes to 3 lanes, average speed decreases by 0,7%.

25. When an incident whose duration is 5 minutes occurs in a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident positions are used, if incident position increases from 1st lane to 2nd lane, average queue length increases by 45,6% and maximum queue length increases by 2,3%.

26. When an incident whose duration is 15 minutes occurs in a three-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident positions are used, if incident position increases from 1st lane to 2nd lane, average queue length increases by 34,6% and maximum queue length increases by 0,6%. If incident position increases from 2nd lane to 3rd lane, average queue length decreases by 11,7% and maximum queue length increases by 1,2%. If incident position increases from 1st lane to 3rd lane, average queue length increases by 18,9% and maximum queue length increases by 0,6%.

27. When an incident whose duration is 5 minutes occurs in a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident positions are used, if incident position increases from 1st lane to 2nd lane, total number of vehicles is the same.

28. When an incident whose duration is 15 minutes occurs in a three-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident positions are used, if incident position increases from 1st lane to 2nd lane, total number of vehicles decreases by 0,8%. If incident position increases from 2nd lane to 3rd lane, total number of vehicles decreases by 0,2%. If incident position

increases from 1st lane to 3rd lane, total number of vehicles decreases by 1,0%.

29. When an incident whose duration is 5 minutes occurs in a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident positions are used, if incident position increases from 1st lane to 2nd lane, total travel time increases by 8,9%.

30. When an incident whose duration is 15 minutes occurs in a three-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident positions are used, if incident position increases from 1st lane to 2nd lane, total travel time increases by 112,8%. If incident position increases from 2nd lane to 3rd lane, total travel time decreases by 45,6%. If incident position increases from 1st lane to 3rd lane, total travel time increases by 15,7%.

31. When an incident whose duration is 5 minutes occurs in a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident positions are used, if incident position increases from 1st lane to 2nd lane, average speed decreases by 2,2%.

32. When an incident whose duration is 15 minutes occurs in a three-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident positions are used, if incident position increases from 1st lane to 2nd lane, average speed decreases by 6,3%. If incident position increases from 2nd lane to 3rd lane average speed increases by 4,0%. If incident position increases from 1st lane to 3rd lane, average speed decreases by 2,5%.

33. When an incident whose duration is 5 minutes occurs in the 1st lane of a two-lane road whose vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different lane widths are used, if

lane width increases from 3 m to 3.25 m, average queue length decreases by 59,0% and maximum queue length decreases by 47,1%. If lane width increases from 3.25 m to 3.50 m, average queue length decreases by 48,5% and maximum queue length decreases by 22,9%. If lane width increases from 3 m to 3.50 m, average queue length decreases by 78,9% and maximum queue length decreases by 59,2%.

34. When an incident whose duration is 10 minutes occurs in the 1st lane of a three-lane road whose vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different lane widths are used, if lane width increases from 3 m to 3.25 m, average queue length decreases by 17,8% and maximum queue length decreases by 3,0%. If lane width increases from 3.25 m to 3.50 m, average queue length decreases by 12,9% and maximum queue length increases by 2,7%. If lane width increases from 3 m to 3.50 m, average queue length decreases by 28,5% and maximum queue length decreases by 0,4%.

35. When an incident whose duration is 5 minutes occurs in the 1st lane of a two-lane road whose vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different lane widths are used, if lane width increases from 3 m to 3.25 m, total number of vehicles increases by 0,2%. If lane width increases from 3.25 m to 3.50 m, total number of vehicles is the same. If lane width increases from 3 m to 3.50 m, total number of vehicles increases by 0,2%.

36. When an incident whose duration is 10 minutes occurs in the 1st lane of a three-lane road whose vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different lane widths are used, if lane width increases from 3 m to 3.25 m, total number of vehicles increases by 3,7%. If lane width increases from 3.25 m to 3.50 m, total number of vehicles is the same. If lane width increases from 3 m to 3.50 m, total number of vehicles increases by 3,7%.

37. When an incident whose duration is 5 minutes occurs in the 1st lane of a two-lane road whose vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different lane widths are used, if lane width increases from 3 m to 3.25 m, total travel time decreases by 29,7%. If lane width increases from 3.25 m to 3.50 m, total travel time decreases by 12,1%. If lane width increases from 3 m to 3.50 m, total travel time decreases by 38,2%.

38. When an incident whose duration is 10 minutes occurs in the 1st lane of a three-lane road whose vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different lane widths are used, if lane width increases from 3 m to 3.25 m, total travel time decreases by 36,9%. If lane width increases from 3.25 m to 3.50 m, total travel time decreases by 1,2%. If lane width increases from 3 m to 3.50 m, total travel time decreases by 37,7%.

39. When an incident whose duration is 5 minutes occurs in the 1st lane of a two-lane road whose vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different lane widths are used, if lane width increases from 3 m to 3.25 m, average speed increases by 0,3%. If lane width increases from 3.25 m to 3.50 m, average speed increases by 2,7%. If lane width increases from 3 m to 3.50 m, average speed increases by 3,0%.

40. When an incident whose duration is 10 minutes occurs in the 1st lane of a three-lane road whose vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different lane widths are used, if lane width increases from 3 m to 3.25 m, average speed increases by 17,1%. If lane width increases from 3.25 m to 3.50 m, average speed increases by 1,1%. If lane width increases from 3 m to 3.50 m, average speed increases by 18,5%.

The general outcomes we obtained as a result of discharge processes are presented below as items.

1. When an incident occurs in the 1st lane of a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident durations are identified, if incident duration increases from 5 minutes to 10 minutes, average speed decreases by 16,2% and the difference between maximum and minimum speed increases by 1,0%. If incident duration increases from 10 minutes to 15 minutes, average speed decreases by 16,0% and the difference between maximum and minimum speed decreases by 3,8%. If incident duration increases from 5 minutes to 15 minutes, average speed decreases by 29,6% and the difference between maximum and minimum speed decreases by 2,9%.

2. When an incident occurs in the 1st lane of a three-lane road whose lane width is 3,50 m and vehicle input is 2000 veh/lane; provided that all other variables are the same, when only different incident durations are identified, if incident duration increases from 5 minutes to 10 minutes, average speed decreases by 14,5% and the difference between maximum and minimum speed increases by 0,01%. If incident duration increases from 10 minutes to 15 minutes, average speed decreases by 15,5% and the difference between maximum and minimum speed is the same. If incident duration increases from 5 minutes to 15 minutes, average speed decreases by 27,7% and the difference between maximum and minimum speed increases by 0,01%.

3. When an incident whose duration is 10 minutes occurs in the 1st lane of a two-lane road whose lane width is 3,50 m; provided that all other variables are the same, when only different vehicle inputs are used, if vehicle input increases from 1000 veh/lane to 1500 veh/lane, average speed decreases by 5,0% and the difference between maximum and minimum speed decreases by 13,5%. If vehicle input increases from 1500 veh/lane to 2000 veh/lane,

average speed decreases by 12,4% and the difference between maximum and minimum speed increases by 0,9%. If vehicle input increases from 1000 veh/lane to 2000 veh/lane, average speed decreases by 16,8% and the difference between maximum and minimum speed decreases by 12,7%.

4. When an incident whose duration is 15 minutes occurs in the 1st lane of a three-lane road whose lane width is 3,50 m; provided that all other variables are the same, when only different vehicle inputs are used, if vehicle input increases from 1000 veh/lane to 1500 veh/lane, average speed decreases by 20,1% and the difference between maximum and minimum speed decreases by 7,0%. If vehicle input increases from 1500 veh/lane to 2000 veh/lane, average speed increases by 3,5% and the difference between maximum and minimum speed decreases by 18,2%. If vehicle input increases from 1000 veh/lane to 2000 veh/lane, average speed decreases by 17,3% and the difference between maximum and minimum speed decreases by 24,0%.

5. When an incident whose duration is 5 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different numbers of lane are used, if number of lane increases from 2 lanes to 3 lanes, average speed decreases by 1,1% and the difference between maximum and minimum speed increases by 10,1%.

6. When an incident whose duration is 15 minutes occurs in the 1st lane of a road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different numbers of lane are used, if number of lane increases from 2 lanes to 3 lanes, average speed decreases by 6,4% and the difference between maximum and minimum speed increases by 9,2%.

7. When an incident whose duration is 5 minutes occurs in a two-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident positions are

used, if incident position increases from 1st lane to 2nd lane, average speed decreases by 14,2% and the difference between maximum and minimum speed increases by 0,3%.

8. When an incident whose duration is 15 minutes occurs in a three-lane road whose lane width is 3,50 m and vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different incident positions are used, if incident position increases from 1st lane to 2nd lane, average speed decreases by 0,9% and the difference between maximum and minimum speed decreases by 18,2%. If incident position increases from 2nd lane to 3rd lane average speed decreases by 11,1% and the difference between maximum and minimum speed increases by 22,9%. If incident position increases from 1st lane to 3rd lane, average speed decreases by 11,8% and the difference between maximum and minimum speed increases by 0,6%.

9. When an incident whose duration is 5 minutes occurs in the 1st lane of a two-lane road whose vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different lane widths are used, if lane width increases from 3 m to 3.25 m, average speed decreases by 0,1% and the difference between maximum and minimum speed increases by 11,3%. If lane width increases from 3.25 m to 3.50 m, average speed increases by 9,9% and the difference between maximum and minimum speed decreases by 3,6%. If lane width increases from 3 m to 3.50 m, average speed increases by 9,8% and the difference between maximum and minimum speed increases by 15,3%.

10. When an incident whose duration is 10 minutes occurs in the 1st lane of a three-lane road whose vehicle input is 1500 veh/lane; provided that all other variables are the same, when only different lane widths are used, if lane width increases from 3 m to 3.25 m, average speed increases by 41,5% and the difference between maximum and minimum speed increases by 29,0%. If lane width increases from 3.25 m to 3.50 m, average speed decreases by

2,4% and the difference between maximum and minimum speed increases by 3,1%. If lane width increases from 3 m to 3.50 m, average speed increases by 38,1% and the difference between maximum and minimum speed increases by 33,1%.

Apart from these, according to our statistical tests;

- When overall simulation periods are analyzed, statistically different results are seen only in incident duration, vehicle input, and lane width changes.
- When discharge processes are analyzed, statistically different results are seen only in incident duration and lane width changes.

This study presents general information about assessment and forecast models for various traffic incident types and Traffic Incident Management. It also developed new traffic simulation models. The created models indicate that there are several factors which influence distinctive traffic incident duration stages. These outcomes are useful and remind traffic administrators to take relating measures. Drivers associated with incidents may be empowered to get through as quickly as time permits with the rules. Incident duration can be reduced in this way. The relation between calculated incident effects and perceived incident effects may be an interesting topic for future research.

For decrease in both general incident durations and secondary accidents, developed incident management methods should be used. Geometric design of the roads must be done appropriately. There may be some differences between theory and practice. Our research includes basic analysis. There is no real data from real life. Moreover, all of the simulations had been done with only 1 repetition because of the simulation software's error during using different random seed. That's why real data should be collected and repetition number should be increased. Different random seed should be used to gain more accurate results for future researches.

To compare the numerical results of the experimental setup table in this thesis, it is necessary to find studies of the same type. However, all studies carried out by other researchers to date contain parameters of their own. Therefore, although the findings of the mentioned literature are not exactly the same as the results of this thesis, the travel time values in the study of Liu et al. and the average speed values in the study of Dia et al. are similar to the results of the thesis [49], [57].

Only traffic flow speed information can be collected using the Traffic Density Map. It is also a very labor-intensive process to collect speed data from all segments per minute on this map. The speed changes obtained with the data collected in this way are showed in Figure (3.4), Figure (3.5), and Figure (3.6). On the other hand, in order to interpret the traffic flow, the number of vehicles passing along and density values as well as the speed data are needed. Basic traffic flow data is collected by the Istanbul Metropolitan Municipality on RTMS and other traffic sensing devices placed on the ring roads of Istanbul in minutes and in lanes for both sides of the road.

For further studies, traffic data (speed, volume, occupation) covering 1 week before and 1 week after the incident day of 5 segments in both directions (before and after) in the downstream and upstream direction of the segment where an incident occurs can be requested. Moreover, if there is participation and separation in the segment where the incident occurs, traffic data for at least 3 segments in these participations and separations are also needed. In addition to the specified data, it may be possible to model the duration of the incident and the effect of different road geometric features on the traffic flow, if data can be obtained from the video images related to the number and length of the lanes temporarily closed due to traffic incidents and the durations when the lanes remain closed. In this way, after calibrating the model according to the real incident data, the difference between simulation and real situation can be clearly revealed.

References

[1] N. Owens, A. Armstrong, P. Sullivan, C. Mitchell, D. Newton, R. Brewster, and T. Trego, "Traffic incident management handbook," Tech. Rep., 2010.

[2] "World health organization - global status report on road safety 2018: Summary," https://apps.who.int/iris/bitstream/handle/10665/277370/WHO-NMH-NVI-18.20-eng.pdf?ua=1, 2018, accessed: 2020-05-25.

[3] "Turkish statistical institute - highway traffic incident statistics 2018," http://www.tuik.gov.tr/PreHaberBultenleri.do;jsessionid=dhpSp4QLvGpwJv210BQycGxL85mr272hfvrhWP1yRbhZwkqfdQlc!1102587391?id=30640, 2018, in Turkish, accessed: 2020-05-25.

[4] R. Jiang, M. Qu, E. Chung *et al.*, "Traffic incident clearance time and arrival time prediction based on hazard models," *Mathematical Problems in Engineering*, vol. 2014, 2014.

[5] C. Wright, R. ORENSTEIN, and P. ORENSTEIN, "Simple models for traffic jams and congestion control." in *Proceedings of the Institution of Civil Engineers-Transport*, vol. 135, no. 3. Thomas Telford-ICE Virtual Library, 1999, pp. 123–130.

[6] P. Roberg-Orenstein, C. Abbess, and C. Wright, "Traffic jam simulation," *Journal of Maps*, vol. 3, no. 1, pp. 107–121, 2007.

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

[8] C. Ding and C. Gou, "Simulation of the effective highway capacity under unexpected traffic incident," in *Information Technology and Intelligent Transportation Systems*. Springer, 2017, pp. 443–452.

[9] P. Farradyne, "Traffic incident management handbook," *Prepared for Federal Highway Administration, Office of Travel Management*, 2000.

[10] H. C. Manual, "Hcm2010," *Transportation Research Board, National Research Council, Washington, DC*, p. 1207, 2010.

[11] K. N. Balke, D. W. Fenno, and B. Ullman, "Incident management performance measures," *prepared for FHWA by Texas Transportation Institute*, 2002.

[12] J. Alexander, P. Barham, and I. Black, "Factors influencing the probability of an incident at a junction: results from an interactive driving simulator," *Accident Analysis & Prevention*, vol. 34, no. 6, pp. 779–792, 2002.

[13] D. Shefer and P. Rietveld, "Congestion and safety on highways: towards an analytical model," *Urban Studies*, vol. 34, no. 4, pp. 679–692, 1997.

[14] J. Peirson, I. Skinner, and R. Vickerman, "The microeconomic analysis of the external costs of road accidents," *Economica*, vol. 65, no. 259, pp. 429–440, 1998.

[15] R. B. Noland and M. A. Quddus, "Congestion and safety: A spatial analysis of london," *Transportation Research Part A: Policy and Practice*, vol. 39, no. 7-9, pp. 737–754, 2005.

[16] C. Systematics, "Incident management: Challenges, strategies, and solutions for advancing safety and roadway efficiency," *Report prepared for the ATA Foundation for National Incident Management Coalition*, 1997.

[17] A. A. Shah and L. J. Dal, "Intelligent transportation systems in transitional and developing countries," *IEEE Aerospace and Electronic Systems Magazine*, vol. 22, no. 8, pp. 27–33, 2007.

[18] M. A. Regan, J. A. Oxley, S. T. Godley, and C. Tingvall, *Intelligent transport systems: safety and human factors issues*, 2001, no. 01/01.

[19] M. C. Turan, "Intelligent transportation systems and simulation of adaptive cruise control system within vehicular networks," M.S. Thesis, Graduate School of Science, Istanbul Technical University, Istanbul, 2011, in Turkish.

[20] P. Noyes, "Its eprimer module 1: Introduction to its," USDOT RITA ITS Professional Capacity Building Program: http://www.pcb.its.dot.gov/eprimer/documents/module1.pdf, 2013, accessed: 2020-05-25.

[21] T. Yokota and R. Weiland, "Its technical note for developing countries," *World Bank. Washington, DC. 2004.*, 2004.

[22] "Republic of turkey-ministry of interior," https://www.icisleri.gov.tr/hayat-kurtaran-uluslararasi-yol-guvenlik-sistemi-turkiye-de-22-01-2013, in Turkish, accessed: 2020-05-25.

[23] "Transportation management center," https://uym.ibb.gov.tr/hizmetler/trafik-bilgilendirme, in Turkish, accessed: 2020-05-25.

[24] H. Geçer, S. Bitim, E. Coskun, and M. Ayancı, "An interactive and web based decision support system proposal for the analysis of traffic accidents," in *Highway Traffic Safety Symposium and Congress*, vol. 4, Ankara, 2013, in Turkish.

[25] D. Ha, "Road safety data availability in asia," in *4th IRTAD Conference*, 2009, pp. 24–32.

[26] K. Özkan and S. Işıldar, "Database management in traffic safety," *3rd Transportation and Traffic Congress*, pp. 183–188, 2001.

[27] "Transportation management center," https://uym.ibb.gov.tr/, in Turkish, accessed: 2020-05-25.

[28] D. Stones, "Best practice in european traffic incident management," Tech. Rep., 2011.

[29] "Uk government-emergency preparation, response and recovery," https://www.gov.uk/government/emergency-preparation-reponse-and-recovery, accessed: 2020-05-25.

[30] P. Jodoin, K. Vasconez, and B. Zimmer, "Best practices in traffic incident management," United States. Federal Highway Administration. Office of Transportation Operations, Tech. Rep., 2010.

[31] "Highway traffic law," https://www.mevzuat.gov.tr/MevzuatMetin/1.5.2918.pdf, in Turkish, accessed: 2020-05-25.

[32] "General directorate of highways-road network information," https://www.kgm.gov.tr/Sayfalar/KGM/SiteTr/Kurumsal/YolAgi.aspx, in Turkish, accessed: 2020-05-25.

[33] "Guideline on measures to be taken in traffic inspections and traffic accidents," http://www.trafik.gov.tr/kurumlar/trafik.gov.tr/03-Mevzuat/Trf_Kaza_Yonerge.pdf, in Turkish, accessed: 2020-05-25.

[34] "112 emergency call center," http://112.gov.tr/, in Turkish, accessed: 2020-05-25.

[35] "112 emergency call centers establishment, duty and work regulation," https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=19670&MevzuatTur=7&MevzuatTertip=5#, in Turkish, accessed: 2020-05-25.

[36] "European emergency number association," https://eena.org/, accessed: 2020-05-25.

[37] "Municipal fire department regulations," https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=10713&MevzuatTur=7&MevzuatTertip=5, in Turkish, accessed: 2020-05-25.

[38] "Tur assist-car towing and recovery standards," http://yolyardimturkiye.com/cekici/araba-cekici/, in Turkish, accessed: 2020-05-25.

[39] “Regulation on the use of rescue vehicles of general directorate of security affairs,” https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=9200&MevzuatTur=7&MevzuatTertip=5, in Turkish, accessed: 2020-05-25.

[40] “Road traffic regulations,” https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=8182&MevzuatTur=7&MevzuatTertip=5, in Turkish, accessed: 2020-05-25.

[41] “Tow truck and crane service of istanbul metropolitan municipality,” https://uym.ibb.gov.tr/kurumsal/haberler-ve-duyurular/istanbul-buyuksehir-belediyesinin-cekici-ve-vinc-hizmeti, in Turkish, accessed: 2020-05-25.

[42] J.-B. Sheu, Y.-H. Chou, and L.-J. Shen, “A stochastic estimation approach to real-time prediction of incident effects on freeway traffic congestion,” *Transportation Research Part B: Methodological*, vol. 35, no. 6, pp. 575–592, 2001.

[43] P. Bhavsar, M. Chowdhury, A. Sadek, W. Sarasua, and J. Ogle, “Decision support system for predicting traffic diversion impact across transportation networks using support vector regression,” *Transportation research record*, vol. 2024, no. 1, pp. 100–106, 2007.

[44] M. Baykal-Gürsoy, W. Xiao, and K. Ozbay, “Modeling traffic flow interrupted by incidents,” *European Journal of Operational Research*, vol. 195, no. 1, pp. 127–138, 2009.

[45] S. Y. Rompis, F. G. Habtemichael, and M. Cetin, “A methodology for calibrating microscopic simulation for modeling traffic flow under incidents,” in *17th International IEEE Conference on Intelligent Transportation Systems (ITSC).* IEEE, 2014, pp. 3161–3166.

[46] C.-S. Chou and E. Miller-Hooks, “Exploiting the capacity of managed lanes in diverting traffic around an incident,” *Transportation research record*, vol. 2229, no. 1, pp. 75–84, 2011.

[47] M. R. b. Kabit, P. Charles, L. Ferreira, and I. Kim, "Modelling major traffic incident impacts and estimation of their associated costs," *Transportation planning and technology*, vol. 37, no. 4, pp. 373–390, 2014.

[48] N. Raju, S. Arkatkar, and G. Joshi, "Methodological framework for modeling following behavior of vehicles under indian traffic scenario," in *Innovative research in transportation infrastructure.* Springer, 2019, pp. 1–11.

[49] X. Liu, G. Zhang, C. Kwan, Y. Wang, and B. K. Kemper, "Simulation-based, scenario-driven integrated corridor management strategy analysis," *Transportation research record*, vol. 2396, no. 1, pp. 38–44, 2013.

[50] G. L. Hamza-Lup, K. A. Hua, R. Peng, and A. H. Ho, "A maximum-flow approach to dynamic handling of multiple incidents in traffic evacuation management," in *Proceedings. 2005 IEEE Intelligent Transportation Systems, 2005.* IEEE, 2005, pp. 1147–1152.

[51] M. Hadi, P. Sinha, and A. Wang, "Modeling reductions in freeway capacity due to incidents in microscopic simulation models," *Transportation research record*, vol. 1999, no. 1, pp. 62–68, 2007.

[52] B. R. Chilukuri, J. Perrin Jr, and P. T. Martin, "Scoot and incidents: Performance evaluation in simulated environment," *Transportation research record*, vol. 1867, no. 1, pp. 224–232, 2004.

[53] S. D. Schrock and T. Maze, "Evaluation of rural interstate work zone traffic management plans in iowa using simulation," in *Mid-Continent Transportation Symposium 2000 Proceedings.* Citeseer, 2000.

[54] S. P. Hoogendoorn, B. De Schutter, and H. Schuurman, "Decision support in dynamic traffic management," *European Journal of Transport and Infrastructure Research*, vol. 3, no. 1, 2003.

[55] A. Dabiri and B. Kulcsár, "Freeway traffic incident reconstruction–a bi-parameter approach," *Transportation Research Part C: Emerging Technologies*, vol. 58, pp. 585–597, 2015.

[56] R. Fries, M. Chowdhury, and Y. Ma, "Accelerated incident detection and verification: A benefit to cost analysis of traffic cameras," *Journal of Intelligent Transportation Systems*, vol. 11, no. 4, pp. 191–203, 2007.

[57] H. Dia and N. Cottman, "Evaluation of arterial incident management impacts using traffic simulation," in *IEE Proceedings-Intelligent Transport Systems*, vol. 153, no. 3. IET, 2006, pp. 242–252.

[58] R. Fries, I. Inamdar, M. Chowdhury, K. Taaffe, and K. Ozbay, "Feasibility of traffic simulation for decision support in real-time regional traffic management," *Transportation research record*, vol. 2035, no. 1, pp. 169–176, 2007.

[59] B. Huang and X. Pan, "Gis coupled with traffic simulation and optimization for incident response," *Computers, environment and urban systems*, vol. 31, no. 2, pp. 116–132, 2007.

[60] L. L. Tupper, M. A. Chowdhury, L. Klotz, and R. N. Fries, "Measuring sustainability: How traffic incident management through intelligent transportation systems has greater energy and environmental benefits than common construction-phase strategies for "green" roadways," *International journal of sustainable transportation*, vol. 6, no. 5, pp. 282–297, 2012.

[61] K. Fehon and T. Klim, "Modeling active traffic management with paramics," *IEEE Intelligent Transportation Systems Magazine*, vol. 2, no. 3, pp. 14–18, 2010.

[62] M. Fellendorf and P. Vortisch, "Microscopic traffic flow simulator vissim," in *Fundamentals of traffic simulation.* Springer, 2010, pp. 63–93.

[63] P. T. V. AG, *Vissim User Manual 10*, Karlsruhe, Germany, 2018.

[64] "One-way anova," https://statistics.laerd.com/statistical-guides/one-way-anova-statistical-guide.php, accessed: 2020-05-25.

[65] "Tukey-kramer test," https://www.real-statistics.com/one-way-analysis-of-variance-anova/unplanned-comparisons/tukey-kramer-test/, accessed: 2020-05-25.

Chapter 6

Appendix

SUMMARY (I.D.1)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 18	120	10987,51	91,56	468,11
EXP 63	120	10278,22	85,65	749,28
EXP 108	120	9691,30	80,76	843,24

ANOVA (I.D.1)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7021,47	2	3510,73	5,1112	0,0065	3,0210
Within Groups	245214,19	357	686,87			
Total	252235,66	359				

SUMMARY (I.D.2)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 39	120	9488,24	79,07	383,53
EXP 84	120	9104,83	75,87	550,34

EXP 129	120	8728,37	72,74	672,57

ANOVA (I.D.2)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2405,91	2	1202,96	2,2465	0,1073	3,0210
Within Groups	191166,57	357	535,48			
Total	193572,48	359				

SUMMARY (V.I.1)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 48	120	10735,83	89,47	1022,44
EXP 63	120	10278,22	85,65	749,28
EXP 78	120	9052,58	75,44	723,48

ANOVA (V.I.1)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12624,81	2	6312,40	7,5894	0,0006	3,0210
Within Groups	296929,22	357	831,73			
Total	309554,02	359				

SUMMARY (V.I.2)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 99	120	10662,6	88,86	1193,54
EXP 114	120	9622,01	80,18	986,44
EXP 129	120	8728,37	72,74	672,57

ANOVA (V.I.2)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	15619,01	2	7809,51	8,2132	0,0003	3,0210
Within Groups	339453,89	357	950,85			
Total	355072,90	359				

SUMMARY (N.L.1)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 18	120	10987,5	91,56	468,11
EXP 24	120	11151,9	92,93	563,04

ANOVA (N.L.1)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	112,57	1	112,57	0,2183	0,6407	3,8808
Within Groups	122706,87	238	515,58			
Total	122819,44	239				

SUMMARY (N.L.2)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 108	120	9691,3	80,76	843,24
EXP 114	120	9622,01	80,18	986,44

ANOVA (N.L.2)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20,00	1	20,00	0,0219	0,8826	3,8808
Within Groups	217731,95	238	914,84			
Total	217751,96	239				

SUMMARY (I.P.1)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 18	120	10987,5	91,56	468,11
EXP 21	120	10743	89,53	653,82

ANOVA (I.P.1)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	249,04	1	249,04	0,4440	0,5059	3,8808
Within Groups	133509,51	238	560,96			
Total	133758,55	239				

SUMMARY (I.P.2)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 114	120	9622,01	80,18	986,44
EXP 117	120	9019,19	75,16	824,66
EXP 120	120	9377,38	78,14	1248,69

ANOVA (I.P.2)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1532,04	2	766,02	0,7511	0,4726	3,0210
Within Groups	364114,17	357	1019,93			
Total	365646,21	359				

SUMMARY (L.W.1)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 1	120	11260,1	93,83	530,10
EXP 2	120	11294,3	94,12	655,64
EXP 3	120	11599,2	96,66	602,69

ANOVA (L.W.1)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	580,64	2	290,32	0,4870	0,6149	3,0210
Within Groups	212822,72	357	596,14			

Total	213403,36	359

SUMMARY (L.W.2)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 67	120	8806,08	73,38	806,20
EXP 68	120	10315,8	85,97	707,73
EXP 69	120	10435,2	86,96	803,60

ANOVA (L.W.2)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13743,79	2	6871,90	8,8956	0,0002	3,0210
Within Groups	275785,15	357	772,51			
Total	289528,95	359				

Table 6.20: Anova Single Factor Test Results of All Scenario Groups for Overall Simulation.

SUMMARY (I.D.1)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 18	54	4379,23	81,10	792,02
EXP 63	54	3669,94	67,96	1046,52
EXP 108	54	3083,02	57,09	799,50

ANOVA (I.D.1)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	15603,26	2	7801,63	8,8721	0,0002	3,0529
Within Groups	139815,74	159	879,34			
Total	155419,00	161				

SUMMARY (I.D.2)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 39	52	3660,32	70,39	636,31
EXP 84	52	3131,1	60,21	729,70
EXP 129	52	2645,99	50,88	600,94

ANOVA (I.D.2)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9899,17	2	4949,59	7,5491	0,0007	3,0552
Within Groups	100314,53	153	655,65			

Total	110213,70	155

SUMMARY (V.I.1)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 48	33	1666,08	50,49	1495,98
EXP 63	33	1582,12	47,94	646,12
EXP 78	33	1386,47	42,01	889,55

ANOVA (V.I.1)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1247,58	2	623,79	0,6173	0,5415	3,0912
Within Groups	97012,47	96	1010,55			
Total	98260,05	98				

SUMMARY (V.I.2)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 99	44	2384,26	54,19	1301,16
EXP 114	44	1905,63	43,31	427,55
EXP 129	44	1971,78	44,81	441,99

ANOVA (V.I.2)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*

Between Groups	3057,59	2	1528,80	2,1129	0,1251	3,0664
Within Groups	93340,37	129	723,57			
Total	96397,96	131				

SUMMARY (N.L.1)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 18	32	2222,72	69,46	980,40
EXP 24	32	2197,86	68,68	1174,45

ANOVA (N.L.1)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9,66	1	9,66	0,0090	0,9249	3,9959
Within Groups	66800,28	62	1077,42			
Total	66809,94	63				

SUMMARY (N.L.2)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 108	51	2783,17	54,57	729,30
EXP 114	51	2605,16	51,08	760,50

ANOVA (N.L.2)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	310,66	1	310,66	0,4171	0,5199	3,9361
Within Groups	74489,86	100	744,90			
Total	74800,52	101				

SUMMARY (I.P.1)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 18	27	1721,93	63,78	950,91
EXP 21	27	1477,45	54,72	1212,35

ANOVA (I.P.1)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1106,86	1	1106,86	1,0233	0,3164	4,0266
Within Groups	56244,84	52	1081,63			
Total	57351,70	53				

SUMMARY (I.P.2)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 114	54	2903,41	53,77	843,67
EXP 117	54	2878,52	53,31	756,56
EXP 120	54	2560,04	47,41	993,75

ANOVA (I.P.2)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1357,73	2	678,86	0,7851	0,4578	3,0529
Within Groups	137480,81	159	864,66			
Total	138838,54	161				

SUMMARY (L.W.1)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 1	25	1562,76	62,51	1132,23
EXP 2	25	1561,63	62,47	1715,10
EXP 3	25	1716,38	68,66	1751,47

ANOVA (L.W.1)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	633,97	2	316,99	0,2068	0,8137	3,1239
Within Groups	110371,36	72	1532,94			
Total	111005,33	74				

SUMMARY (L.W.2)

Groups	*Count*	*Sum*	*Average*	*Variance*
EXP 67	38	1509,00	39,71	680,47
EXP 68	38	2134,96	56,18	786,35
EXP 69	38	2084,66	54,86	913,12

ANOVA (L.W.2)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6366,14	2	3183,07	4,0124	0,0208	3,0781
Within Groups	88057,85	111	793,31			
Total	94423,99	113				

Table 6.40: Anova Single Factor Test Results of All Scenario Groups for Discharge Process.

Group No.	Tukey - Kramer Post Hoc Test Result							
Inc. Dur. 1	Between	Difference	n1	n2	SE	q	critical value	result
	EXP 18 - EXP 63	5,91	120	120	2,39	2,471	3,335	no difference
	EXP 63 - EXP 108	4,89	120	120	2,39	2,044	3,335	no difference
	EXP 18 - EXP 108	10,80	120	120	2,39	4,515	3,335	difference
Veh. Inp. 1	EXP 48 - EXP 63	3,81	120	120	2,63	1,448	3,335	no difference
	EXP 63 - EXP 78	10,21	120	120	2,63	3,880	3,335	difference
	EXP 48 - EXP 78	14,03	120	120	2,63	5,328	3,335	difference
Veh. Inp. 2	EXP 99 - EXP 114	8,67	120	120	2,81	3,081	3,335	no difference
	EXP 114 - EXP 129	7,45	120	120	2,81	2,646	3,335	no difference
	EXP 99 - EXP 129	16,12	120	120	2,81	5,726	3,335	difference
Lane. Wth. 2	EXP 67 - EXP 68	12,58	120	120	2,54	4,959	3,335	difference
	EXP 68 - EXP 69	1,00	120	120	2,54	0,392	3,335	no difference
	EXP 67 - EXP 69	13,58	120	120	2,54	5,351	3,335	difference

Table 6.41: Tukey - Kramer Post Hoc Test Results of All Scenario Groups for Overall Simulation.

Group No.	Tukey - Kramer Post Hoc Test Result							
	Between	Difference	n1	n2	SE	q	critical value	result
Inc. Dur. 1	EXP 18 - EXP 63	13,14	54	54	4,04	3,255	3,356	no difference
	EXP 63 - EXP 108	10,87	54	54	4,04	2,693	3,356	no difference
	EXP 18 - EXP 108	24,00	54	54	4,04	5,948	3,356	difference
Inc. Dur. 2	EXP 39 - EXP 84	10,18	52	52	3,55	2,866	3,356	no difference
	EXP 84 - EXP 129	9,33	52	52	3,55	2,627	3,356	no difference
	EXP 39 - EXP 129	19,51	52	52	3,55	5,493	3,356	difference
Lane. Wth. 2	EXP 67 - EXP 68	16,47	38	38	4,57	3,605	3,377	difference
	EXP 68 - EXP 69	1,32	38	38	4,57	0,290	3,377	no difference
	EXP 67 - EXP 69	15,15	38	38	4,57	3,316	3,377	no difference

Table 6.42: Tukey - Kramer Post Hoc Test Results of All Scenario Groups for Discharge Process.

Grp. No	Exp. No	Avg. QLEN (m)	Total VEHS (veh)	Total TRAV TM (sec)	Avg. SPEED. Simulation (km/h)	Avg. SPEED. Incident (km/h)	Speed Difference - Incident (km/h)
Inc. Dur. 1	18	21,7	3047	4182,0	91,6	81,1	98,2
	63	60,0	3047	6203,8	85,7	68,0	99,2
	108	99,0	3047	8704,0	80,8	57,1	95,4
Inc. Dur. 2	39	28,8	5639	5947,9	79,1	70,4	90,9
	84	66,4	5534	7360,3	75,9	60,2	90,9
	129	102,7	5278	8889,3	72,7	50,9	90,9
Veh. Inp. 1	48	21,2	2031	4362,3	89,5	50,5	111,5
	63	60,0	3047	6203,8	85,7	47,9	96,4
	78	77,2	3834	9948,7	75,4	42,0	97,3
Veh. Inp. 2	99	17,6	3049	3863,2	88,9	54,2	103,0
	114	87,8	4500	7116,4	80,2	43,3	95,8
	129	102,7	5278	8889,3	72,7	44,8	78,4
N. Lane 1	18	21,7	3047	4182,0	91,6	69,5	94,4
	24	10,4	4500	3734,3	92,9	68,7	104,0
N. Lane 2	108	99,0	3047	8704,0	80,8	54,6	95,4
	114	87,8	4500	7116,4	80,2	51,1	104,2
Inc. Pos. 1	18	21,7	3047	4182,0	91,6	63,8	94,4
	21	31,6	3047	4556,1	89,5	54,7	94,8
Inc. Pos. 2	114	87,8	4500	7116,4	80,2	53,8	104,2
	117	118,2	4463	15141,8	75,2	53,3	85,2
	120	104,4	4456	8233,5	78,1	47,4	104,8
Lane Wth. 1	1	36,4	2026	5953,4	93,8	62,5	98,5
	2	14,9	2031	4183,1	94,1	62,5	109,7
	3	7,7	2031	3677,3	96,7	68,7	113,6
Lane Wth. 2	67	69,2	4341	8338,7	73,4	39,7	80,4
	68	56,8	4500	5260,2	86,0	56,2	103,7
	69	49,5	4500	5198,5	87,0	54,9	107,0

Table 6.43: Simulation Results of All Scenario Groups.

Scenario Group	**Average QLEN (m)**	**Total VEHS (veh)**	**Total TRAVTM (sec)**	**Average SPEED. S. (km/h)**	**Average SPEED. I. (km/h)**
Inc. Dur. 1	+	0	+	- -	- -
Inc. Dur. 2	+	-	+	-	- -
Veh. Inp. 1	+	+	+	- -	-
Veh. Inp. 2	+	+	+	- -	-
N. of Lane 1	-	+	-	+	-
N. of Lane 2	-	+	-	-	-
Inc. Pos. 1	+	0	+	-	-
Inc. Pos. 2	+	-	+	-	-
Lane Wth. 1	-	+	-	+	+
Lane Wth. 2	-	+	-	+ +	+ +

Table 6.44: Effects of All Scenario Groups on Performance Evaluation Criteria (+: directly proportional, + +: directly proportional and statistically different, -: inversely proportional, - -: inversely proportional and statistically different, 0: ineffective).