UNIVERSITY OF CINCINNATI

AUGUST 12, 2003

I, ABHRO MITRA,

hereby submit this as part of the requirements for the degree of:

MASTER OF COMMUNITY PLANNING

in THE COLLEGE OF DESIGN, ARCHITECTURE, ART AND PLANNING

It is entitled

SIMULATION APPROACH FOR EVALUATION OF AN ITS DEVICE ON FREEWAY WORK ZONES USING VISSIM

Approved by:

Prahlad D. Pant

SIMULATION APPROACH FOR EVALUATION OF AN ITS DEVICE ON FREEWAY WORK ZONES USING VISSIM

A thesis submitted to the

Division of Research and Advanced Studies

of the University of Cincinnati

in partial fulfillment of the

requirements for the degree of

MASTER OF COMMUNITY PLANNING

in the School of Planning

of the College of Design, Architecture, Art, and Planning

2003

by

Abhro Mitra

B. Planning, School of Planning and Architecture

New Delhi, India

2000

Committee Chair: Jay Chatterjee, Professor

Faculty Member: Dr. Prahlad Pant, Emeriti Faculty

Reader: Dr. Cheng-I. Tsai, Assistant Professor

ABSTRACT

The interstate highways all over the county are under constant repair and maintenance; hence work zones on the interstates are becoming a regular feature now. Severe traffic congestions on the work zones and delays are very common and to handle this, many new technologies under the name of ATIS (Advance Travel Information System) and ATMS (Advance Traffic Management Systems) that come under the realm of Intelligent Transportation Systems (ITS), are deployed to resolve the conflicts of traffic management on the freeway work zones. Testing the efficacy of an ITS component without deploying on the site can be achieved only by either micro or macro simulating techniques.

Simulation modeling is a cost effective decision support tool, in cases where it is not practical to test a future traffic condition without a practical implementation, like on work zones. A number of simulation tools are available nowadays to model different traffic behaviors and characteristics and many studies have been conducted that involves the use of these various simulation techniques. However, there has been no study that involves the use of VISSIM as a micro-simulation tool to evaluate the effect of speed reduction strategies on a freeway work zone area with VMS signs.

This study aims to simulate the effect of speed on a freeway work zone using this upcoming micro-simulation tool called VISSIM, by static network modeling. First the model was calibrated for a test bed and tested for its accuracy. Later various scenarios have been generated depicting different traffic conditions and the results have been quantified in terms of various MOE's. Finally a multiple regression model has been developed that represents the delay as a function of speed and lane-width for the work zone area.

ACKNOWLEDGEMENT

I would like to take this opportunity to thank all my committee members Prof. J. Chatterjee, Dr. P. D. Pant and Dr. C. I. Tsai whose guidance and advice has helped me to complete my Master's Research. I would especially like to thank Dr. Pant for providing unflinching support, valuable suggestions and assistance without which this work would not have been possible. I am indebted to him for his valuable advice for my academic and professional career, during my stay at the University of Cincinnati.

I would like to extend my gratitude to my loving fiancé Sumee, for her support and encouragement at various stages, and for listening to me patiently. Last, but not the least I would like to thank my mother who has always supported me at every stage of my career.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 Background

The interstate highway system of the country has been designed long back. The service life of the highways is nearing to its end and hence it needs repairs. Because of this highways all over the country are under repair and work zones on the highways are becoming a regular feature now. With an expansion of the highway system there has also been a significant increase in traffic volume and so managing traffic on the work zones is a challenge for the traffic engineers and transportation planners. Severe traffic congestions on the work zones and delays are very common. In order to handle this advance technologies under the name of ATIS (Advance Travel Information System) and ATMS (Advance Traffic Management Systems) are employed to resolve the conflicts of traffic management on the freeway work zones *(1)*. ATMS and ATIS systems have the potential to improve the performance of the transportation system and influence the travel behavior of the commuter. The technologies within these can be grouped within the larger spectrum of transportation planning called Intelligent Transportation System (ITS). ATIS differs from ATMS in the fact that, the former provides prior information to the road user through some specialized traffic control devices like VMS, HAR etc. and the later manages the traffic situation with the use of certain other traffic control devices like cameras, detectors etc. Both the ITS technologies are guided towards resolving the traffic situation on the freeway work zones.

There are various types of traffic control ATIS devices that can be used lay effect on work zones. In order to analyze the effect of various ATIS components simulation models are becoming more and more effective and popular. Simulation techniques are one of the cheapest and effective ways to test the efficacy of a certain ITS component on work zones in the real world scenario. Traffic simulation is of two kind; micro simulation and macro simulation. Macro simulation is the evaluation of the traffic situation as a network but micro simulation is the evaluation of the traffic as single entities. When the effect of traffic on the work zone is considered as a system then macro simulation tools are used and when every mode is seen as a separate entity then micro simulation tools are adopted.

Simulation modeling helps in studying a wide variety of dynamic traffic problems that is otherwise very difficult to comprehend. Simulation is used when the various parameters of a problem cannot be comprehended simultaneously as a single entity and every parameter cannot be analyzed mathematically. Microscopic simulation models can be used in a variety of transportation applications. They can be used to evaluate a new intersection design or a signalized synchronized system etc and lately it is widely used in evaluating new emerging new technologies in intelligent transportation systems (ITS).

Simulation is mainly used nowadays as a decision support tool and in the cases when it is not practical to evaluate a situation on the field, rather perform a dummy run and see the effectiveness. A number of simulation tools are nowadays available to model different situations of traffic behaviors.

1.2 Problem Statement

Delay in a work zone is one of the evident features now. Lots of research is going on in reducing the traffic chaos in the work zone and to smoothen the traffic flow. Deployment of ATIS systems can reduce the delay and traffic conditions can be improved. Studies have been done on evaluation the impact of certain traffic control ATIS devices for resolving the work zone delays using HAR, Rumble strip etc. These have been put on to a network and the system functioning has been tested using various simulation models. Some of the work is explained in the literature review section of this proposal. However, there has not been any study that has used the model VISSIM and the VMS as an ITS component. This research will try to quantify the benefits of installation of VMS and varying the speed along a freeway and quantify in terms of certain MOE's. Micro-simulation technique is to be applied using the VISSIM model. VISSIM is one of the most useful models to simulate VMS, ITS component. The MOE's can be quantified in terms of travel time, delays, queue length, speed-space and time-space diagrams and also on terms of certain environment indicators.

1.3 Objectives of the Study

The objectives of the study are:

- To use VMS as an ITS component that can be applied to reduce the traffic chaos in work zones.
- To simulate the existing scenario using micro-simulation.
- To test the effect of the VMS component on the work zone.
- To generate and test various scenarios on the work zone with the deployment of the ITS systems. The scenarios could be:

- Speed reduction on the work zone area
- Speed reduction with lane closure on the work zone area
- Speed reduction with varying lane width on the work zone area

- To measure the impact in terms of various measures of effectiveness viz
  - Delay
  - Travel time
  - Density etc.
- Perform a sensitivity analysis using statistical tests for quantifying the results.
- To model the traffic behavior before and after the ITS components are installed and to test the significance of varying the speed limit.

2. LITERATURE REVIEW

2.1 Introduction

A lot of research has been done in evaluating the effect of ITS systems on work zone traffic. Peeta , Poonuru and Sinha *(1)* evaluated the impact of five AIS (Advance Information System) techniques viz. Pre-Trip Information, En Route Information, Incident Management Systems, Variable Message Signs (VMS) and Multiple Information Sources (MIS), are used to evaluate the effect on the Borman Expressway in northwest Indiana. In this study, three scenarios the peak period traffic, lane closure and link closure was compared with the base case scenario. A simulation model named DYNASMART (DYnamic Network Assignment Simulation Model for Advanced Road Telematics) was used to evaluate the effect of the AIS on the three scenarios. The study concluded that the VMS was most effective and has the maximum benefits than the other AIS technologies. However a need for a study demonstrating the additive effect of all the technologies was felt.

Rippeon, Miller, Demetsky *(2)* evaluated four detour scenarios on an active incident management site. It was seen that in one of the cases one of the detour alternative caused more delay on the alternative path and the travel time of the commuter was found to be more. CORSIM (Corridor Simulation) a part of the TSIS package was used to evaluate the scenarios. This study highlighted the fact that many diversion scenarios may not handle traffic in the best possible way, and this was possible to model using the simulation package.

Bernhard, Virkler and Shaik *(3)* in their study evaluated the effect of individual traffic control devices. The primary MOE's used were lane distribution, mean speed and speed variance. This study recommended the need for the evaluation of a set of traffic control devices using simulation techniques.

Schrock and Maze *(4)* used simulation using TSIS (Traffic Software Integrated System) to evaluate the effect of delay on work zones. Alternative work zone traffic management plans were evaluated for the scenarios 1) the "do nothing" 2) increase the pace of construction work 3) paving additional lanes and 4) diversion of traffic from the work zone. However ITS tools were not used for measuring the impact of delay on the traffic system. This study however demonstrates the power of simulation to give an estimate of the best possible alternative on a work zone.

In lieu of all these simulation tools that are available, one of the most useful tool in ITS evaluation is VISSIM. The traffic flow model of VISSIM is discrete, stochastic and dynamic. Various studies have been done to identify the behavior of VISSIM and COSIM and to test the applicability of both the models for real world scenarios. In one of the research studies by Brian Moen and PE Joel (7) the benefits of VISSIM model on other models has been demonstrated.

2.2 Use of Various Simulation Models

The simulation models can be classified based on the magnitude of detail that a model can represent. It can be microscopic, macroscopic or mesoscopic. A microscopic model will represent interactions between different elements in a great level of detail. The lane changing and the car following representation is done by microscopic models.

Macroscopic models will represent the interactions of different components in a larger level for example the traffic detail can be represented not in terms of individual vehicles but as a function of density Or level of service of the stream. Mesoscopic models are between the micrsoscopic and the macroscopic level. Models like CORSIM, INTEGRATION and VISSIM are microscopic simulation models. Simulation models can also be classified into stochastic and deterministic based on the type of logic that the model follows. The following discussion will explain about three different simulation models and their merits and demerits in lieu of this paper.

CORSIM

The CORSIM is a microscopic stochastic traffic simulation model. This model is best suited for freeway and non-freeway operations. The model has two models build in it called as FRESIM (for freeway operations) and NETSIM (for arterial network operations). Lot of studies have been done using this model. In a research done by Rippeon, Miller, Demetsky (2) four detour scenarios were evaluated on an active incident management. It was seen that in one of the cases one of the detour alternative caused more delay on the alternative path and the travel time of the commuter was found to be more. CORSIM (Corridor Simulation) a part of the TSIS package was used to evaluate the scenarios. This study highlighted the fact that many diversion scenarios may not handle traffic in the best possible way, and this was possible to model using the simulation package. The effect of individual traffic control devices has been seen on a study by Bernhard, Virkler and Shaik (3) in their study. The primary MOE's used were lane distribution, mean speed and speed variance.

Merits

The main advantage of the model is that it can simulate freeway and non-freeway operations very efficiently. The MOE's can be written as ASCII files and also data can be imported as ASCII files into the model.

Demerits

Although it is one of the most recommended models for freeway operations, however this model is not at all capable of simulation work zones. Also CORSIM lacks the capability of modeling ITS features and neither the program supports compatibility with ITS elements like CMS (changeable message signs), work zone modeling etc.

INTEGRATION

This is one of the most powerful models in terms of modeling ITS features. It also has the capability to handle the varying density of flow of traffic along a network.

Merits

This model first attempted to provide a tool for integration the arterial and freeway modeling. This also had the capability to model ATMS and ATIS features in ITS operations, in addition to this the model is capable to model emission factors also.

Demerits

Inspite of all the best available features, considering the scope of this research this model could not be used for modeling the freeway work zone that is under consideration for this study. One of the inputs to the model is a detailed O-D data for the area, and this was not available to be used.

2.3 Conclusion

There are many simulation models that can be used to evaluate a micro-simulation scenario. But for the purpose of this study VISSIM will be used because it can evaluate ITS components like VMS (through the introduction of reduced speed scenario), very effectively.

A detailed description of the VISSIM model will be presented in the subsequent chapters in this project report. One of the chapter of this report will deal specifically with the operation and the process of simulation using VISSIM.

3. METHODOLOGY

The study will use VMS as an ATIS component and evaluate the transportation benefits obtained by installing this on a freeway work zone will be tested. A micro-simulation model VISSIM will be used to evaluate the impact of the ITS components. The methodology is divided into five stages, which are explained as follows:

Stage1. In this stage of the study, extensive literature review will be done on the proposed topic. This will be followed by a problem statement based on the literature review, concerning the traffic problems on the work zones. This is followed by a set of objectives that needs to be fulfilled for the study. Also in this stage based on the study area requirements for the ITS components will be identified that will be further evaluated in the later stages of the study.

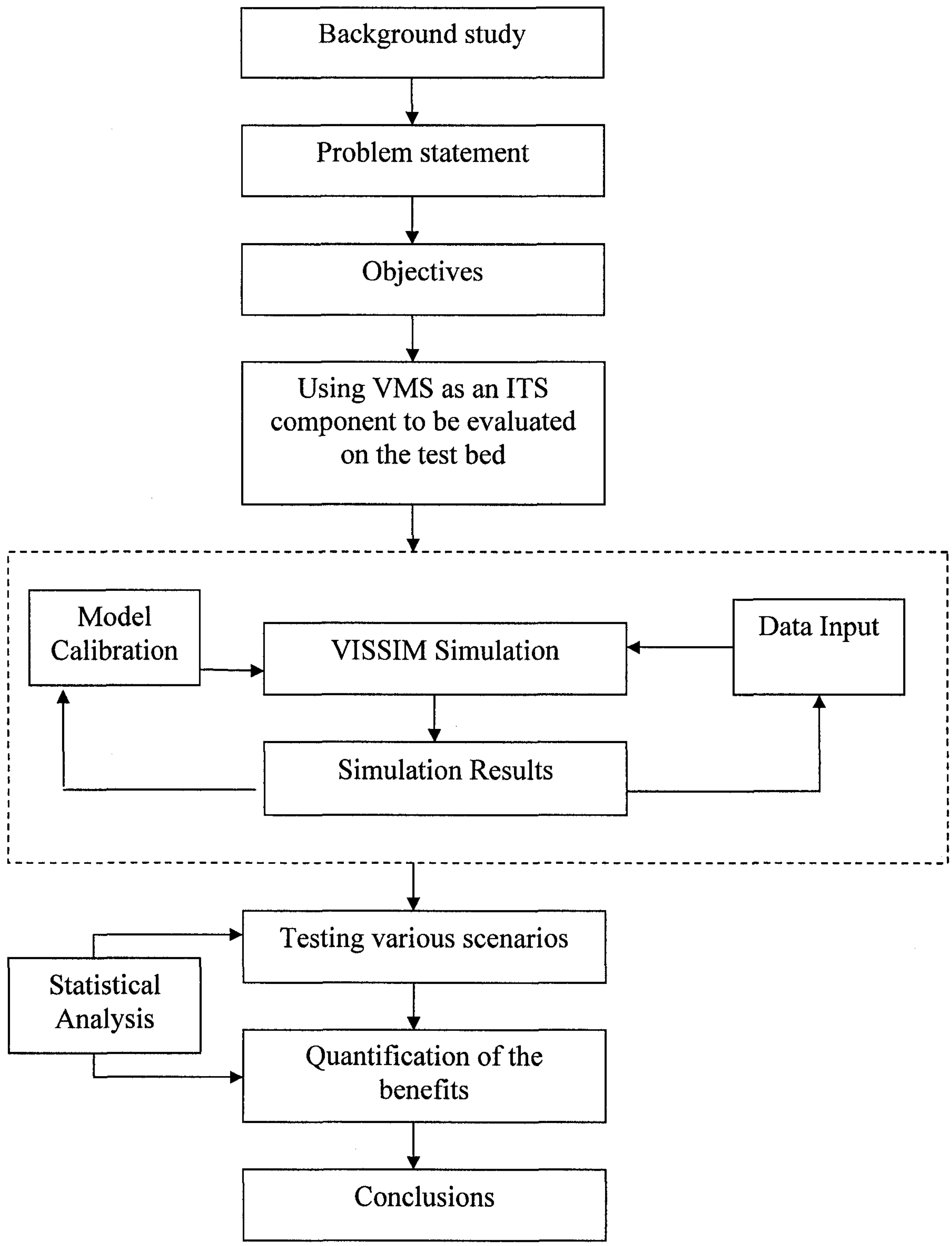
Stage2. In this stage, the simulation model that is proposed to be used will be prepared for calibration and validation. For this the data that is required will also be identified based on the objectives of the study and also on the types of MOE's that are desired form the model. This is a very crucial and time consuming stage of the study and will comprise a significant part of the research. A detailed methodology for this stage is explained in the subsequent passage. In this stage the simulation results will be tested with the existing site conditions and hence the validation of the model will be completed.

Stage3. In this stage various scenarios for the work zone will be considered that will be tested with the calibrated model. The various MOE's that were desired will be obtained for these scenarios and will be compared with the existing situation. The model calibration and validation in the previous stage forms a crucial part for this stage, because the results that are obtained for the scenarios will be dependent on this previous stage and the accuracy of the results will also be guided by the fact that the model is calibrated accurately.

Stage4. In this stage the various MOE's will be tabulated for the various scenarios and a statistical sensitivity analysis will be done to test the efficacy of the model and to test the system performance.

Stage5. In this stage the final conclusion of the study are jotted down along with some future recommendation if required.

Methodology



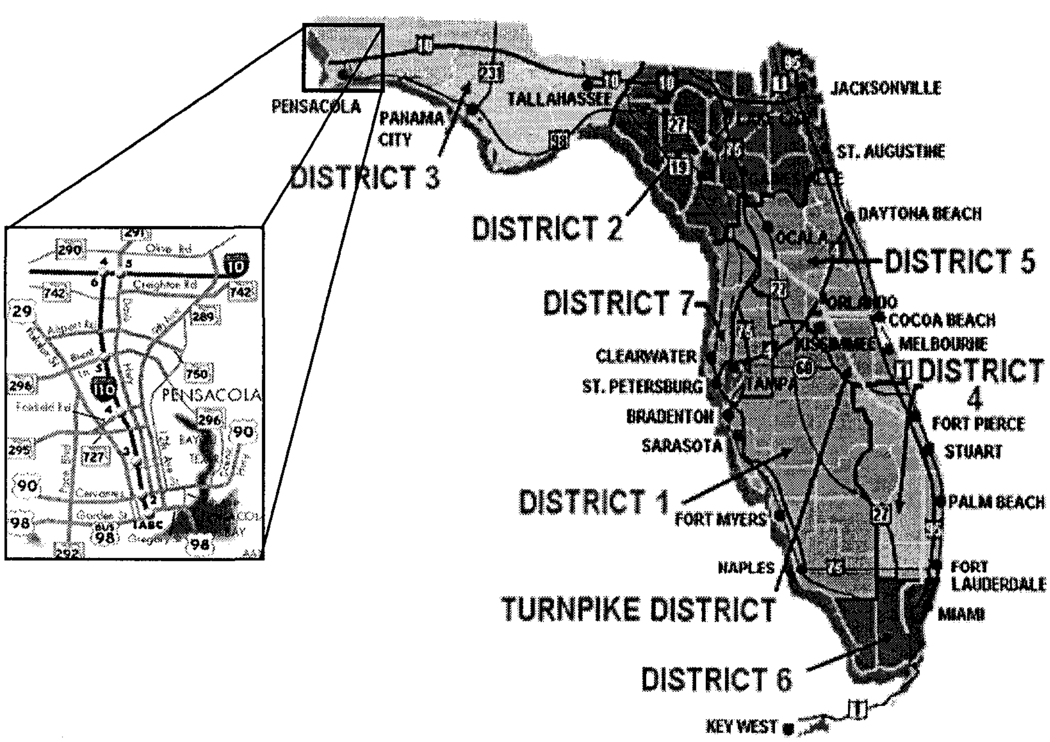
4. TEST BED

4.1 Introduction.

The site is a section of the I-10 interstate in Escambia-county in the north-western part of Florida region. The core work is going on the interchange of I-110 and I-10 section. The I-10 is being resurfaced and also being converted into a six lane highway along this section. There is a proposal of adding two ramps from the I-110 so as to east the traffic on the interstate.

The interstate is largely rural in character but as it enters the Escambia county and approaches the exits 5 and 7, it changes into a urban freeway. At the exits 10 and 13 there is a huge traffic backup and the condition worsens. After it passes the county the

Fig 1: I-10 and I-110 section in northwest Florida



Source: www.flroads.net

character again changes to completely rural again. The adjoining figure shows the section of the I-10 and I-110 in the Escambia county in the northwestern part of the Florida region.

4.2 Traffic and Transportation characteristics of the study area.

In the subsequent passages below, the traffic characteristics of the regions will be highlighted. Very briefly the project characteristics will also be discussed.

4.2.1 Traffic Characteristics.

The table below summarizes the different traffic and parameters for the different sections of the I-10 and I-110 interchange.

Table1. Traffic data for the I-10 / I-110 section.

Road section	**AADT**	**Speed**	**No. of lanes**	**Truck Traffic**
I-110 (south-north)	26220	55	2	4
I-110 (north-south)	19600	55	2	9
I -10 (east-west)	38750	55	2	14
I-10 (west-east)	34750	55	2	20
Ramp(1-10toI-	9100	40	1	13
Ramp(I-110toI-10)	6750	40	1	11

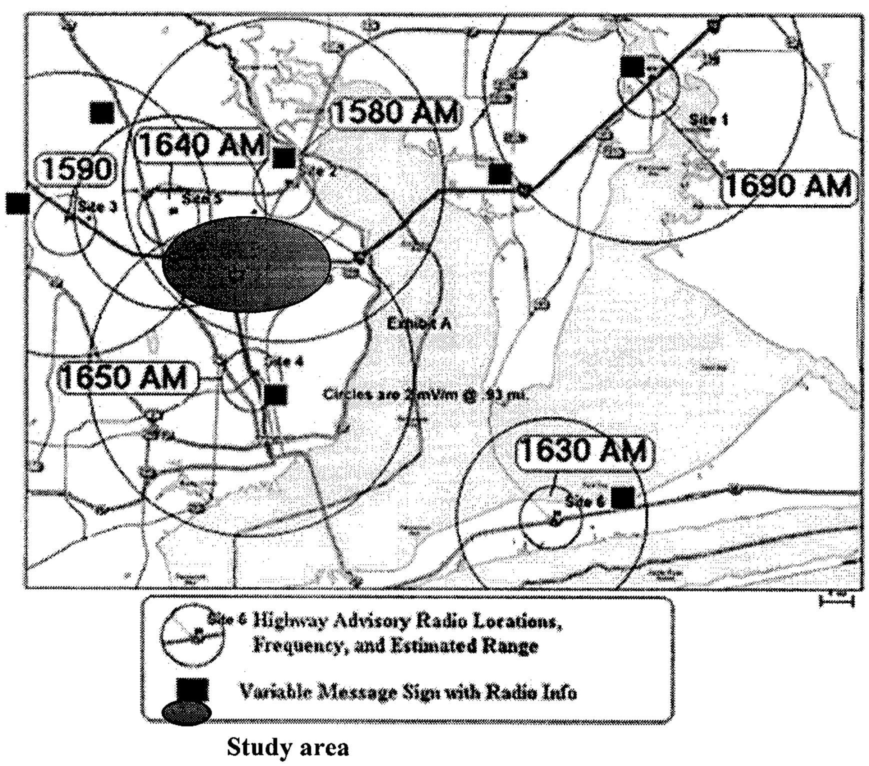
Source: Florida Dept. of Transportation

Currently the traffic from the south on the I-110 is heavy as it approaches the I-10 interchange. There is a heavy percentage of tuck traffic that moves along the I-10 interstate. The speed limit on the I-10 and I-110 interstate is 55miles/hr and the numbers of lanes are 2 all along the interstates, within the study area.

4.2.2 Project characteristics

I-110 interstate is the only major freeway that connects the south of the northwestern Florida to the north part of the Escambia county. Due to the heavy traffic flow and the bust nature of the freeway, it is proposed that the I-110 to be widened to 3 lanes and a section of the I-10. A ramp connecting the I-10 from the west to the south of the I-110 channel zing the westbound traffic to the south of I-110 is also proposed.

Fig.2 Location of HAR and VMS in the study area region.



Source: www.FDOT Escambia County Transportation Improvement Projects.htm

The commuters are given daily update of the traffic by way of five HAR and six VMS along the major routes in the region. The VMS are located at: (1) Southbound Avalon Boulevard approaching I-10; (2) Westbound I-10 near the Blackwater River in Santa Rosa County; (3) Southbound U.S. Highway 29 approaching US 90 Alt (Nine Mile

Road); (4) Eastbound I-10 between Exit 5 (Nine Mile Road) and Exit 7 (Pine Forest Road);(5) Northbound I-110 near the Texar Drive overpass; and, (6) Westbound U.S. Highway 90 near Scenic Highway. The HAR's are located at (1) 1590 AM (Pine Forest Road area); (2) 1640 AM (US 29 and Nine Mile Road area); (3) 1580 AM (Davis Highway and Nine Mile Road area); (4) 1690 AM (Bagdad/Milton area); (5) and, 1650 AM (Interstate 110 area). (Source: www.FDOT Escambia County Transportation Improvement Projects.htm).

4.3 Conclusion

This test bed was selected for this research project because of the availability of data from the Florida Dept. of Transportation web site and also to understand the simulation with VISSIM with a live project. The project web site is updated daily and can be referred to for updated till the project is completed.

5. THE VISSIM MODEL

5.1 Introduction.

The simulation model used in this study is VISSIM, version 3.70. Unlike many other modes that are used extensively in United States, this model VISSIM is relatively new. This model is a time step and behavior based simulation model developed to model urban traffic and transit operations, under various situations like, lane configurations, traffic composition, work zone lane closures and display of VMS, traffic signals etc. *(10)*. This model is developed on the principles of car following and gap acceptance theory suggested by Widemann and works on the psychophysical behavior of the driver. The basic concept is that as the driver sees the vehicle ahead of him moving faster he slows down till the vehicle ahead of him again starts accelerating. So this vehicle moves with an iterative process of acceleration and deceleration *(11)*.

5.2 Characteristics of VISSIM.

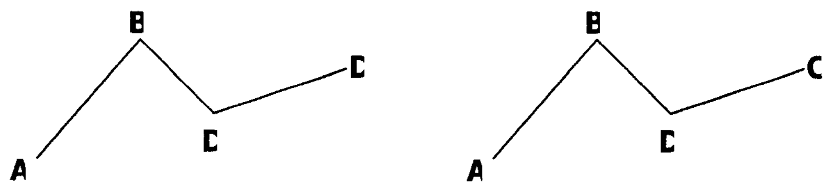
Some of the characteristics of the model in comparison to other extensively used model like CORSIM are:

1. This is not a link-node based model unlike the CORSIM.

2. The inputs into the model are in the form of:- geometric components, arial photographs, traffic demand, traffic data, control data etc.

3. This model functions on the car following logic.

4. This generates the travel time both link by link and as well as the total path based travel time, unlike the CORSIM that can only give a route travel time.



CORSIM $_{tt\,(A\ to\ d)}$ **=** AD_{tt} **VISSIM** $_{tt\,(A\ to\ d)}$ **=** $AB_{tt} + BC_{tt} + CD_{tt}$

Conceptual depiction of travel time analysis by both the models.

5. Mode separated data can be depicted in the VISSIM model, ie specific output only on buses, or trucks or both can be obtained.

6. This model can well model the impacts of ITS components live CMS, Ramp metering, VMS, interchange design etc. unlike many other models.

VISSIM can be applied as a useful tool for various functions. It can be used to both model dynamic and static route guidance. Some of the specific application of the model are (10):

1. VISSIM can be used to evaluate the feasibility of integrating the light rail into the urban street network.

2. It can model various types of signal control logic, viz. vehicle actuated signal controls and fixed signal controls. The external signal state generator (VAP) allows the user to generate user defined signal control logic.

3. VISSIM also allows modeling of stop sign controlled roundabouts, and intersections and also grade separated interchanges.

4. It has also been used for the analysis of slow speed merging and weaving areas and ramp metering using stop and yield priority logic.

5.3 The Logic for the model

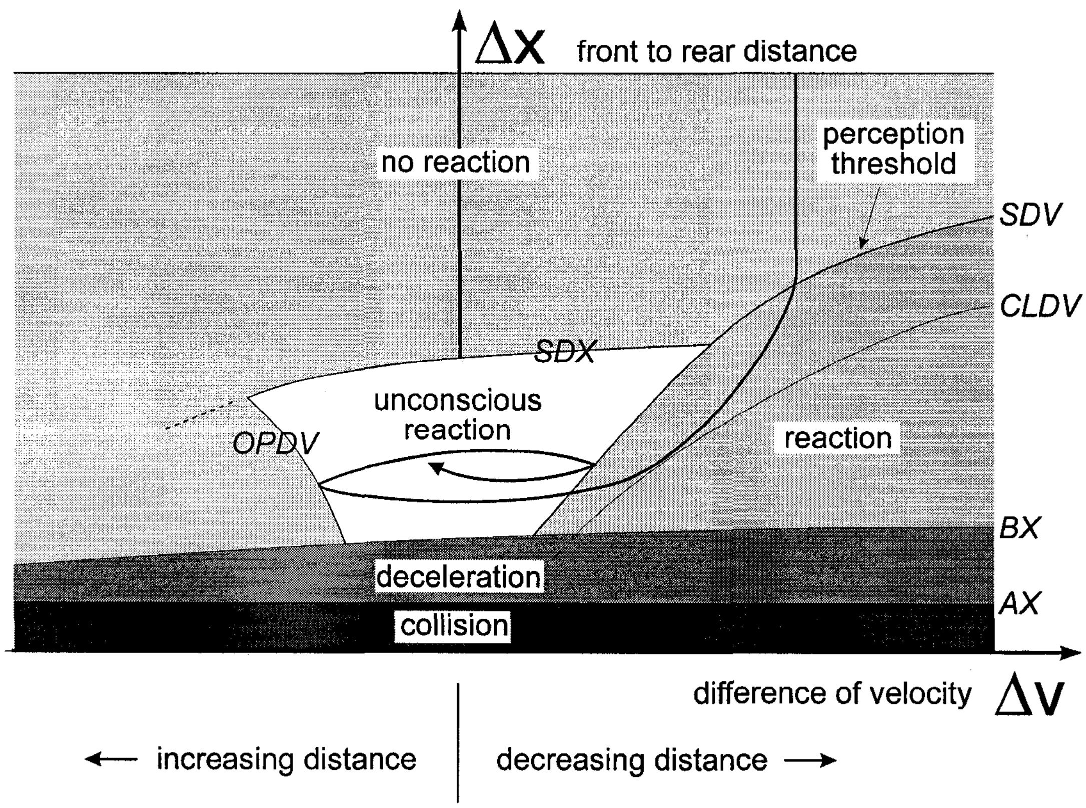
The model works on the basic car-following and gap acceptance theory given by Wiedemann. The kernel of this theory is that as a faster vehicle approaches a slower vehicle on the roadway then it decelerates to change the lane. The reaction of changing the lane depends on the speed of the vehicle, the driver behavior and the distance between the headway.

The figure below explains the kernel of the model and the principle on which it works. As can be seen that the fast moving vehicle decelerates as it approaches the slow moving vehicle and the difference in the time lag is the reaction time that the vehicle experiences due to the driver behavior. The basic logic of the car following thery can also be explained by the formula below:

$a_f = F(v_l, v_f, s, d_l, d_f, R_f, P_i)$

where a_f = the acceleration of the following vehicle that is dependent on these various factors $v_l, v_f, s, d_l, d_f, R_f, P_i$. This is the basic idea of the car following theory that is the kernel of this VISSIM model.

Fig3. The Kernel of VISSIM model in graphical format.



Source: VISSIM Traffic flow simulation Technical Description, PTV Germany.

The model functions on two fundamental principles of traffic behaviour.:

a) The car following theory

b) The lane changing/gap acceptance theory

As per Wiedman's principle a driver can primarily be in three states when he is in motion; one can be that he will be accelerating; the other could be that he can be decelerating or the third state of motion could be that he could be driving in a constant speed. The figure below gives a pictorial representation of this state of motion. The red car is the driver and the surrounding cars (in its lane and in the lane beside the red car) are the effectors.

Fig 4. Car following, lane changing and gap acceptance represented graphically.

Sourece: Univ. of Calgary

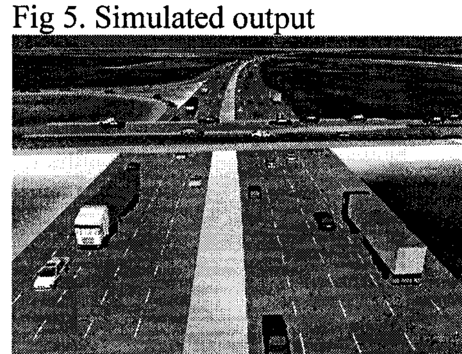
As per the lane changing theory; a driver will only change lane if he finds that the gap between his and the trailing vehicle is sufficient to do this kind of a behaviour.

5.4. Application areas

The model has various areas of application. It can be used to simulate various aspects of traffic and transportation planning. Some of the specific aplication areas of this simulation tool are:

5.4.1. Microscopic and macroscopic traffic simulation: This model can be used to simulate freeways and arterial streets. The results can be obtained in the form of both macro area or in the form of mocro simulated area for the region.

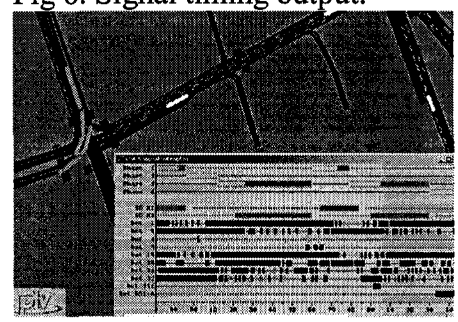
Fig 5. Simulated output



The figure on the right shows the 3D view of a freeway, that has been simlated using this simulation tool.

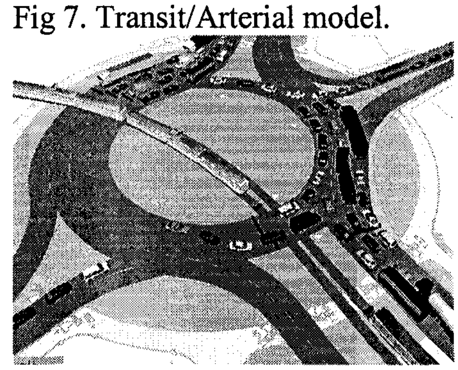
5.4.2. Modeling and testing of actuated signal control: VISSIM can model both the fixed time and the vehicle actuated signal controls. However this standard VISSIM, can only handle the fixed signal control. For the vehicle actuated signal control an additional plug in required. However this tool is also very useful in evaluating the non-signalized intersections.

Fig 6. Signal timing output.



5.4.3. Transit modeling: VISSIM is one of the very few simulation tools in the market that can handle the simulation of a transit network along with the arterial road network. In addition it can also model roundbouts. Emission statistics can also be obtained from the output of this tool which is in conformity with the MOBIL 5 guidelines.

Fig 7. Transit/Arterial model.



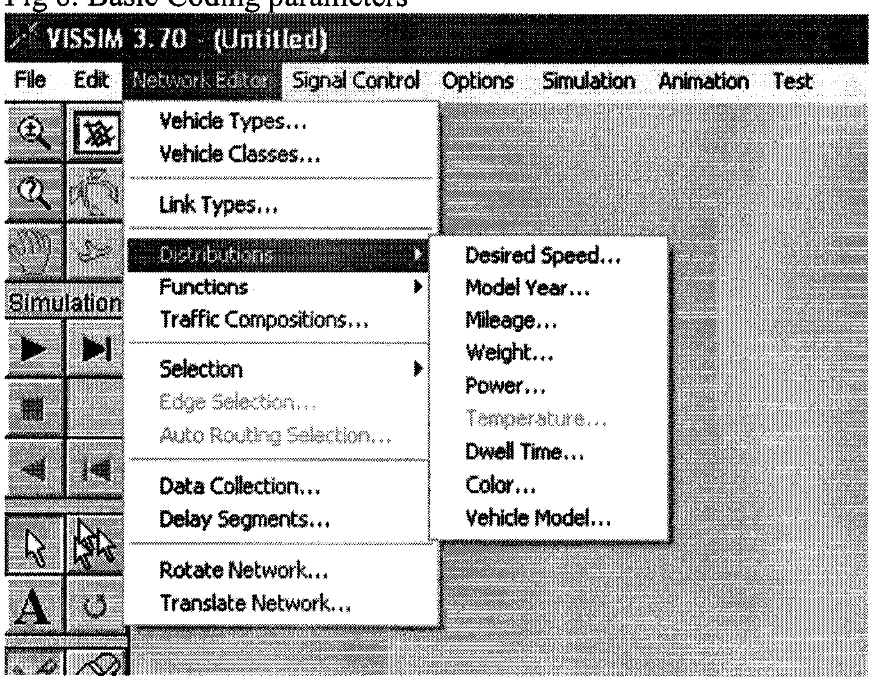
5.5 The simulation set up by VISSIM for case study.

This simulation model is a very user friendly tool to handle the modeling procedure for various traffic and transportation planning applications. The step by step modeling procedure is explained in the subsequent discussion below.

5.5.1 Modeling procedure.

The modeling procedure for this model can be primarily be divided into the following six sections. Each section deals with the specification of certain parameters and traffic data. The following sections will discuss in detail the different procedures in a detailed manner.

Fig 8. Basic Coding parameters



Source: VISSIM

5.5.1.1 Basic Coding Parameters.

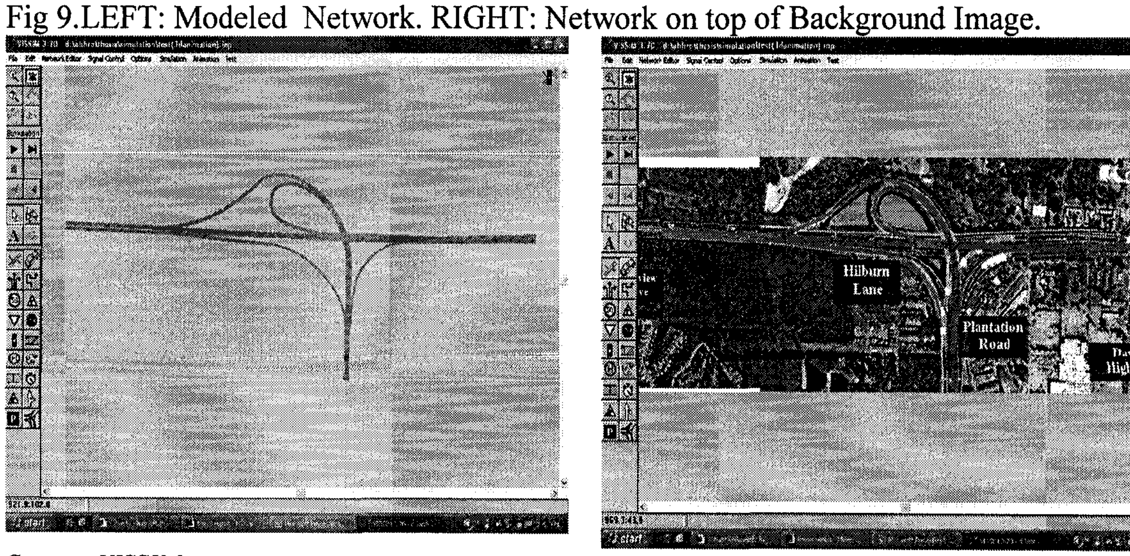
In this step various coding parameters that are to defined before starting the modeling procedure for the case study area. It is important to know that what kind of output is desired and then accordingly set all the parameters in the model. Various parameters that need to be set are: Desired speed, Model year, Weight, Power, Dwell time, Color, Vehicle model. The figure above is the screen from the model that shows all the parameters that need to be specified. These parameters are the basis for the coding for the rest of al other parameters that will be discussed in the subsequent passages.

5.5.1.2 Network Coding.

VISSIM, unlike other models like CORSIM, SIDRA etc. requires a background image for the basic network to be replicated on top of that. The amount of detail required for modeled roadway infrastructure depends on the purpose of the application. While a rough outline can be used for testing a traffic situation but a more detailed drawing needs to be put into for simulation analysis. To model the network in VISSIM the following need to be done:

(I) Importing maps and images: First a background image of the study area needs to be imported on to the network. The image has to be in the 'file.bmp' format and needs to be scaled according to the actual scenario. The figure below depicts the background image and the network drawn on the image.

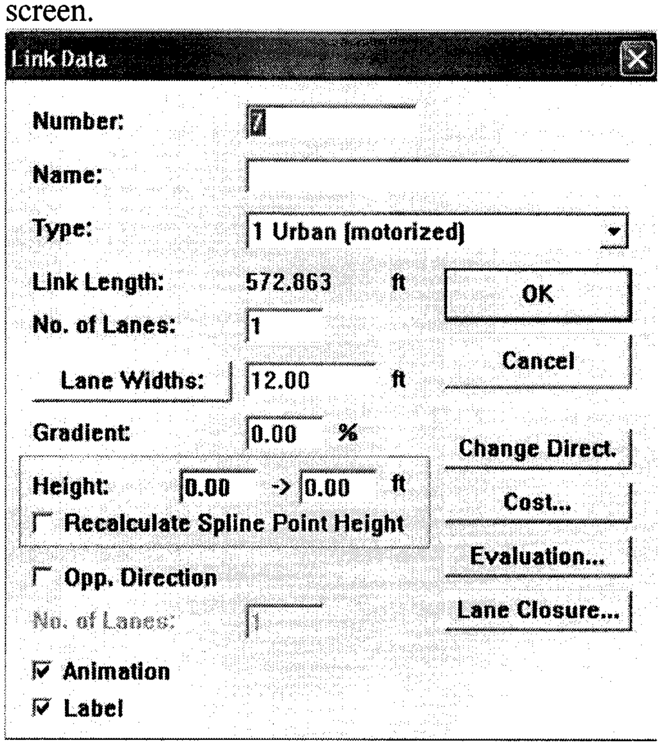
Fig 9.LEFT: Modeled Network. RIGHT: Network on top of Background Image.



Source: VISSIM

(II) Link and Connector creation: The next step is to very carefully model the network of the area under consideration. It is very important to get a significantly detailed map of the area that is to be studied if a simulation is to be done using VISSIM. If an auto cad drawing of the area is also available then, that can be imported as a background image into the model and the rest of the parameter specifications can be done. Links and connectors are drawn on the image to model any study area in VISSIM.

Fig 10. Link data parameter screen.

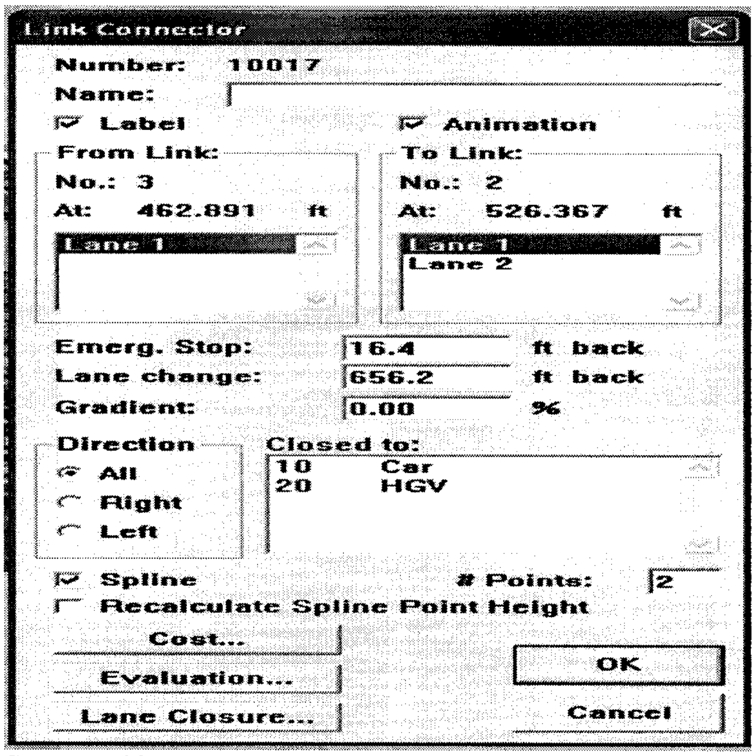


Source: VISSIM

The figure on the top shows the various parameters that need to be specified when a link is drawn on the background image. Parameters like lane width, no. of lanes, type of road section etc. needs to be specified.

The figure on the below shows the various link connector parameters that need to be specified when the links modeled on the image are connected by the connectors to draw the whole network. The types of vehicle on the link and connector are also a data specification, for this screen in the VISSIM model.

Fig 11. Link connector parameter screen.



Source: VISSIM

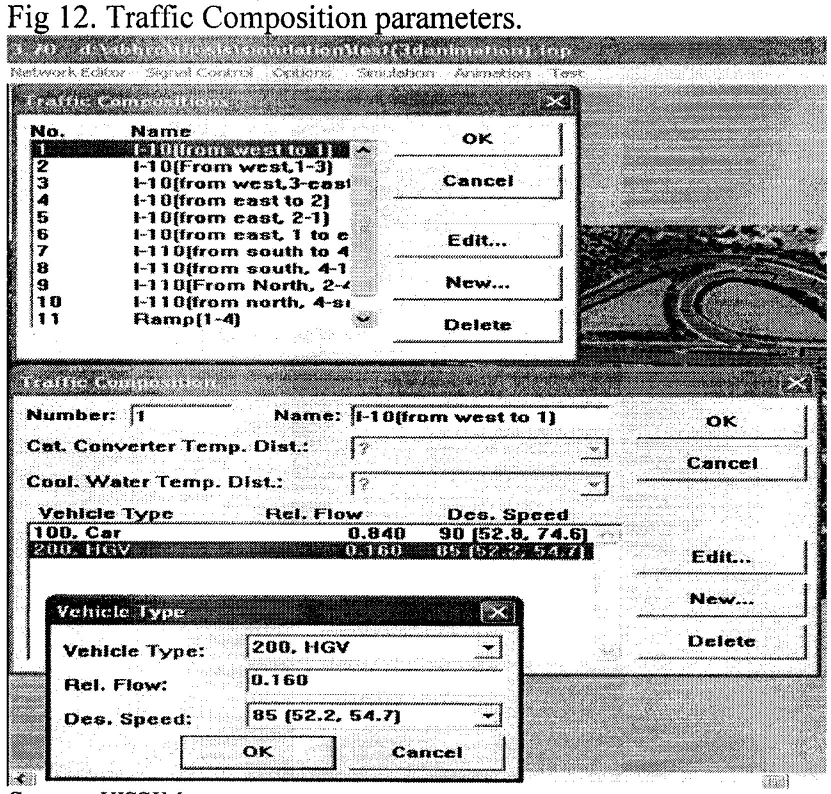
5.5.1.3 Defining the network and link parameters: Before coding the network and the links and the connectors in the VISSIM model it is necessary that some of the parameters be specified in the model. Some of the specifications like acceleration and deceleration both the actual on the site and the desired needs to be specified.

5.5.2 Traffic Coding

This section of the model deals with the traffic data and the various traffic related parameters that need to be put in the model so as to run the simulation. The following discussion will explain the various types of coding that need to be done for the traffic in VISSIM.

5.5.2.1 Traffic composition: This is a part of any vehicle input in VISSIM and needs to be defined prior to the actual vehicle input flow. The screen on the right shows that for defining this input, first the relative traffic composition needs to be selected from the pre-coded drop down and then the composition according to the various types that are there on the network, the percentage is put in the screen. The various types of vehicles moving on the network needs to be defined on link by link basis prior to this step.

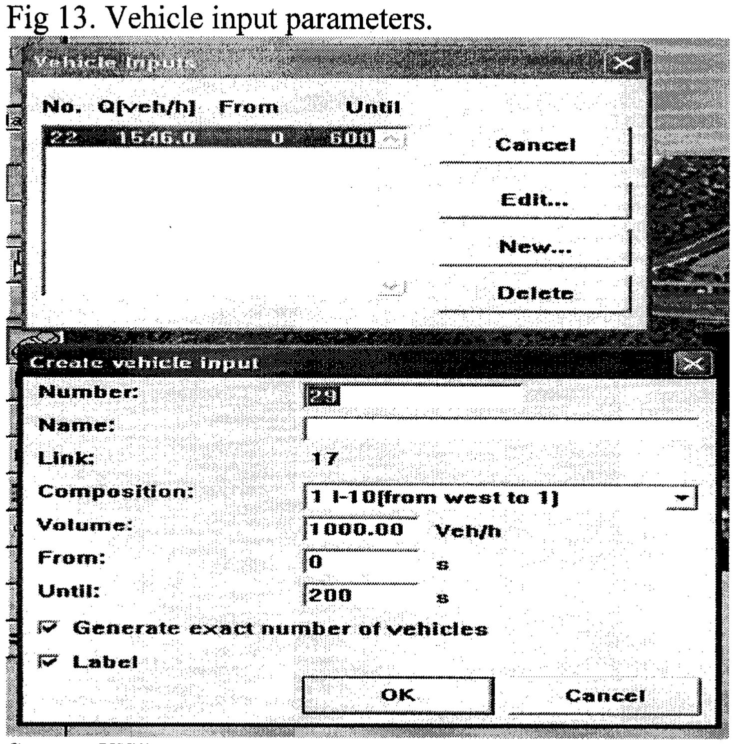
Fig 12. Traffic Composition parameters.



Source: VISSIM

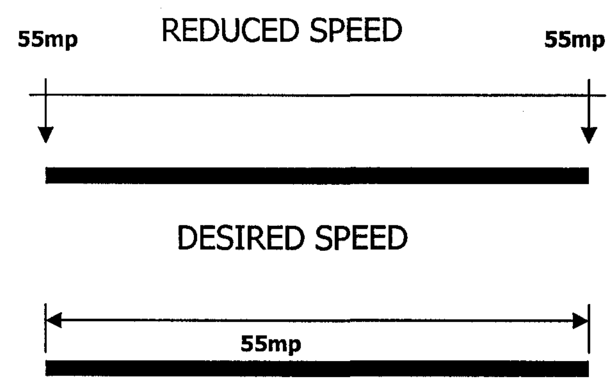
5.5.2.2 Vehicle Input: The user can specify time variable traffic volumes in the network on link by link basis. The volume is on vehicle/hr basis and it not a PCU value for the peak hour. The figure on the right shows the screen for various parameters that needs to be put as a vehicle input for the simulation. The link number and the length are selected by default as the input starts. The volume needs to be specified. The simulation period also needs to be specified, but at this point it need not be put into this screen, because when the simulation parameters are put the by default the simulation period appears in all the link volume data. The traffic composition that was already modeled prior to this step pops up automatically for each and every link as we start putting the traffic volume data.

Fig 13. Vehicle input parameters.



Source: VISSIM

5.5.2.3. Speed Characteristics: The speed characteristics are first pre defined when the basic coding procedure is completed. A speed range is specified instead of a fixed speed value in the basic speed input. There are two criterions when speed was specified a) Desired speed and the b) Reduced speed. The difference between the two lies in the type of application. The reduced speed is defined when a ramp is being modeled or in work zone areas. The desired speed is defined when a permanent speed limit is enforced in an area.

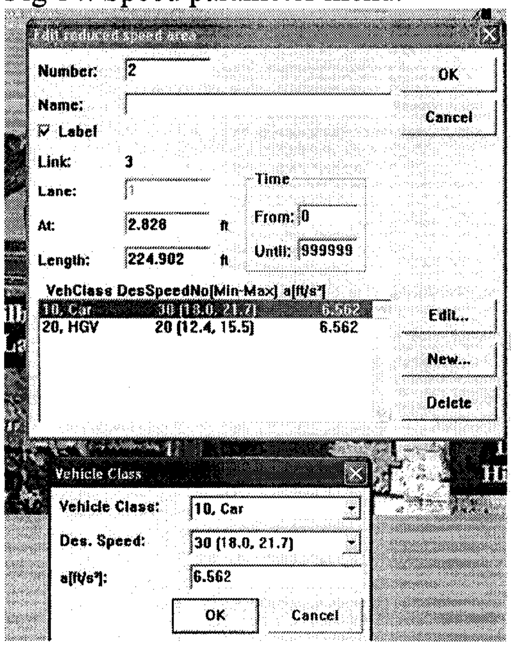


The figure above shows that basic difference in the application of the reduced and the desired speed areas. In the reduced speed, the speed is effective throughout the section of the roadway and so the driver before approaching the section first decelerates or accelerates and maintains the speed throughout and once it crosses the section it again regains its original speed.

In case of the desired speed once the vehicle crosses the start point then it starts accelerating or decelerating and attains the speed somewhere in between and before exiting it again regains the speed and returns to the original speed.

The screen on the right shows the range of the speed for all the composition of traffic that is taken into consideration. The range of the acceleration and deceleration also needs to be specified for the traffic composition along with the speed specification.

Fig 14. Speed parameter menu.



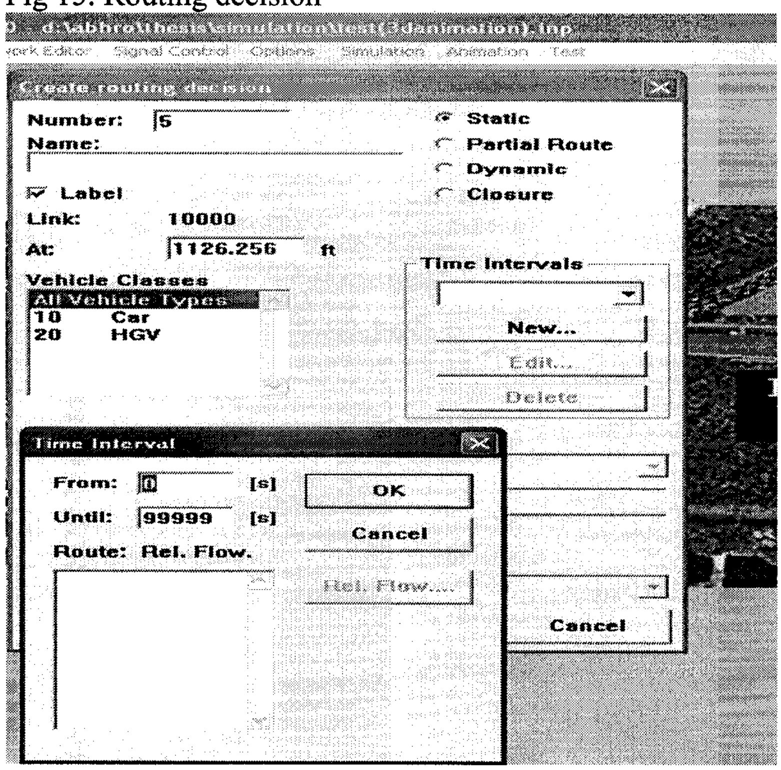
Source: VISSIM

5.5.3. Routing Decisions.

VISSIM supports two types of routing decisions a) Static routing and b) Dynamic routing. For modeling the dynamic routing dynamic network modeling should be used that is not within the scope of this study. In this kind of modeling the routes are selected based on the OD matrix that is specified while the coding is done. The route selection in dynamic modeling is dependent on the minimal cost and optimal route selection approach.

The screen below shows the parameters that need to be specified when a static routing is defined for a section of the highway or an area. The routing decision can also be selected for a specific class of vehicles. So if a work zone is being modeled then the partial routing option is used that closes a section of the highway to a certain composition of traffic. Also, lane closures can be specified in cases when there is a complete lane closure. In this menu a time interval for the simulation also needs to be specified. It is recommended that the end simulation period to be 9999 [s] which is the default of the model. For the partial route specifications the percentage of the traffic also needs to be given for all the alternate routes.

Fig 15. Routing decision

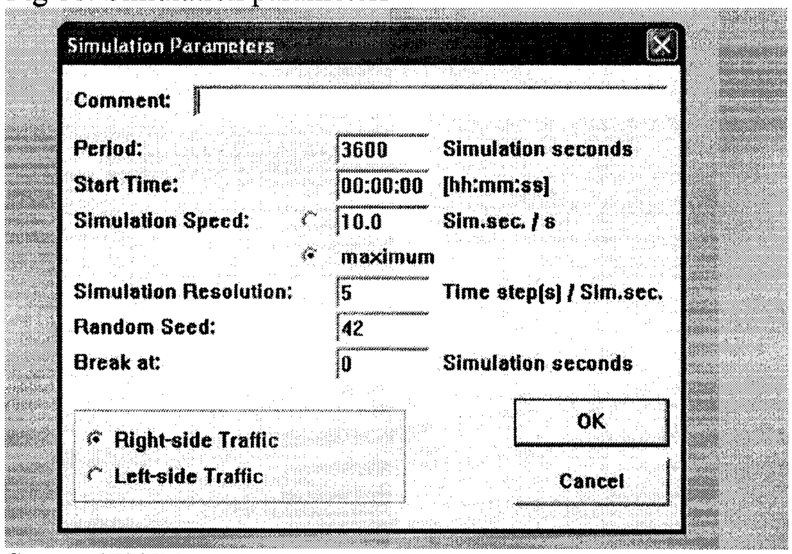


Source: VISSIM

5.5.4. Simulation and animation control.

The final most step in simulating the VISSIM model for a static network modeling study is to run the simulation. The figure below lists all the inputs in the simulation screen that needs to be specified for the model to run. The resolution of the simulation can be controlled by the simulation resolution and the random seed variable.

Fig 16. Simulation parameters



Source: VISSIM

In addition there is also an option in the VISSIM model to record the simulation file as an file.avi format and play it separately without using the model. While specifying the recording parameters it is necessary to record it in small compressed format so as to make sure that the file is not too big to handle.

5.6. Conclusions

It can be noted that this model VISSIM is capable of many traffic and transportation simulation and modeling. The use of the model also guides the type of parameters that need to be specified. In this discussion only the static network modeling component has been discussed, keeping in mind the scope of this study. However as discussed in earlier section this model is capable to handle many other applications also.

6. CALIBRATION OF THE MODEL

6.1 Methodology of calibration

Calibration of any traffic simulation model is very crucial, as it would lead to obtaining the results as accurately as possible. Model calibration as defined by Hellinga [9] is a process by which the user of a model adjusts various parameters of the model so as to obtain the results the closely reflects the ground parameters as on the test bed.

Calibration of the VISSIM involved many stages. First the various parameters that need to be calibrated were identified. The various MOE's as desired by the model were also defined prior to the calibration so that the parameters that need to be calibrated are clear. In the first stage the required field data is identified and fed into the model keeping in mind the desired output. The second stage involved the input of the date into the model. The third stage is the generation of the various desired output form the model and testing it with the test bed results. At this stage it becomes necessary to re-calibrate and adjust certain parameters in the model if the simulation results are not in consonance with the test bed conditions.

Stage – I (Identification): In this case during the first stage it was identified that static network modeling process will be used instead of the dynamic modeling procedure in the VISSIM, for this case study. The data requirements that were identified were:

- Geometrics of the network
- Traffic volume of the various links on the network
- The routing (static) behavior of the network

- Speed, acceptable gaps, acceleration and deceleration values etc were also identified for the test bed scenario

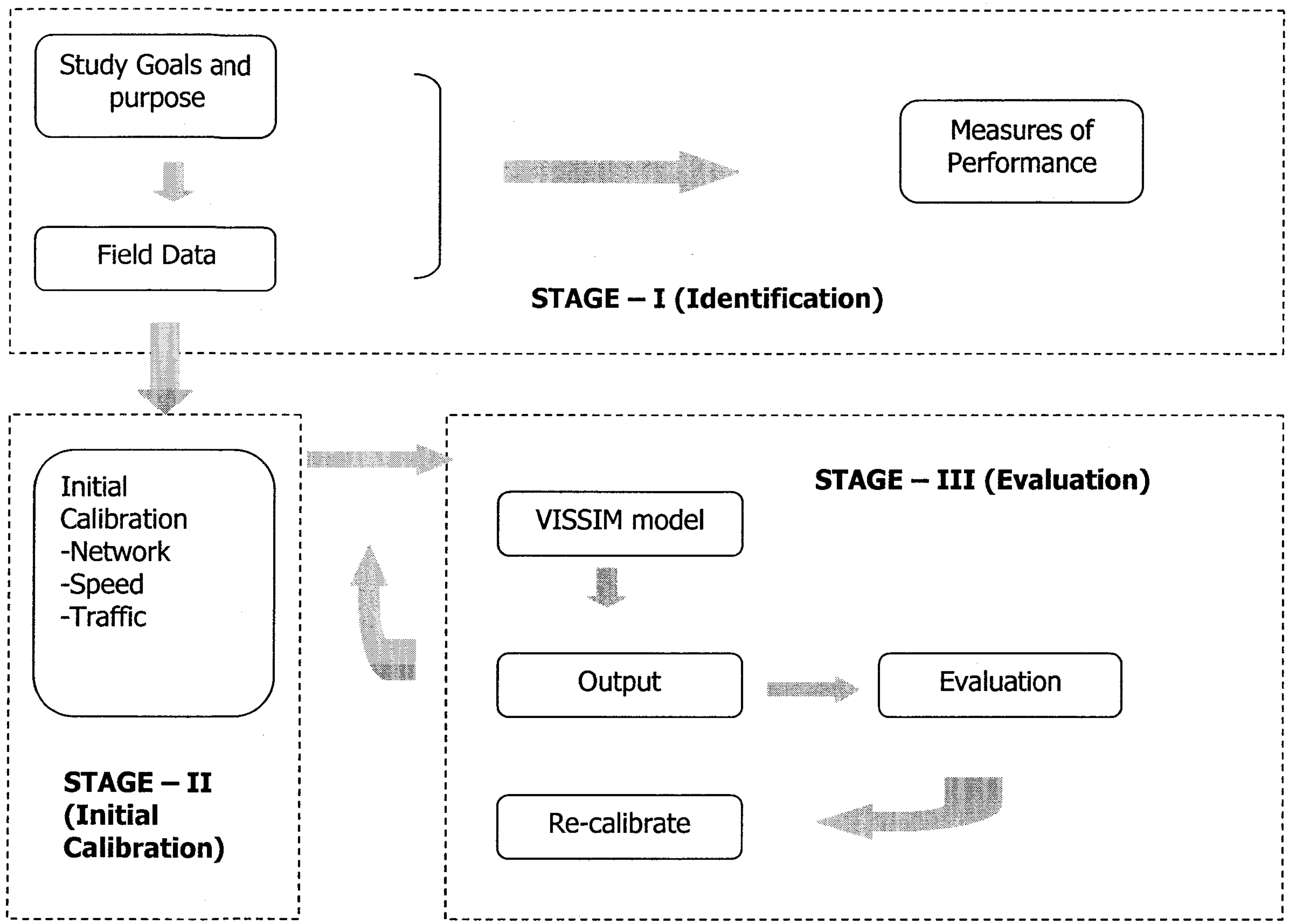
The various MOE's that were desired was specified in the model to be evaluated. only those options of evaluations were activated that were pertinent to the desired result.

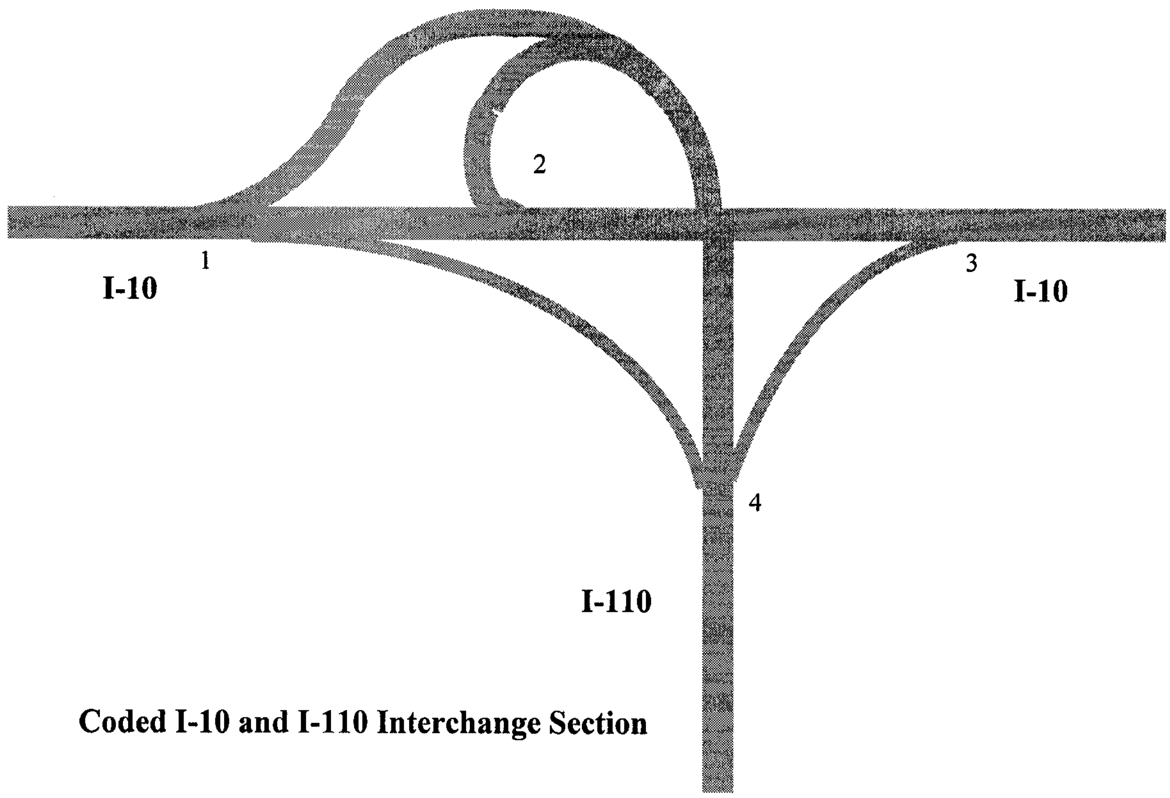
Stage – II (Initial Calibration): In this stage various traffic parameter that were identified in stage – I were put in the model. This stage also involves identification of certain other parameter that might be considered to be required in the subsequent stages.

Stage – III (Evaluation): In this stage the various outputs that were obtained were evaluated and tested for the base scenario. This stage decided the necessity to re-calibrate the model and to modify certain input parameters in case the model output does not match up with the base scenario. In the subsequent discussion the various parameters that were looked into again will be described and the re-calibration procedure will be discussed in detail.

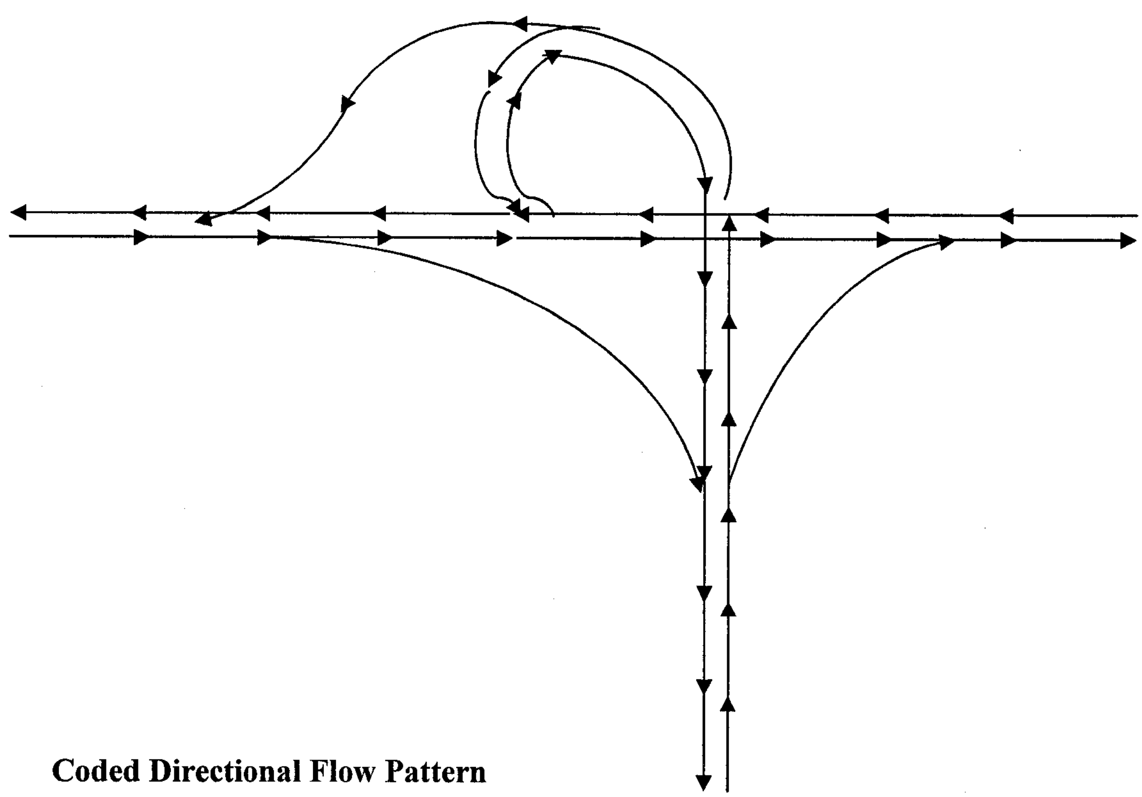
6.2 Calibration.

a) Network Building: The test bed network was built in VISSIM using the aerial photographs that were obtained form the FDOT web site for the area under consideration. Considering the resolution of the data that was available and the scope of this study only the I-10 and I-110 interchange was built into the model for the simulation. The total area was 2miles (approx) both in the north-south and east-west direction. The directional flow is shown in the figure below in the figure.


Study Goals and purpose
Field Data
Measures of Performance
STAGE – I (Identification)
Initial Calibration
-Network
-Speed
-Traffic
STAGE – II (Initial Calibration)
STAGE – III (Evaluation)
VISSIM model
Output
Evaluation
Re-calibrate



Coded I-10 and I-110 Interchange Section



Coded Directional Flow Pattern

Table 2. Link code in the model and the corresponding links on the test bed

Code No.	Direction on the test bed
1	I-10 (from west to 1)
2	I-10 (from west, 1 to 3)
3	I-10 (from west, 3 to east)
4	I-10 (from east to 2)
5	I-10 (from east, 2 to 1)
6	I-10 (from east, 1 to east)
7	I-110 (from south to 4)
8	I-110 (from south, 4 to 1)
9	I-110 (from north 2 to 4)
10	I-110 (from north, 4 to south)
11	Ramp (1 to 4)
12	Ramp (4 to 3)

b) Speed characteristics: The speed characteristics have been calibrated differently for the cars and HGV vehicles. For cars the base case range is between 55-70 mph and for the HGV it is between 50-55 mph. The range ID is 90 and 85 respectively. The speed characteristics are different for the ramp that is joining the south of the section to the west of I-10. Also on the ramps due to the merging and the diverging behavior the speed characteristics are different.

c) Static Routing Decisions: There are six routing decisions that were specified to calibrate the model according to the test bed condition. Each of the routing decision was a static route (pre-defined), as the scope of the study does not necessitate a dynamic routing calibration. The route codes and the routes are explained in the table below.

Table 3. Routing code in the model and the actual direction

Code No.	Routing decision
2-1	I-10 east to west
2-2	I-10 east to I-110 south
9-1	I-10 west to east
9-2	I-10 west to I-110 south
10-1	I-110 south to I-10 west
10-2	I-110 south to I-10 east

d) Output file specification: To get various MOE's in the results, the model has to be specified with various outputs results. There are various files that are generated with various types of parameters. The table below lists the type of files that are generated as outputs and the various MOE's that can be obtained through the tables

Table 4. Output files and the MOE's produced by the VISSIM model.

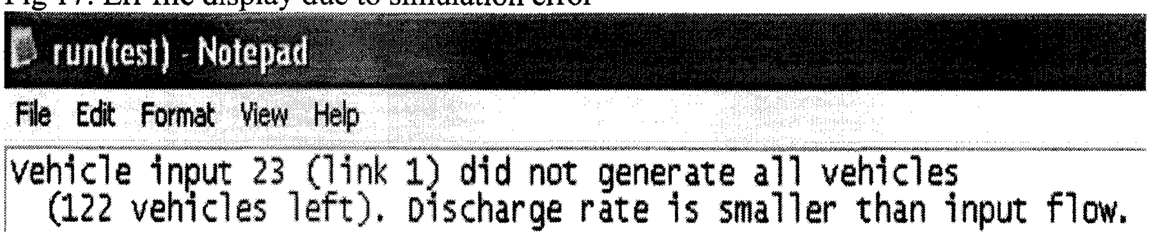
File Type	Type of evaluation	MOE's obtained
*.str	Link Evaluation	Delay, volume, speed etc.
*.vlz	Table of delay	Delay time, #veh delayed etc.
*.rsz	Travel time	#veh, travel time, etc.
*.npe	Network performance	Overall network performance

6.3 Results of unacceptable calibration after first simulation

After the first simulation on calibrating the model the results that were obtained were not acceptable. Some of the outputs that VISSIM generated which necessitated the re-calibration process are discussed as below.

a) Simulation error: After the first simulation run the VISSIM output generated an *.err file saying that the simulation has encountered an error. A text output file generated by a test simulation is shown below.

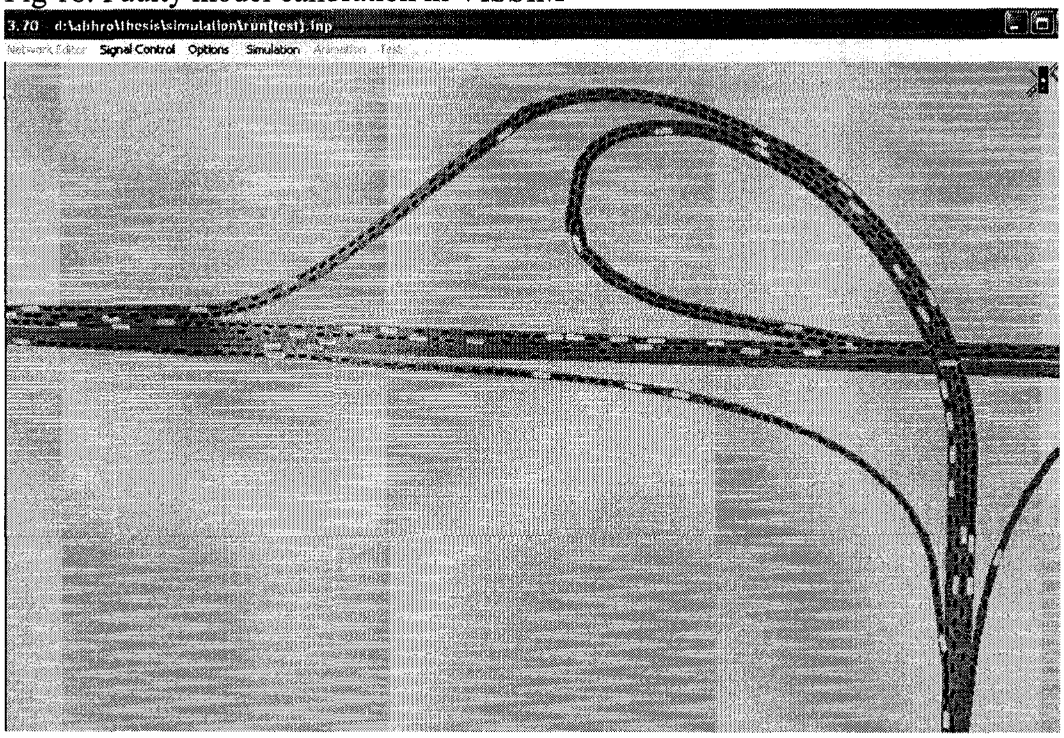
Fig 17. Err file display due to simulation error



As can be seen above the message shows that the total no. of input vehicles in the link 1 (input code 23) were not generated, that should have been, so as to saturate the network. A total of 122 vehicles were remaining that should have been generated and the discharge rate should have been equalized with the input so as to match up with the real scenario. In the subsequent discussion the procedure to correct this error will be discussed.

b) Error in merge and diverge behavior: This type of error is generally visible in the graphical output of the model. The snapshot of such a error is shown below. The figure shows that there is a complete blockage on all the approach ramps and the merging ramps during the simulation process. This is totally an unrealistic scenario as it is known that such kind of situation is not at all present in the base scenario on the test bed network. This error arises due to faulty merge and diverge calibration in the model. In the subsequent discussion dealing with the re-calibration of the model this will be explained and the corrective measures will be discussed.

Fig 18. Faulty model calibration in VISSIM



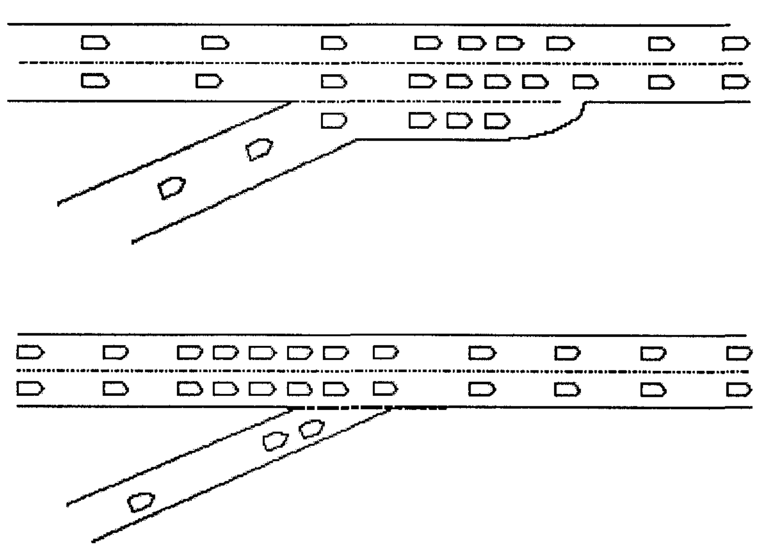
6.4 Re-calibration of the model

After studying the error types that were generated the model was re-calibrated and checked for accuracy. To deal with the first type of error the model was sun "N" number if times to adjust for the pre-run time. It was observed that the pre-run time of the simulation was 540 simulation second. That means that after 540 simulation seconds the network would have reached the point when the total input of the vehicles is equal to the total output form the network. The "*.npe" file helped to look for this value. This file gives the total number of vehicles in the network and the simulation time. Since the peak hour volume was known so, the accurate pre-run time could be obtained mathematically, and the simulation with this new value was tested for that pre-run time.

The VISSIM model is very sensitive to the way the merge and the diverge is to be modeled. All the sections where there was a merge and a diverge section the following points were taken into consideration:

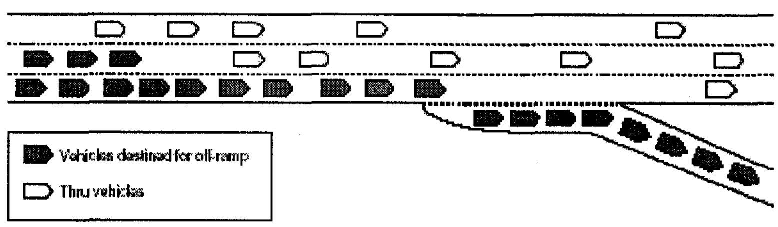
- The merge section (weaving section) should be one link with the number of lanes equal to the number of lanes on the main freeway plus the number of lanes merging onto the freeway.
- There should be only one connector after the merge link (weaving section) to the main freeway. For graphical reasons an additional dummy link (not a connector) can be added at the end of the merging lane(s) to smoothen the lane reduction.
- The routes of the merging traffic must also extend past the merge link (weaving section) If not, vehicles on the merge link will not know that they need to change lanes in order to get on to the main link prior to the end of the merging lane(s).

Fig 19. Modeling merge in VISSIM



The figure above shows how VISSIM takes into account the merge behavior pattern. The first figure depicts the exact nature by which the merge is to be modeled in VISSSIM. A faulty simulation will result if the merge behavior is modeled as shown in the second picture. The merge lane should be an independent lane and should merge with the traffic stream as a dedicated lane.

Fig 20. Modeling diverge.

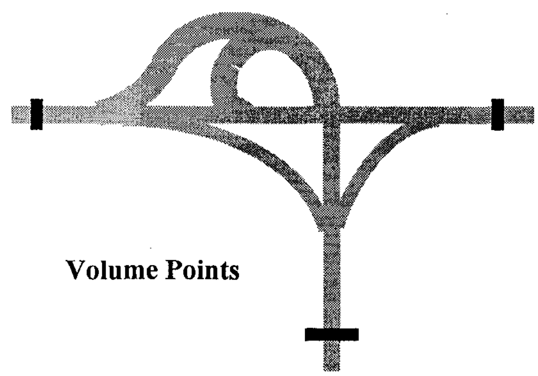


The diverge should also be carefully modeled so as to avoid any queuing in the network. The deceleration lane should be a dedicated lane and should be separated from the last lane that start the diverge. After the careful consideration of the merge, diverge and the simulation run errors the simulation was run again for with the pre-run time specified, and no error was observed any more.

However, correction of the apparent errors in the simulation does not imply that the model is fully calibrated. In order to test the model for accurate representation of the test bed scenario, a test of calibration was performed with one of the output parameters. The subsequent discussion will describe the sensitivity test that was performed to determine the accuracy of the calibrated model.

6.5 Sensitivity analysis for testing the accuracy of the calibrated model

The sensitivity analysis was done with the volume that was obtained by the simulation and the actual volume that was reported for the test bed. For the east, west and the south direction of the network the volume figure was calculated. The figure below shows the points for which the volume was obtained.



The bold lines on the three legs are the points where the volume was collected. The table below gives the figures for a simulation period of 1200 simulation seconds from the time 600 simulation seconds, for the three directions.

Table 5. Simulated volume at the points

Simulation time	East	West	South
600	4159	4046	5568
660	4553	3440	4775
720	3424	4379	4955
780	4038	4575	5000
840	4587	4624	6479
900	5130	3854	5880
960	3985	4617	5025
1020	3631	3416	5526
1080	3970	3470	5706
1140	3733	4687	5908
1200	4680	4142	5950

With the simulated volume form the model the confidence was calculated with a confidence interval of 95% using the "*Excel Confidence Function*". The formula for calculation of the confidence interval can be depicted as below:

$$\bar{x} \pm 1.96\left(\frac{\sigma}{\sqrt{n}}\right)$$

where x = mean
n= sample size of the data
1.96 is the α value for a confidence of 95%
σ = standard deviation

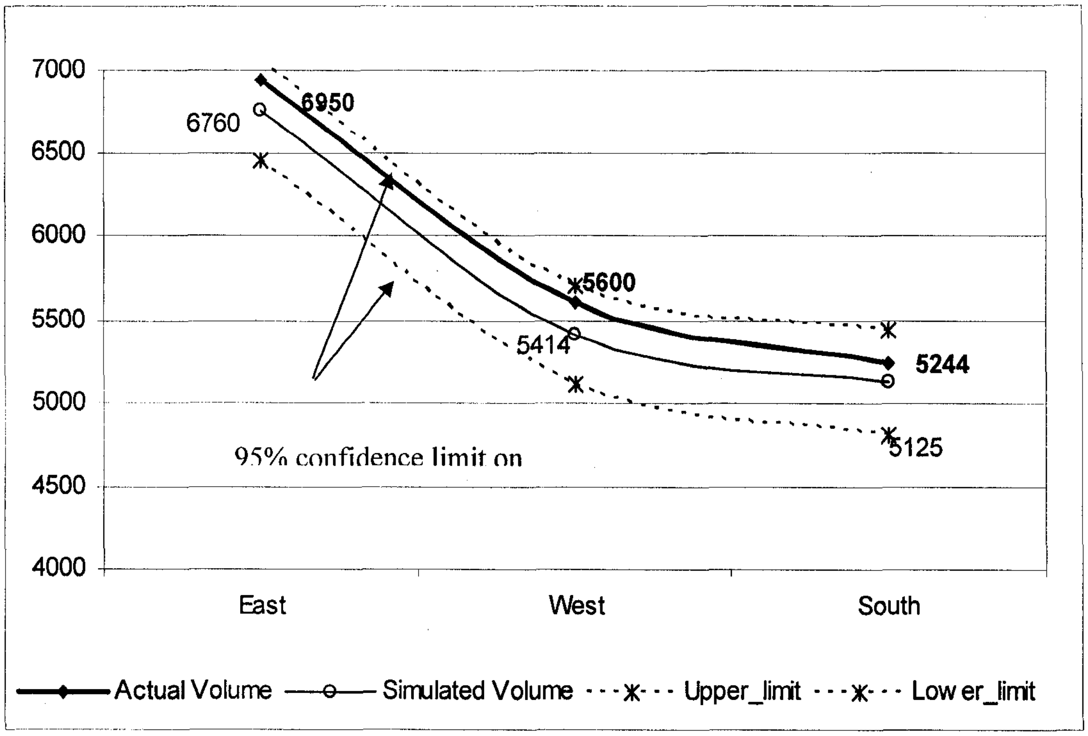
The table below depicts calculation of the confidence interval with the above formula using the data analysis tool pack in excel.

Table 6. Calculation of confidence for the simulated volume

Average Simulated volume (x)	6760	5414	5125
Stand. Dev (σ)	513.1113	505.2443	530.1436
Confidence Interval (with $\pm$ 1.96)	303.2236	298.5746	313.2889

With the calculated confidence interval the deviation of the simulated volume and the actual volume as on the test bed is described in the graph below. It can be seen form the graph below that the actual volume of the traffic on the three points lies within a level of 95% significance of confidence interval of the simulated volume. This shows the model is fairly well calibrated as the volume depicted is within the 95% confidence level.

Fig 21. Statistical significance of the simulated and the actual volume



As can be send from the graph above that the actual volume on the test bed is lying within the 95% confidence limit of the simulated volume. From this point onward the model is assumed to be fairly well calibrated and will be used for further analysis in this study.

6.6 Conclusion

A statistically analysis of the simulation run shows that the model is fairly well calibrated and so it can generate almost accurate results depicting the test bed scenario. The confidence is 95% which is very high for this calibrated model scenario.

7. ANALYSIS OF SIMULATION RESULTS

7.1 Introduction

After the calibration of the model three scenarios were tested and analyzed for the test bed. The first scenario is the base scenario and the other two scenarios are with the introduction of the work zone in the simulation model. In the subsequent discussion a detailed analysis of these three case will be explained in detail.

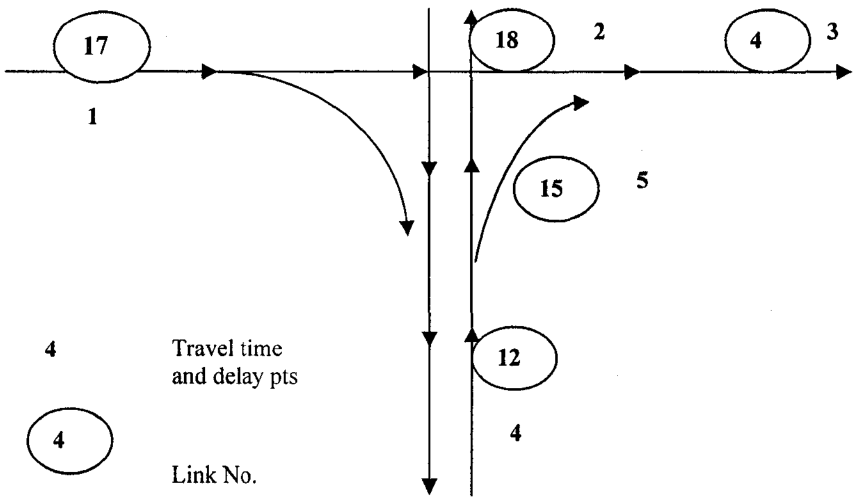
The simulation was carried out for a simulation period of 3600 simulation seconds and the data was collected at 60 seconds interval from 540 simulation second to 3600 simulation second. The travel time and the delay data was collected at some specific links as shown in the table and the picture below.

Table 7. Travel time and delay collection points on the test bed

Link no.	**Travel time code**	**Delay code**	**Simulation time**
17	1	1	540-3600
18	2	2	540-3600
4	3	3	540-3600
12	4	4	540-3600
15 through 10003	5	5	540-3600

Although the data is collected for all the coded links in the network, but or the purpose of further analysis emphasis is given on the link no. 18. This is the link where the work zone is defined and various speed reduction strategies are tested with and without lane closure option. Further discussion will highlight the methodology of data analysis for the other two options.

Fig 22. Travel time and delay collection points.



7.2 Scenario – I (Base case)

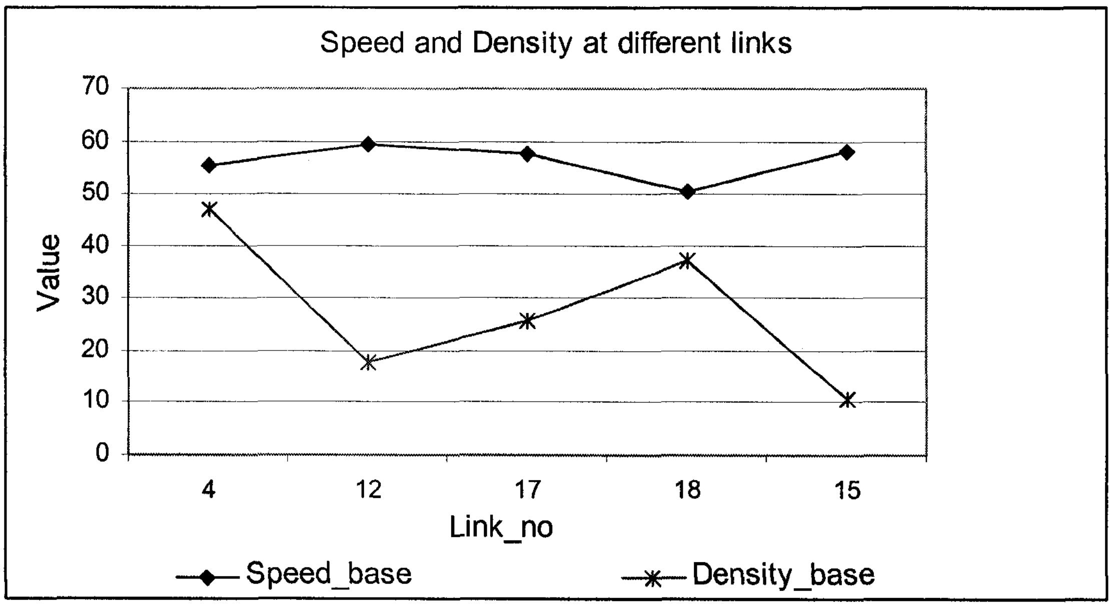
The base scenario is the simulation for the test bed. The table below depicts the results in terms of certain MOE's like speed, volume, density and lost time for the links that have been considered as mentioned above in the figure.

Table 8. MOE's for the base scenario.

Link	Speed(mph)	Volume	Density(veh/mile)	Lost_time(sec)
4	55.168039	2580.82549	46.89627451	0.05254902
12	59.548627	1055.932745	17.74117647	0.006470588
17	57.563725	1485.143725	25.84117647	0.020196078
18	**50.69176**	**1887.7594**	**37.36451**	**0.0266667**
15	58.151961	622.9668627	10.74039216	0.025098039

As can be seed form the table the average speed on all the links except the link 18 (which will be effected later as work zone) is same.

Fig 23. Speed and Density values on different links for the base scenario.



The graph above shows that the density for the link 12 and 15 are significantly low and there is a lot of variation in the density value. However there is not much deviation in the speed values for these links other than at the link no. 18.

7.3 Scenario – II (Reduced speed on link no. 18)

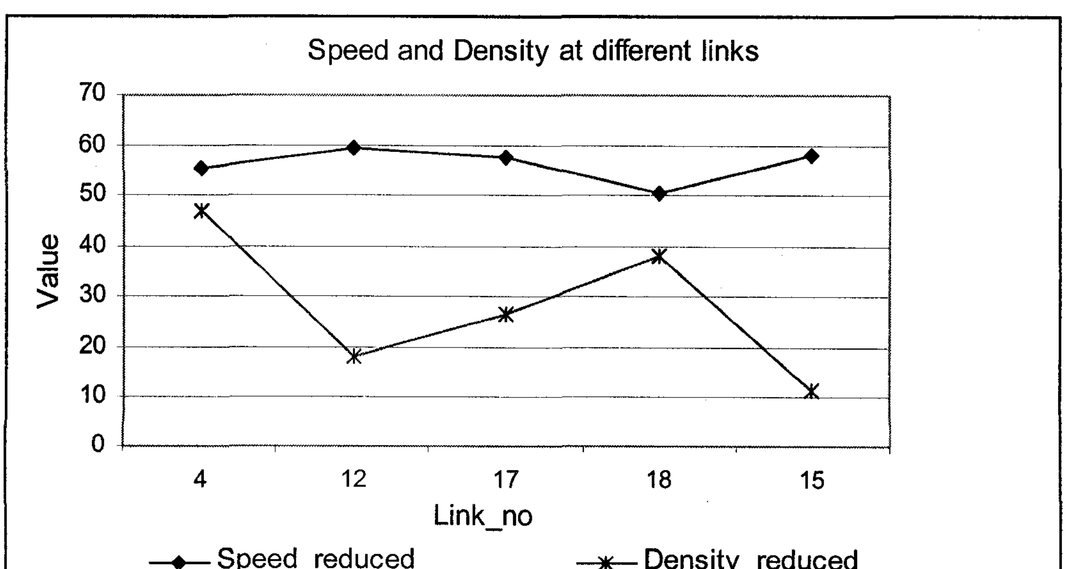
In this case a speed reduction is introduced for the link no. 18 and the MOE's are then obtained for all the links. The speed reduction range is from 50mph – 55mph, as it is observed normally on the work zone areas.

Table 9. MOE's for the reduced speed on the link no. 18

Link	Speed(mph)	Volume	Density(veh/mile)	Lost_time(sec)
4	55.167647	2580.842745	46.89647059	0.05254902
12	59.421176	1087.744902	18.37921569	0.007843137
17	57.436275	1516.955882	26.47921569	0.021568627
18	**50.56412**	**1919.5706**	**38.002549**	**0.0280392**
15	58.094902	656.4629412	11.39078431	0.025294118

As can be observed form the table above there not much of a significant difference in the values for different MOE's in this scenario. For the link no. 18 the average density is more than the base case scenario and so is the speed value changed but for the other sections there is not much of a change. This can be due to the fact that the length of the work zone on the link 18 is very less and so there is not much impact on the speed and the other factors.

Fig 24. Speed and Density values on different links for the reduced speed scenario



As can be seen form the graph above that there is not much change in the speed and the density values for this scenario with an introduction of a reduced speed on the link no. 18.

7.4 Scenario – III (Reduced speed and lane closure on link 18)

In this case a reduced speed is introduced on the link 18 and also of the lane of this link is closed for the movement of all the types of traffic.

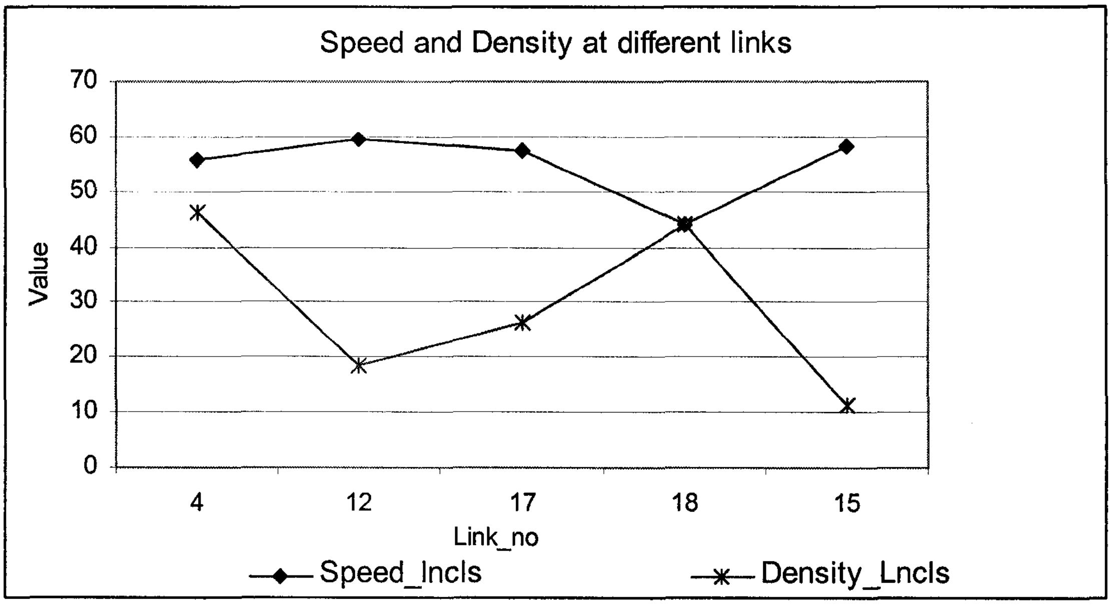
Table 10. MOE's for the reduced speed and lane closure on the link no. 18

Link	Speed(mph)	Volume	Density(veh/mile)	Lost_time(sec)
4	55.75549	2557.253529	45.95117647	0.044117647
12	59.452353	1088.272745	18.34627451	0.00745098
17	57.494118	1517.459608	26.43215686	0.020196078
18	**43.96196**	**1897.1445**	**44.089804**	**0.1564706**
15	58.20451	656.5933333	11.34607843	0.024509804

It can be observed form the table above that a significant change has occurred on the link no 18 as the lane is closed on this link. There is a significant reduction in the speed as compared to the previous two scenarios. For obvious reasons there is an increment in the density value and the average lost time on this link also.

The figure below depicts the change in a better pictorial manner. The density on the link 18 is 44.08 vehicles/mile and the average sped is 43 mph. the average list time in sec/veh is 0.15 and which is higher than any other value for any other link in the table.

Fig 25. Speed and Density values on different links for the reduced speed with link closure scenario



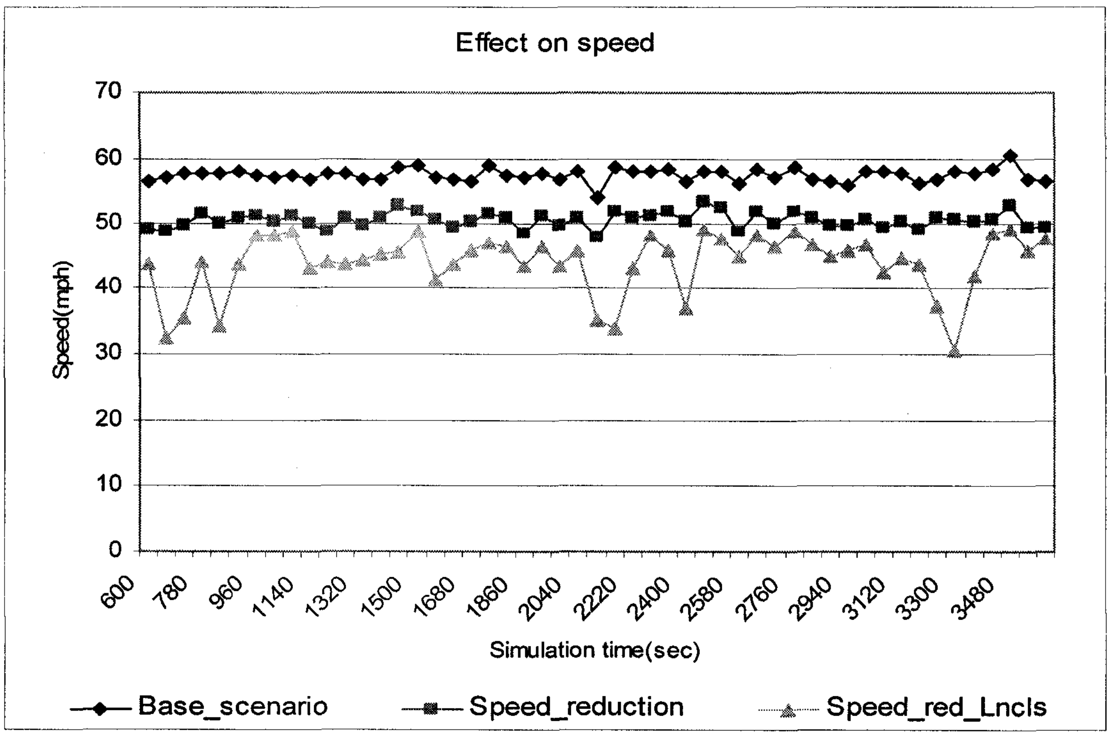
7.5 Analysis of the results for the link no. 18

A detailed analysis of the various MOE's for the link no 18 will give a better understanding of the sensitivity that effects this link due to the various types of measures that are undertaken.

7.5.1 Effect on speed

In the graph shown below the effect on speed for various simulation times is shown for the link 18 for all the scenarios. It can be seen that for the base scenario and the sped reduction the speed is consistent throught the simulation time, but when one lane is closed then there is a severe fluctuation in the speed value for the simulation period. The minimum speed is as low as 30mph and the maximum speed is 50mph. Also it is apparent that the speed reduces when the lane is closed than when there is only reduction in the speed for obvious reasons.

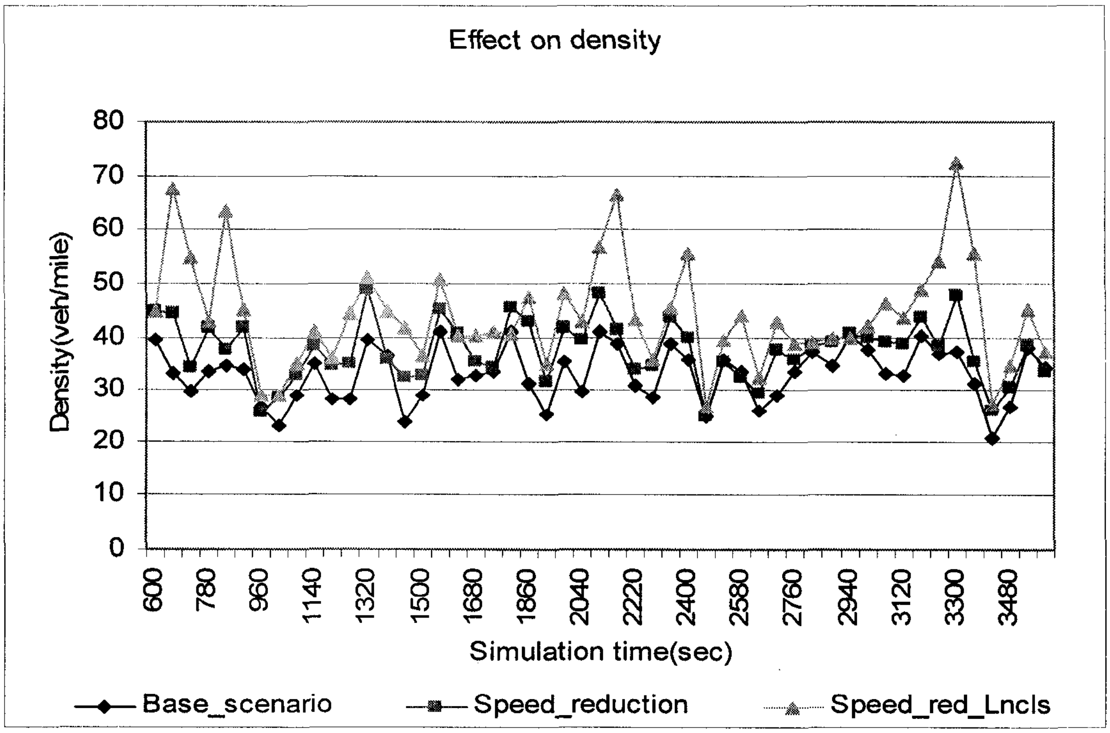
Fig 26. Effect on speed for various scenarios on link no. 18.



7.5.2 Effect on the density

The effect on the density is very fluctuating for all the scenarios. However for all the case the density is highest for the lane closure scenario than the base case. The graph below shows that the density varies form as low as 28 veh/mile to 72 veh/mile. For the whole simulation period the fluctuation is maximum for the lane closure scenario. This can be explained by virtue of the fact that density depends in various factors that are taken into account, so the variation is very rough.

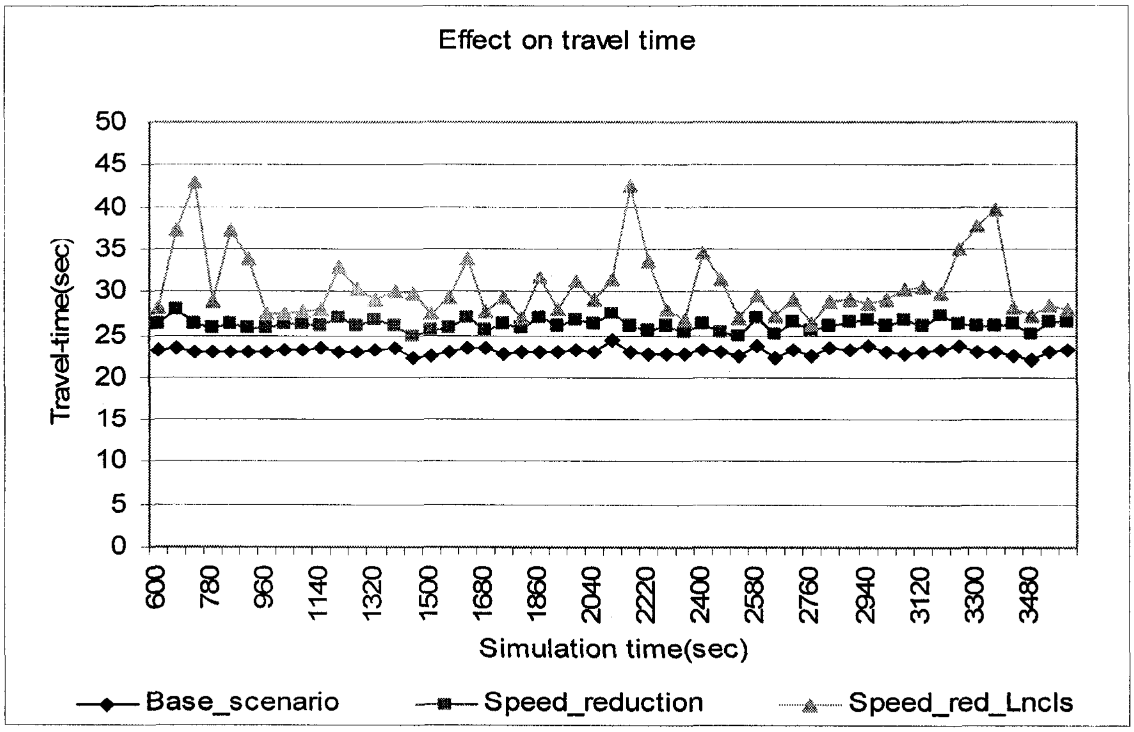
Fig 27. Effect on density for various scenarios on link no. 18



7.5.3 Effect on travel time

Travel time was also evaluated as one of the MOE's as a part of the evaluation for the link no. 18. The graph for the travel time shows that the travel time has been consistent for the first two scenarios but is very inconsistent for the scenario when one of the lane is closed for the link no 18. The travel time varies from a value of as low as 26 sec to 45 sec on the link. Due to variation in the speed and the change in the density for various simulation period there is a consistent effect on the travel time. This trend necessitate the evaluation of the link no 18 with a varying value of speed for different conditions.

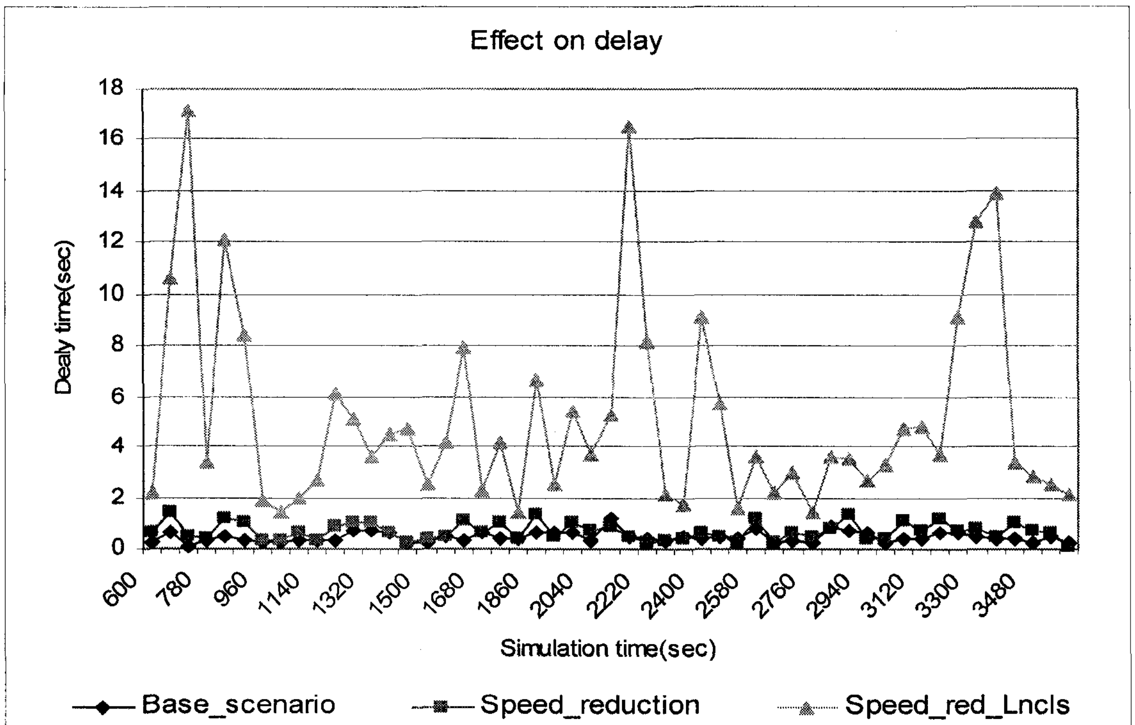
Fig 28. Effect on travel time for various scenarios on link no. 18



7.5.4 Effect on delay

The effect on the delay time is very clearly visible for the whole simulation period from 600 simulation seconds to 3600 simulation seconds. For the base case scenario and the speed reduction scenario the effect is not that very different, but for the lane closure scenario the effect is very drastic. On the simulation time 780, 2280 and 3420 seconds the delay time is very high. The animation for this simulation second also shows that there is a sudden queuing of vehicles at certain points on this link and so this results in a high delay time for the overall simulation period and the link overall. This phenomenon is not observed for the other tow scenarios but only for the lane closure scenario.

Fig 29. Effect on delay time for various scenarios on link no. 18



In the further a case sensitive analysis for the link no 18 will be conducted with varying speeds. Also a multiple regression will be developed that will be helpful in evaluation this link for various speed conditions without the need for running the simulation with VISSSIM.

7.6 Conclusion

It can be concluded that there is not much of a significant change on the whole network when there is a speed change or due to the closure of one lane on the link no. 18. However there is a quite an effect on the link 18 due to these measures. The effect on the change in travel time is most starkly noticeable for the three scenarios. This change is more apparent for the link 18 in specific than the whole network as a whole.

A further analysis in the sections below will reveal the sensitivity of this link towards the change in the speed and will bring up more issues. In the subsequent discussion a multiple regression model will be built that can be used to predict the speed value for any value of delay or the travel time as the independent MOE. This model will help in the situation when there wont be a need to sun the simulation on VISSIM and predict the effect on the speed on this link.

8. DEVELOPMENT OF MATHEMATICAL MODEL

8.1 Introduction

The sensitivity of the speed variation on the link no. 18 with lane closure suggested the possibility of expressing this phenomenon in the form of a mathematical model. In this section the development of a multiple regression model will be expressed in which speed will be one of the variables. The subsequent discussion will highlight the development of the model and will explain the steps. The statistical package SPSS was used to arrive at the mathematical equation.

8.1 Multiple Regression Model – concept

The multiple regression analysis is a method to explain a phenomenon and to predict the future occurrences by way of a mathematical equation. Mathematically a multiple regression equation can be expressed as:

$$\mathbf{Y = aX_1 + bX_2 + cX_3 \ldots\ldots\ldots + dX_N + C}$$

where a, b, d.....C = constant
Y = dependent variable
X_1, X_2, X_3 ....X_N = independent variables

Under the ideal conditions a highly sensitive multiple regression model should have a very strong correlation with each of the independent variables with the dependent variables and very less correlation between the independent variables within each other.

The objective of developing this regression model will be to develop the relationship between speed on the link 18 with certain other controllable variables. This would help to avoid using a simulation on VISSIM to predict the effect of a certain speed on the work zone on link no. 18. with different lane width combinations.

8.2 Model generation

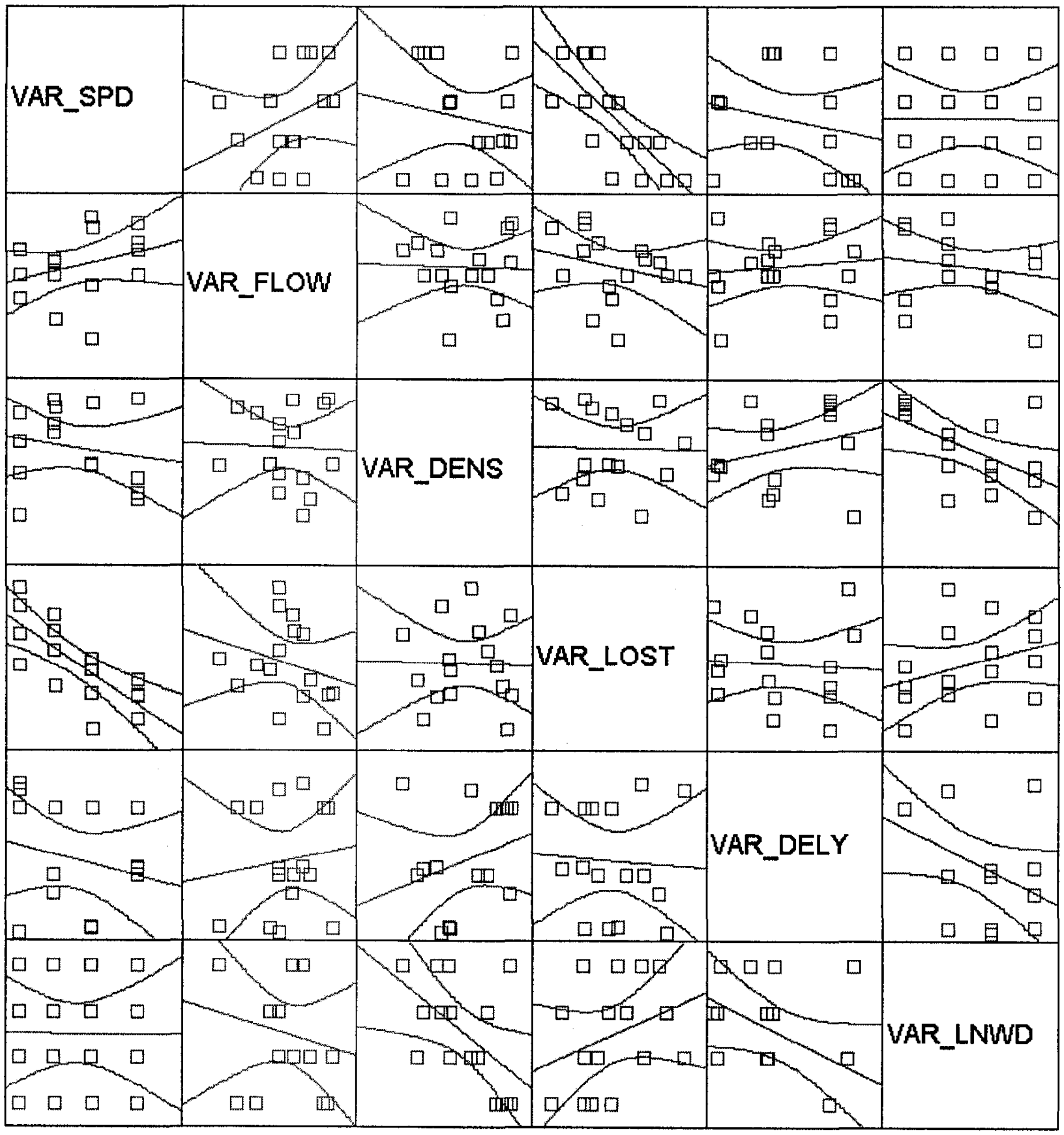
The first step in generating the model was to analyze the scatter plot of all the possible variables including speed. In this case the different variables that were considered were, speed, flow, delay, density, lost time and lane width. The figure below is the scatter plot of all these variables. It can be observed that there is a significant linear relationship between certain variable and for some of them the relationship is not linear at all. More linear the relation is more stronger the variables are related and better is their sensitivity. For example the relation between speed and the lost time is highly linear.

However for the purpose of this study we will try to see the relationship between speed and the other variables. The table 10 below the scatter plot show the inter-factor correlation for all the variables under consideration. It can be seen from the correlation numbers that some other parameters other than speed have a higher relation to the certain variables, but since the controllable parameters are fixed we will further analyze speed, lane width and delay. Keeping this mind delay will be expressed as a function of speed and lane width. Delay will be the dependent variable and speed and the lane width will be the independent variables mathematically it can be represented as:

$$\mathbf{f\{delay\}\ \alpha\ f\{speed\} + f\{lanewidth\}}$$

here delay is dependent on speed and lane-width.

Fig 30. Scatter plot of different variables



From this point forward the objective of the multiple regression model would be to find a relation between these three.

Table 11. Inter-factor correlation between variables

		VAR_SPD	VAR_FLOW	VAR_DENS	VAR_LOST	VAR_DELY	VAR_LNWD
VAR_SPD	Pearson Correlation	1.000	0.332	-0.165	-0.750	-0.216	-0.008
	Sig. (2-tailed)	.	0.209	0.542	0.001	0.422	0.976
	N	16.000	16.000	16.000	16.000	16.000	16.000
VAR_FLOW	Pearson Correlation	0.332	1.000	-0.038	-0.250	0.126	-0.180
	Sig. (2-tailed)	0.209	.	0.889	0.350	0.641	0.505
	N	16.000	16.000	16.000	16.000	16.000	16.000
VAR_DENS	Pearson Correlation	-0.165	-0.038	1.000	-0.023	0.277	-0.548
	Sig. (2-tailed)	0.542	0.889	.	0.934	0.300	0.028
	N	16.000	16.000	16.000	16.000	16.000	16.000
VAR_LOST	Pearson Correlation	-0.750	-0.250	-0.023	1.000	-0.056	0.327
	Sig. (2-tailed)	0.001	0.350	0.934	.	0.836	0.216
	N	16.000	16.000	16.000	16.000	16.000	16.000
VAR_DELY	**Pearson Correlation**	**-0.216**	**0.126**	**0.277**	**-0.056**	**1.000**	**-0.460**
	Sig. (2-tailed)	**0.422**	**0.641**	**0.300**	**0.836**	**.**	**0.073**
	N	**16.000**	**16.000**	**16.000**	**16.000**	**16.000**	**16.000**
VAR_LNWD	Pearson Correlation	-0.008	-0.180	-0.548	0.327	-0.460	1.000
	Sig. (2-tailed)	0.976	0.505	0.028	0.216	0.073	.
	N	16.000	16.000	16.000	16.000	16.000	16.000

The controllable parameters that can be manipulated on the work zone are speed, lane width. Analyzing the inter-factor correlation matrix for delay, speed and lane-width shows that delay is highly related to speed and lane-width individually. As explained in the empirical equation The multiple regression form this point onwards is carried out with delay as the dependent variable and speed & lanewidth as the independent variables.

Table 12. Correlation matrix for speed, delay and lanewidth

		VAR_DELY	VAR_SPD	VAR_LNWD
Pearson Correlation	VAR_DELY	1.00	-0.22	-0.46
	VAR_SPD	-0.22	1.00	-0.01
	VAR_LNWD	-0.46	-0.01	1.00
Sig. (1-tailed)	VAR_DELY	.	0.21	0.04
	VAR_SPD	0.21	.	0.49
	VAR_LNWD	0.04	0.49	.
N	VAR_DELY	16	16	16
	VAR_SPD	16	16	16
	VAR_LNWD	16	16	16

The correlation matrix above shows that delay is negatively correlated with speed and lanewidth. For a total sample size of 16 the correlation factor for speed is -0.22 and for lanewidth its -0.46. The inter correlation between speed and lanewidth shows that the factor is of the order of -0.01 which is very low. Hence it can be inferred safely that speed and lanewidth are not interdependent with each other, and so it is statically valid to develop a multiple regression equation with these variables into consideration.

Table 13. Model Summary

R	R Square	Std. Error of the Estimate
0.5094	0.2595	0.1045
a	Predictors: (Constant), VAR_LNWD, VAR_SPD	
B	Dependent Variable: VAR_DELY	

The table above is the model summary that is generated as a part of the SPSS output to test for the sensitivity of the regression model that is developed. It can be inferred form the output generated that the R^2 value is of the order of 0.2595 and the standard error of estimate is of the order of 0.1045. Statistically smaller the value of the standard error of estimate and larger the R^2 value, the better is the model.

Table 14. The coefficients for the variables and significance level

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.9772	0.2870		3.4052	0.0047
VAR_SPD	-0.0032	0.0034	-0.2196	-0.9201	0.3743
VAR_LNWD	-0.0452	0.0234	-0.4614	-1.9331	0.0753

Table 13 above lists the coefficients for the dependent and the independent variables for the multiple regression model. the "t" ratio evaluates the level of significance and the accuracy of the coefficients in the model. the larger the t-value the higher is the confidence level for the equation. As it can be seen that the t-value for the variable speed is -0.9201 which is very low, this shows that the coefficient estimated for this variable is not very much sensitive.

This could be due to many reasons. First due to a smaller sample size and due to the outlier values in the sample the regression may not be that strong. Although the inter-correlation factors give a true picture of the inter factors but at the end the regression model may get effected. However overall the multiple regression equation stands high level if sensitivity if all the analysis is seen. The **regression model** can be finally represented as:

$$\textbf{Delay} = -0.0032*(\text{speed}) - 0.0452*(\text{lanewidth}) + 0.9772$$

8.3 Conclusion

Further sensitivity analysis of this equation will yield a result that will be case sensitive and can be related only to this case. This regression model cannot be generalized and applied for different circumstances on different parts of the links on the network. If some other lane of effected by closure or speed reduction then that has to be statically modeled separately.

9. DISCUSSION

9.1 Introduction

The objective of this study was to simulate a work zone area and to evaluate the effect of speed variation by an ITS component. Since variable message signs (VMS) is one of the ITS devices that is widely used to deploy speed reduction strategies it was chosen as the ITS component. VISSIM was chosen as the simulation tool to test the speed variation strategies. It was first calibrated, tested for accuracy by validating it with the test bed data and then used for evaluating the effect of speed reduction strategies using VMS signs.

9.2 Discussion

Through an extensive literature review it was found that many studies have been conducted on work zones to evaluate the traffic behavior of different kinds. Also, its was found that many types of simulation tools have been used, for the same. It was concluded that for evaluation of ITS devices simulation tools like INTEGRATION and VISSIM were the best under specific circumstances depending on the type of simulation.

Considering the scope of the study and the data availability it was decided that VISSIM will be the ideal tool for conducting this research. Although simulation tools like CORSIM are well known, but they would not have been ideal for microscopic freeway simulation with VMS as an ITS component. Although simulation with INTEGRATION would have been ideal for this study, but that would have been much more data intensive and considering the type of data and the scope of this research it would not have been feasible.

The simulation model was first calibrated using a test bed data in Florida for the I-10 and I-110 interchange section. After calibration of the model multiple simulation runs were performed to validate the data to the test bed scenario. The final simulated model was found to lie within 95% confidence interval. After this validation a work zone was introduced on a section of the interchange and various speed reduction strategies were tested for various scenarios.

The various MOE's that were obtained for the scenarios was assimilated and analyzed. A multiple regression model was generated to express delay as a function of speed and varying lane widths on the work zone section. However, it should be mentioned that the model that was generated at the end was very specific to this case and separate models needs to be generated for any other scenario that might introduced.

During the course of the calibration of the model and developing a regression model with speed as one of the variable, it was observed that more microscopic analysis could be done using this simulation tool VISSIM. Some of the recommendations for further work will be discussed subsequently. Considering the availability of data and the type of resolution of the data available for this research, the study could not have been extended beyond the present scope.

9.3 Future work

It is recommended that further studies should be carried out with this simulation tool VISSIM using the dynamic network modeling. This research work focused on the static network modeling, but it is highly recommended that a study may be carried out using the dynamic modeling procedures. Although it might demand a mote intensive data requirement to fulfill this kind of objective. It is also recommended that a study might be conducted to test the efficacy of this simulation tool with other competitive tolls like INTEGRATION. It I possible to do network fragmentation in VISSIM, so a research might be conducted with further resolution of the output within some specified network.

Based on all the discussion and the scope and the limitations of this study, it can be safely concluded that all the research objectives pertaining to this study are well acheived.

REFERENCES

[1]. Peeta, S., Poonuru, K., Sinha, K., "Evaluation of Mobility Impacts of Advanced Information Systems", Journal of Transportation Engineering, May-June 2000.

[2]. Rippeon, H., Miller, J., Demetsky, M., "Quantifying the Benefits of Active Incident Management in Rural Areas", report no. UVA/29242/CE99/101, School of Engineering and Applied Science University of Virginia, May 1999.

[3]. Bernhardt, K., Virkler, M., Shaik, N., "Evaluation of Supplementary Traffic Contol Measures for Freeway Work-zone Approaches", Transportation Research Board, January 2001.

[4]. Schrock, S., Maze, T.H., "Evaluation of Rural Interstate Work Zone Traffic Management Plans in Iowa Using Simulation", Mid Continent Transportation Symposium 2000 Proceedings, 2000.

[5]. Clark, J., Daigle, G., "The Importance of Simulation Techniques in ITS Research and Analysis", Proceedings of the 1997 Winter Simulation Conference, 1997.

[6]. Schnell, T., Mohor, J.S., Aktan, Faut., "Evaluation of Traffic Flow Analysis Tools Applied to Work Zones Based on Flow Data Collected in the Field", Transportation Research Board, January 2002.

[7]. Brian Moen, P.E., Joel Fitts, EIT, Dave Carter, P.E., and Yang oUyang, P.E., "A Comparison of the VISSIM Model to Other Widely Used Traffic Simulation and Analysis Programs.

[8]. Schuter, B. De., Bellemans T., Logghe S., Stada J., Moor B. De., Immers B., "Advance Traffic Control on Highways", Journal A, vol. 40, no. 4, pp. 42-51, Dec. 1999.

[9]. Hellinga Bruce R., "Requirements for the Calibration of Traffic Simulation Models".

[10]. PTV Planug Transport Verkehr AG. Innovative Transportation Concepts. January 2003. VISSIM Version 3.70 Manual.

[11]. Brian, B and Schneeberger, J.D. November 2002. "Microscopic Simulation Model Calibratin and Validation: A Case Study of VISSIM for a Coordinate Actuated Signal System." TRB Annual Meeting 2003.

[12]. Horowitz, A. J., Weisser, I., Notbohom, T. "Diversion from a Rural Work Zone Owing to a Traffic-Responsive Variable Message Signage Syatem", TRB 2003 Annual Meeting, 2003.

[13]. Wang, C., Dixon, K., Jared, D. "Evaluation of Speed Reduction Strategies for Highway Work Zones", TRB 2003 Annual Meeting, 2003.

[14]. Liberman, E., Rathi, A. K., "Traffic Simulation".

[15]. Jayakrishnan, R., Oh, J., Sahraoui, K., "Calibration and Path Dynamics Issues on Microscopic Simulation for Advanced Traffic Management and Information Syatems", Institute of Transportation Studies, 2000.

[16]. Park, B., Yadlapati, S., "Development and Testing of Variable Speed Limit Logics at Work Zones using Simulation", TRB 2003 Annual Meeting, 2003.

[17]. Rakha, H., Hellinga, B., Aerde, M. V., Perez, W., "Systematic Verification, Validation and Calibration of Traffic Simulation Models", TRB Annual Meeting.

[18]. Park, B., Schneeberger, J.D., "Microscopic Simulation Model Calibration and Validation: A Case Study of VISSIM for a Coordinated Actuated Signal System", TRB 2003 Annual Meeting, 2003.

[19]. Hourdakis, J., Michelopoulos, P. G., Kottommannil, J., "A Practical Procedure for Calibrating Microscopic Traffic Simulation Models", TRB 2003 Annual Meeting, 2003.

Appendix A Assimilated data for link No. 18

speed	delay	Volume	Density	Lost time	link
32.21959	0.481633	2030.26	62.39918	0.01449	9
38.44458	0.481633	1995.699	63.57388	0.012917	9
44.8502	0.481633	2144.577	64.69612	0.009592	9
52.63653	0.481633	2152.894	65.78694	0.012245	9
32.19327	0.522449	2068.884	56.22204	0.020408	10
38.25854	0.339583	2093.582	58.15396	0.017083	10
44.64854	0.227083	2161.431	51.48667	0.012292	10
52.57083	0.341667	2121.066	43.96479	0.013333	10
32.07958	0.216667	2067.515	49.40896	0.018958	11
38.25979	0.339583	2067.319	60.19625	0.015625	11
44.63708	0.227083	2052.299	51.41396	0.014167	11
52.50957	0.353191	2069.11	45.31426	0.010426	11
32.09396	0.535417	2109.781	40.47688	0.016875	12
38.25979	0.302083	2090.247	65.28292	0.018333	12
44.6234	0.231915	1965.235	51.16957	0.014894	12
52.50128	0.355319	2108.674	48.39787	0.012128	12

Appendix B. Base Scenario data

Link	t	v(0)	Volume(0	Density(0	LostT(0)	TravelT	Delay
18	600	56.67	2235.07	39.44	0.02	23.2	0.2
18	660	57.07	1883.22	33	0.02	23.5	0.6
18	720	57.83	1715.5	29.66	0.01	23	0.1
18	780	57.8	1937.86	33.53	0.01	22.9	0.3
18	840	57.66	1983.67	34.41	0.02	22.9	0.5
18	900	57.99	1958.39	33.77	0.02	23	0.3
18	960	57.51	1528.6	26.58	0.01	22.9	0.2
18	1020	57.11	1307.07	22.89	0.01	23.2	0.2
18	1080	57.35	1658.42	28.92	0.01	23.2	0.3
18	1140	56.77	1989.22	35.04	0.01	23.4	0.3
18	1200	57.81	1626.26	28.13	0.01	23	0.3
18	1260	57.75	1619.82	28.05	0.04	22.9	0.7
18	1320	56.8	2233.46	39.32	0.03	23.2	0.7
18	1380	56.95	2065.55	36.27	0.03	23.5	0.6
18	1440	58.8	1397.38	23.76	0.01	22.3	0.2
18	1500	59.02	1701.15	28.82	0.01	22.6	0.2
18	1560	57.17	2340.41	40.94	0.02	23	0.5
18	1620	56.9	1810.06	31.81	0.01	23.4	0.3
18	1680	56.41	1846.85	32.74	0.03	23.4	0.6
18	1740	58.95	1977.21	33.54	0.01	22.7	0.4
18	1800	57.5	2364.15	41.12	0.02	23.1	0.4
18	1860	57.06	1778.65	31.17	0.02	23.1	0.6
18	1920	57.76	1445.69	25.03	0.02	23.1	0.6
18	1980	56.91	2001.86	35.18	0.03	23.3	0.6
18	2040	58.01	1714.8	29.56	0.01	23	0.3
18	2100	54.2	2214.02	40.85	0.05	24.3	1.2
18	2160	58.56	2274.41	38.84	0.02	23.1	0.5
18	2220	58.05	1782.17	30.7	0.01	22.7	0.4
18	2280	58.03	1659.59	28.6	0.02	22.8	0.3
18	2340	58.53	2266.9	38.73	0.02	22.7	0.5
18	2400	56.65	2024.82	35.74	0.02	23.2	0.4
18	2460	58.17	1436.56	24.7	0.03	23.1	0.5
18	2520	58.22	2082.61	35.77	0.02	22.5	0.4
18	2580	56.32	1875.64	33.3	0.03	23.6	0.8
18	2640	58.24	1503.85	25.82	0.02	22.4	0.2
18	2700	57.27	1659.42	28.98	0	23.3	0.3
18	2760	58.68	1965.63	33.5	0.02	22.5	0.2
18	2820	56.92	2108.58	37.04	0.03	23.5	0.9
18	2880	56.49	1959.57	34.69	0.03	23.2	0.7
18	2940	55.96	2248.74	40.19	0.02	23.8	0.6
18	3000	57.94	2165.52	37.38	0.01	23	0.2
18	3060	58.04	1916.07	33.01	0.02	22.7	0.4
18	3120	57.65	1884.16	32.68	0.01	23	0.4
18	3180	56.39	2261.37	40.1	0.03	23.3	0.6
18	3240	56.76	2086.84	36.77	0.03	23.6	0.6
18	3300	58.2	2155.48	37.04	0.02	22.9	0.5
18	3360	57.9	1812.92	31.31	0.02	22.9	0.4
18	3420	58.49	1202.05	20.55	0.01	22.6	0.4
18	3480	60.6	1607.16	26.52	0.01	22.1	0.2
18	3540	56.81	2160.41	38.03	0.02	23.1	0.5
18	3600	56.54	1942.48	34.36	0.01	23.3	0.2

Appendix C. Speed Reduction scenario data

Link	t	v(0)	Volume(0	Density(0	LostT(0)	TravelT	Delay
18	600	49.16	2188.24	44.51	0.04	26.3	0.6
18	660	48.93	2174.98	44.45	0.04	27.9	1.4
18	720	49.85	1709.49	34.29	0.02	26.4	0.5
18	780	51.6	2160.16	41.86	0.02	25.8	0.4
18	840	50.24	1890.75	37.64	0.05	26.4	1.2
18	900	50.95	2127.92	41.77	0.04	25.9	1
18	960	51.27	1309.82	25.55	0.01	25.8	0.3
18	1020	50.37	1433.97	28.47	0.02	26.3	0.3
18	1080	51.29	1669.73	32.55	0.02	26.2	0.6
18	1140	50.01	1916.72	38.33	0.01	26.1	0.3
18	1200	49.05	1702.19	34.71	0.05	27.1	0.9
18	1260	51.14	1778.41	34.78	0.03	26	1
18	1320	49.82	2427.49	48.72	0.04	26.7	1
18	1380	51.19	1823.35	35.62	0.02	26.1	0.6
18	1440	52.94	1706.29	32.23	0.01	25	0.2
18	1500	52.05	1693.83	32.54	0.02	25.5	0.4
18	1560	50.71	2285.73	45.08	0.02	25.9	0.5
18	1620	49.53	2006.75	40.52	0.04	27.1	1.1
18	1680	50.39	1780.25	35.33	0.03	25.7	0.6
18	1740	51.52	1770.18	34.36	0.03	26.3	1
18	1800	50.98	2326.31	45.63	0.02	25.9	0.4
18	1860	48.52	2068.2	42.63	0.04	27.1	1.3
18	1920	51.21	1609.04	31.42	0.02	26.1	0.5
18	1980	49.8	2084.91	41.86	0.04	26.7	1
18	2040	51.04	2004.84	39.28	0.03	26.2	0.7
18	2100	48	2299.4	47.9	0.03	27.5	0.9
18	2160	51.86	2142.72	41.32	0.02	26	0.5
18	2220	51.19	1736.21	33.92	0.01	25.6	0.2
18	2280	51.25	1777	34.68	0.01	26	0.3
18	2340	51.88	2252.32	43.41	0.02	25.3	0.4
18	2400	50.41	2004.55	39.76	0.02	26.2	0.6
18	2460	53.53	1318.05	24.62	0.01	25.4	0.5
18	2520	52.65	1854.75	35.23	0.01	24.9	0.2
18	2580	48.76	1570.61	32.21	0.04	27	1.2
18	2640	51.98	1517.36	29.19	0.02	25.2	0.2
18	2700	50.12	1880.05	37.51	0.02	26.6	0.6
18	2760	51.91	1860.33	35.84	0.02	25.6	0.5
18	2820	51.02	1953.98	38.3	0.03	26.1	0.8
18	2880	49.71	1938.22	38.99	0.05	26.5	1.3
18	2940	49.91	2020.85	40.49	0.01	26.7	0.4
18	3000	50.8	2029.99	39.96	0.02	26.1	0.4
18	3060	49.38	1936.28	39.22	0.05	26.8	1.1
18	3120	50.57	1954.92	38.66	0.02	26.1	0.7
18	3180	49.28	2155.83	43.75	0.04	27.2	1.2
18	3240	50.94	1944.31	38.17	0.03	26.3	0.7
18	3300	50.62	2406.1	47.53	0.03	26.1	0.8
18	3360	50.56	1780.12	35.21	0.02	26	0.5
18	3420	50.68	1312.22	25.89	0.04	26.2	1
18	3480	52.9	1601.49	30.27	0.03	25.2	0.7
18	3540	49.51	1905.06	38.48	0.02	26.5	0.6
18	3600	49.57	1665.55	33.6	0.01	26.5	0.1

Appendix D. Speed Reduction and lane closure scenario data

Link	t	v(0)	Volume(0	Density(0	LostT(0)	TravelT	Delay
18	600	43.63	1954.74	44.8	0.14	28.2	2.2
18	660	32.46	2191.11	67.5	0.36	37.3	10.6
18	720	35.54	1952.03	54.93	0.31	42.9	17.1
18	780	43.97	1885.13	42.88	0.16	28.8	3.4
18	840	34.23	2169	63.36	0.35	37.4	12.1
18	900	43.56	1965.96	45.14	0.17	33.7	8.4
18	960	48.37	1403.93	29.02	0.06	27.4	1.9
18	1020	48.19	1391.9	28.88	0.05	27.5	1.4
18	1080	48.8	1712.98	35.1	0.07	27.6	2
18	1140	43.04	1768.68	41.09	0.16	28	2.7
18	1200	44.1	1591.49	36.09	0.14	32.8	6.1
18	1260	43.75	1944.11	44.44	0.17	30.2	5.1
18	1320	44.43	2277.33	51.26	0.15	29	3.6
18	1380	45.38	2033.15	44.8	0.13	30	4.5
18	1440	45.61	1906.29	41.79	0.13	29.7	4.7
18	1500	48.97	1788.08	36.52	0.09	27.5	2.5
18	1560	41.28	2093.23	50.7	0.21	29.4	4.2
18	1620	43.68	1757.8	40.24	0.15	33.9	7.9
18	1680	45.8	1846.89	40.33	0.11	27.7	2.3
18	1740	47.02	1925.34	40.94	0.12	29.4	4.2
18	1800	46.56	1890.75	40.61	0.11	27	1.4
18	1860	43.27	2052.86	47.44	0.17	31.7	6.7
18	1920	46.53	1627.7	34.98	0.11	28	2.5
18	1980	43.55	2087.27	47.93	0.16	31.3	5.4
18	2040	45.85	1967.7	42.92	0.12	29.2	3.7
18	2100	35.12	1992.2	56.73	0.29	31.5	5.3
18	2160	34.02	2266.18	66.6	0.35	42.6	16.5
18	2220	43.2	1871.88	43.34	0.17	33.5	8.2
18	2280	48.22	1718.64	35.64	0.07	28	2.1
18	2340	45.87	2082.58	45.4	0.12	26.8	1.7
18	2400	37.03	2062.46	55.7	0.28	34.6	9.1
18	2460	49.34	1309.01	26.53	0.07	31.4	5.7
18	2520	47.57	1868.71	39.28	0.1	26.9	1.6
18	2580	45	1971.81	43.82	0.11	29.6	3.6
18	2640	48.38	1570.44	32.46	0.08	27.2	2.2
18	2700	46.58	1986.25	42.64	0.09	29.2	3
18	2760	48.97	1901.97	38.84	0.08	26.3	1.4
18	2820	46.89	1839.11	39.22	0.11	28.8	3.6
18	2880	45.01	1796.15	39.91	0.14	29.1	3.5
18	2940	45.96	1835.99	39.95	0.09	28.7	2.7
18	3000	46.76	1961.17	41.94	0.1	29.1	3.3
18	3060	42.5	1960.78	46.13	0.18	30.2	4.7
18	3120	44.6	1945.75	43.63	0.13	30.4	4.8
18	3180	43.78	2135.23	48.77	0.15	29.7	3.7
18	3240	37.18	2005.32	53.93	0.29	35	9.1
18	3300	30.5	2205.51	72.31	0.42	37.7	12.8
18	3360	41.73	2314.11	55.46	0.2	39.6	13.9
18	3420	48.46	1311.61	27.07	0.08	28.2	3.4
18	3480	49.2	1708.28	34.72	0.09	27.3	2.8
18	3540	45.76	2063.5	45.09	0.1	28.3	2.5
18	3600	47.63	1764.35	37.04	0.07	28	2.1