**An Analysis of Traffic Behavior at Freeway Diverge Sections using Traffic Microsimulation Software**

Nicholas Paul Kehoe

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science In
Civil Engineering

Hesham A. Rakha, Chair
Bryan J. Katz
Sangjun Park

June 22, 2011
Blacksburg, Virginia

Keywords: Freeway Diverge, Microscopic Simulation Models, Lane Distribution, Lane Changing

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# Abstract

Microscopic simulation traffic models are widely used by transportation researchers and practitioners to evaluate and plan for transportation facilities. The intent of these models is to estimate the second-by-second vehicle movements and interactions on such facilities. Due to constraints related to time, budget, and availability of data, these models are typically designed in such a way where the microscopic output is viewed on the macroscopic level. Inherently, this can leave uncertainty to how the model estimates the individual interactions between vehicles on the microscopic level. This thesis utilizes three microsimulation models, INTEGRATION, VISSIM, and CORSIM, to investigate the lane changing behavior as vehicles approach a freeway diverge area. The count of lane changes, lane use distribution, and visual inspection of the simulated lane changing behavior was compared to video data collected at two freeway diverge areas on U.S. 460 in the vicinity of Blacksburg, Virginia during both off-peak and peak periods. It was observed that all three models generally overestimated the number of lane changes near the diverge areas compared to field observations. By modifying the models' lane changing logic, the models were able to closely match field observations in one of the four scenarios. It was found that microsimulation models accurately estimated the lane use distribution. In addition, the INTEGRATION lane use distribution results were found to be more consistent when compared to observed lane use distribution than either VISSIM or CORSIM.

# Acknowledgements

I would like to express indefinite gratitude to my advisor and committee chair, Dr. Hesham Rakha, for his support and guidance throughout the various phases of my graduate career. I would also extend my thanks to my other committee members Dr. Bryan Katz and Dr. Sangjun Park for sharing their time and expertise in order to improve not only my thesis, but my overall knowledge of the subject. In addition, I would also like to express my sincerest thanks to Dr. Hesham Rakha and Dr. Bryan Katz as well as SAIC and VTTI for providing financial and professional support over these last few years.

I would also like to thank everyone else who provided support during my six short years at Virginia Tech. This includes all of the professors who I have ever taken a class with as well as all of the Department of Civil and Environmental Engineering staff. I want to especially thank those who took the time to provide me guidance when I neglected to read the e-mails the first time around: Lindy Cranwell and Val Dymond. Also, I want to thank those in SAIC's Transportation Solutions Division for showing me the ins and the outs as well as those who covered for me when I was underwater from the combination of school and work, especially Heather and Kari.

I want to thank all my friends, especially Fitz, Jimbo, Justin, Nick, Rick, Steve, and Tom for the good times and fun experiences which surrounded my college experience and for showing me the meaning of the work-life balance. From the many road trips to the many long nights, I could not have asked for anything better.

Without question, special acknowledgement goes to my father who always had me reaching to fill the diploma frame and my mother who provided the motivation to continue through it all. I want to thank my brother Mark and my sister Christina for not only providing encouragement and support, but for educating me some of the finer things in life such as hula poppers and the restaurant lemon. Also, I want to thank Xavier for sharing his never-ending hunger for more.

Finally, I would like to thank Chauncey for standing alongside of me throughout the whole process. She provides the support to work through the long days and helps me refocus when the goal gets blurred.

I could not have done it without all of you.

Thank you.

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# Chapter 1 – Introduction

The planning, design, and construction of any transportation facility is something that does not come easily. Every step in the process, from design to operation and maintenance, often takes considerable time, funding, and effort. One of the techniques which researchers have developed to assist in the design process is transportation modeling.

Over the last 50 years, transportation modeling has come a long way. Early transportation modeling started as transportation forecasting. Transportation forecasting is important because it allows practitioners to create transportation facilities of the correct size and function based on future estimates of roadway usage. If a practitioner constructed a roadway without anticipating future traffic flows on the roadway, it would not be long until the roadway would need modification or expansion. On the other hand, if a roadway was built too large for the given demand, funding would have been wasted. While much of this forecasting was conducted manually, the emergence of computers has led to the development of computer simulation modeling tools.

## 1.1     Simulation Modeling

The Highway Capacity Manual defines simulation modeling as a computer program that uses mathematical models to conduct experiments with traffic events on a transportation facility or system over extended periods of time. (1)   Such models are used to simulate real-world conditions, often for planning or evaluation purposes. Traffic models can be broken into three general categories: macroscopic, mesoscopic, and microscopic. Each category of models has a different scope and is generally used for a slightly different purpose. This study will cover a brief introduction of each of the three types of modeling.

### 1.1.1   Macroscopic Modeling

Macroscopic models are those which model on the largest scale. Typically, macroscopic models will use inputs such as free flow speed, density, and capacity and provide outputs on a section-by-section basis. These models are useful to determine demands and volumes over an entire transportation network. These models generally do not consider the vehicle interaction and instead model traffic flow as a fluid stream as opposed to individual particles.

### 1.1.2   Microscopic Modeling

On the smallest scale is microscopic modeling. Microscopic models are models which simulate on a vehicle-by-vehicle basis. These models use inputs such as driver behavior, vehicle characteristics, and the fundamental laws of motion to simulate traffic. Microscopic models calculate the positions and speeds of every vehicles over the course of the study period and are useful for understanding and estimating how traffic will behave on any given transportation facility as opposed to across an entire network.

### 1.1.3  Mesocopic Modeling

A mesoscopic model is a hybrid of both macroscopic and microscopic models, and uses different aspects of each to calculate traffic behavior. For instance, mesoscopic models can simulate vehicle individual vehicles but at a less level of resolution compared to microscopic models. A problem with mesoscopic models is that they can be inconsistent.

## 1.2  Problem Overview

Due to funding and land use constraints, it is often difficult to address increasing levels of congestion with traditional methods such as increasing the number of lanes or creating new transportation facilities. Because of these constraints, greater importance is being assigned to the ability to design efficient transportation facilities or other innovative strategies to increase mobility on already congested roadways. While macroscopic models have their applications, microscopic models can produce a greater understanding of how vehicles will interact on a roadway which could lead to evaluating congestion issues due to the emphasis placed on the deci-second by deci-second movement of each vehicle in the network. Microsimulation models can model different vehicle types and intersection controls, temporal and spatial interactions, different traffic dynamics, behavioral assumptions, and provide visualization of the estimated traffic flow. These attributes make microsimulation attractive to both researchers and planners.

As with all tools, microsimulation is more useful in some situations than others and there are challenges with using such models. The first challenge is regarding calibration. Due to the fact that microsimulation models focus on the interaction between vehicles on less than a second-by-second basis, there are often many parameters which can be modified during the calibration process, making the process time consuming. For the average planner and practitioner, time is of the essence and this calibration process can make models difficult to use. A second challenge with these models is the lack of available data needed to validate these models. Often times planners who would benefit from using a microsimulation model may not have available access to the proper data to calibrate their model. (2)

Another difficulty stemming from microsimulation modeling is ensuring that what is modeled is valid (i.e. accurately replicating field conditions), down to the vehicular level. There is no use in spending time and effort designing, coding, and calibrating such models if they output unrealistic scenarios. This study will investigate a freeway diverge area modeled in different microsimulation packages and provide comparisons to each other and to field data. Microscopic models were used in this thesis because of the fact that they can simulate individual vehicular movements down to the deci-second and as shown above are more useful in investigating vehicle interaction on specific transportation facilities, like a freeway diverge section.

## 1.3  Thesis Objectives

There are two major objectives of this thesis. First, the research conducts a sensitivity analysis of driver behavior at diverge sections using three microsimulation models. This sensitivity analysis explores the affects of deceleration lane length on network performance. Observations

from this analysis provide a need for a closer look at vehicle interactions at freeway diverges. To further explore freeway diverges, the study also collects, analyzes and compares field observations to the three traffic simulation model outputs. The goals of this thesis are to compare microscopic traffic characteristics such as lane changing behavior as well as lane use distribution observed in field observations with those that are estimated by microsimulation models as well as highlight strengths and weaknesses with current microsimulation models.

## 1.4    Research Approach

The literature review of this study contains information from numerous studies on the development and usage of microsimulation models as well as the significance of freeway diverge areas. This information provides the foundation for the remainder of the study.

The modeling approach taken in this study is a two-pronged approach. To highlight challenges with microsimulation software, a sensitivity analysis was conducted with each of the three microsimulation software packages for a diverge area. This sensitivity test examined the changes in simulation output as a function of the number of lanes and off-ramp demand. The findings from this section lead into the need for future analysis and field data collection to validate the study findings.

To obtain the field data needed for a further analysis of a freeway diverge area, video was captured at off-peak and peak periods at two freeway diverge areas of U.S. 460 in Blacksburg, Virginia. These field observations were then visually analyzed to observe traffic volumes and behavior.

Next, the three microsimulation software packages were once again utilized in combination with geometric freeway characteristics and field observed traffic volumes. The field observations were modeled each with ten random seeds to mitigate effects of stochastic variance. In addition, both the default lane changing logic as well as a modified lane changing logic was modeled in an attempt to closely mimic field observations. Finally, the results of the simulation models were compared as well as validated against field observations.

## 1.5    Thesis Contributions

Although research has been conducted on validating microsimulation models with field observations, much of this research focuses on the validation of microscopic simulation models with macroscopic traffic characteristics. These models are often validated to macroscopic traffic data due to the availability of macroscopic data as well as the difficulty in validation using disaggregate data. This thesis will explore traffic behavior at a freeway diverge area at the microscopic level by analyzing vehicles' lane changing behavior as well as lane utilization and compare this to results produced by microsimulation models.

## 1.6    Thesis Layout

This thesis layout will be as follows:

- Chapter 1 – Introduction,
- Chapter 2 – Literature Review,
- Chapter 3 – Microsimulation Sensitivity Analysis of a Freeway Diverge Area,
- Chapter 4 – Data Collection and Modeling,
- Chapter 5 – Results and Discussion, and
- Chapter 6 – Conclusion

# Chapter 2 – Literature Review

## 2.1    Introduction
This literature review consists of two main components.  The first component will explain the significance of freeway diverge areas thus providing a foundation for the subsequent modeling of in this thesis.  Secondly, this literature review contains a review of the elements, development, and use of microsimulation models.

## 2.2    Freeway Diverge Areas
The majority of the literature can be separated into two categories: safety and operations.  The research presented in this study does not directly focus on safety, but it may be possible to correlate the number of lane changes recorded in each scenario with safety as the number lane changes increase, so does the chance of conflict between vehicles.  Also, research presented in this paper looks to analyze the behavior of vehicles on the mainline of the freeway as opposed to the vehicle behavior on the deceleration lane itself.   This research, especially that of the sensitivity analysis, can be directly related to the operational aspects of freeway diverge areas.

### 2.2.1   Safety Aspects of Freeway Diverges
Over 40 years ago, Cirillo analyzed deceleration lane safety as a function of deceleration lane length.  Cirillo's findings determined that as the length of a deceleration lane increases, the risk of an incident between drivers decreases.  (3)

Livneh later analyzed vehicle behavior on deceleration lanes.  Livneh's study reviewed three separate deceleration lanes on: a four-lane freeway interchange, four-lane expressway intersection, and a two-lane highway intersection. Livneh found that short deceleration lanes force vehicles to begin to decelerate in the mainline of the roadway before entering the deceleration lane in order to properly navigate the exit ramp.  Livneh also found that the majority of motorists tend to enter a deceleration lane early and use the majority of the length of the deceleration lane.  (4)

Garcia investigated the safety effects of a deceleration lane based on the length.  In this study, the authors were able to modify the configuration of the deceleration lane with the use of road marking tape.  Through this process, Garcia was able to view driver behavior on eight different deceleration lane lengths ranging from 107 to 440 meters in length.  Garcia found that the deceleration length affected both the speed and safety of the vehicles, and that vehicles tend to decelerate on the mainline regardless of deceleration lane length. The study found that short deceleration lanes are dangerous because the drivers are forced to exit the mainline at a higher speed or to decelerate on the mainline.  It was also found that longer deceleration lanes were dangerous as they can allow vehicles time to accelerate and pass mainline traffic.  The study concluded that a balance of safety and main roadway speeds can be found on intermediate length

deceleration lanes. (5)  These findings differed from those of Cirillo as Cirillo did not note the potential hazards associated with longer deceleration lanes.

El-Basha et al. investigated driver behavior on deceleration lanes in an attempt to construct statistical models to evaluate various driver behavior measures at freeway diverge areas.  This study found that the length of the deceleration lane was a significant factor in driver diverge speed and also the speed differentials between mainline and exiting vehicles.  It was determined that shorter deceleration lanes resulted in a higher speed differential between mainline traffic and exiting vehicles, again showing that exiting vehicles would be forced to decelerate on the mainline before entering a short deceleration lane. (6)

More recently, Chen et al. conducted research of 74 freeway diverge areas in Florida. Researchers used a combination of video data as well as crash records to determine geometric conflicts, a crash analysis, and a crash predictive model.  Chen et al. found that, among other variables, the crash rate at a freeway diverge was a function of the length of the deceleration lane.  This means that the longer the deceleration lane, the more crashes would be seen. (7) While this is very similar to Garcia's finding, Chen et al. did not look at short deceleration lanes.

Furthermore, in an effort to provide additional deceleration lane design guidelines, Zhou et al. utilized CORSIM microsimulation model to predict crash counts, crash rates, percentage of severe crashes, and delay for a number of different deceleration lane lengths.  Similar to previous findings, Zhou et al. recommended caution be taken from designing a deceleration lane which is either too long or too short due to the combination of operational and safety concerns. (8)

### 2.2.2   Operational Aspects of Freeway Diverges
The most significant characteristic of a freeway diverge section is the choice it allows passing motorists.  On any given freeway diverge section, some motorists will continue and remain on the mainline while others will exit the freeway.  In order for the exiting motorists to navigate off the freeway, they will generally need to engage in lane changing maneuvers.  Lane changes, in and of themselves, have been shown to increase delay in a freeway system by Coifman et al. (9) Likewise, Al-Kaisy et al. describe freeway diverge areas as potential bottlenecks.  (10)

Cassidy et al. studied how queues forming on freeway off-ramps affected the mainline flow near the off-ramp.  The authors of this paper studied the vehicular flow on five lanes of a major Interstate.  Data was collected over four days, two with over-saturated off-ramp conditions and two with under-saturated conditions.  The combination of video, floating car runs, loop detector data, and the use of oblique plots allowed the authors to come up with a number of conclusions. First, a bottleneck was observed to have become active at times when there was queuing present in the off-ramp and exit lane.  This bottleneck was found to end with the dissipation of queue in the exit lane.  On days when no queuing was found on the off-ramp and exit lane, the authors did not find the presence of any bottleneck.  These results show that improperly designed off-ramps and deceleration lanes can be the cause of delay to through traffic on the mainline.  (11)

Another challenge with lane changes occurring near a freeway diverge is that these lane changes often trigger an oscillation in freeway flow, much like a kinematic wave. This wave is detrimental to the performance of the freeway as it adds delay into the freeway network. These oscillations seem to be a function of a number of factors, including traffic volume and off-ramp demand. (12)

As has been shown in this literature review on freeway diverge areas, there are a number of both safety and operational issues which can arise from a standard, one lane deceleration lane. In areas of complex traffic patterns and high traffic demand, these simple freeway diverges may not suffice. Lu et al. performed a thorough analysis of 424 diverge areas in Florida, utilizing crash history as well as microsimulation modeling. This study reviewed different exit ramp types, sizes, and signing in relation to their safety and occupational affects. Among other findings, results of this study present minimum deceleration lane lengths to assist in mitigating both safety and operational hazards. (13)

### 2.2.3  Summary of Freeway Diverge Literature Review

Past research has found that while deceleration lanes which were too short were unsatisfactory, deceleration lanes which were too long were also found to be unfavorable. The two main factors which deceleration lanes affect are the: safety of the motorists, and operational issues such as delay which motorists experience. In addition, this research highlights the significance of freeway diverge areas and the importance of correctly designing and constructing such facilities. Because design is often assisted through the use of microsimulation modeling, it is important to investigate how microsimulation models model these areas.

## 2.3    Microsimulation Models

This section of the literature review will begin with an introduction to microsimulation components, followed by an introduction to the three models utilized in this studied, and finally past research performed highlighting the three microsimulation models.

### 2.3.1  Car Following

One of the main components of microsimulation models is the car following model. One of the first groups of car following models was developed by General Motors over fifty years ago. The main characteristic of these car following models was that the response of the following vehicle was directly related to a function of stimulus and sensitivity. The stimulus was derived from a change in headway between following and lead vehicle as well as change in the lead vehicle's speed. The response was defined as an acceleration or deceleration of the following vehicle. (14) Since the creation of the GM car following model, many others have been designed based off of traffic stream models produced by Greenshield, Pipes, and Van Aerde.

#### 2.3.1.1 Greenshield Model

The Greenshield model is one of the older and widely used traffic stream models. This model assumes a linear relationship between speed and density in uninterrupted flow. In addition, this

model assumes a parabolic relation between flow and speed as well as flow and density. One major issue with the Greenshield model is that the speed at capacity is defined to be half of that of the freeflow speed, and this can be difficult to validate using field data. A comparison of the Greenshield model, as well as the Pipes and Van Aerde traffic stream models can be seen in Figure 1.

### 2.3.1.2 Pipes Model

The Pipes model utilizes some of the features of the Greenshield model and adds parameters to more closely model field data. The Pipes model divides the traffic stream into two regimes: uncongested and congested. A short-coming of the Pipes model is the fact that in the uncongested regime, the model does not account for traffic density in the calculation of speed. (15)

### 2.3.1.3 Van Aerde Model

The Van Aerde Model combines some features of the Pipes model with that of the Greenshield model. (16) For example, the Pipes model assumes a constant speed in the uncongested speed with the speed at capacity equal to the freeflow speed while the Greenshield model assumes a nonlinear decrease in speed as the flow increases in the uncongested regime. In the Greenshield model, the speed at capacity is not equal to the freeflow speed, in fact it is often much less. The Van Aerde model maintains a speed at capacity greater than what is found in the Greenshield model, yet less than the freeflow speed as seen in the Pipes model. The advantages of this model are that the speed at capacity does not have to equal the freeflow speed as in Pipes and that the speed at capacity does not have to equal half of the freeflow speed, as seen in Greenshield.
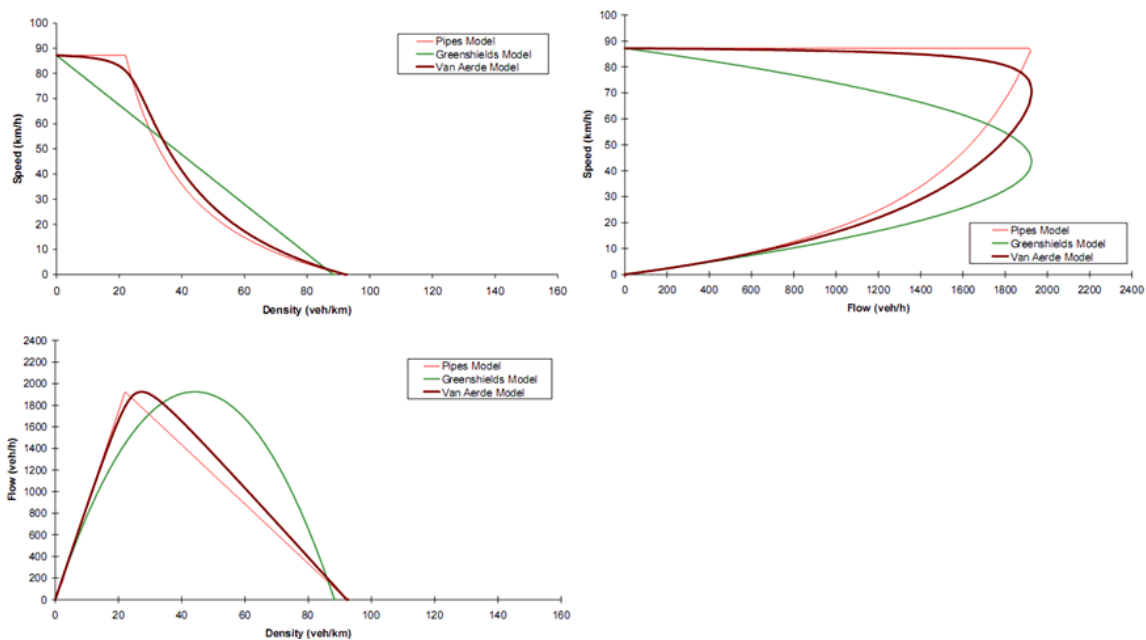


Figure 1: Comparison of Traffic Stream Models (15)

### 2.3.2   Lane Changing Models

Lane changes are generally classified as either mandatory or discretionary lane changes. (17) Mandatory lane changes are those which need to be completed in order for a motorist to maintain on their route to arrive at their destination.  Discretionary lane changes generally occur when traffic conditions in adjacent lanes appear more attractive to the driver than the traffic condition in the current lane.  Other models have been developed to incorporate forced or cooperative lane changing. (18)

The key components of any lane changing model are the location of the target lane, and the location of an appropriate gap in the flow of vehicles in the target lane for the subject vehicle to enter.  The selection of these gaps is often governed in lane changing models by a critical gap; the smallest gap which a driver would safely accept.  This critical gap is calculated as the distance between the vehicles which will become the lead and lag vehicles if the subject vehicle has completed its lane change.  In addition to the critical gap, the driver must also maintain a safe gap between their front bumper and the lead vehicle's rear bumper as well as the subject vehicle's rear bumper and the front bumper of the lag vehicle.

### 2.3.3   Select Microsimulation Models

For the purpose of this study, three microsimulation models were utilized: INTEGRATION 2.3, CORSIM (utilizing TSIS 6.2), and VISSIM 4.3.  These three models were selected for reasons including popularity, availability, and model features.  Specifically, each of these models produces an array of output files needed to understand how vehicles are interacting as well as offer a graphical visualization of the predicted freeway usage for review.

#### *2.3.3.1 INTEGRATION*

INTEGRATION is a trip-based microscopic traffic simulation model capable of illustrating vehicle behavior at the deci-second time step.

INTEGRATION's car following logic follows the Van Aerde model and is based on macroscopic link parameters entered by the practitioner as well as an acceleration and deceleration component.  The practitioner provides link specific free-speed, speed-at-capacity, and jam-density when creating the network, and INTEGRATION calculates vehicle behavior on each link in such a way that traffic flows match the input macroscopic parameters.  INTEGRATION calculates vehicle residual headways at each time step and this determine the action of the vehicle in the following time step.  For example, a following vehicle will estimate excess headway between itself and a lead vehicle.  INTEGRATION considers excess headway the headway between vehicles less the minimum headway.  The excess headway is used to determine a comfortable deceleration rate so that the subject vehicle can achieve the speed of the lead vehicle.  If the lead vehicle is accelerating, the subject vehicle will also accelerate until achieving its desired travel speed.

INTEGRATION's lane changing logic specifies lane changes in two categories: mandatory or discretionary. In this model, mandatory lane changes are usually caused by roadway geometry while discretionary are caused by prevailing traffic conditions. Mandatory lane changes are calculated due to the vehicles need to navigate to their destination. In regard to discretionary lane changes, at every time step each vehicle calculates three speed alternatives. One of the speed alternatives is based on traffic conditions in the current lane while one speed alternative is calculated for each the left and right adjacent lanes determined based on headways and predetermined lane biases. Afterwards, the subject vehicle will attempt to join the lane which offers the highest of the three potential speeds. If a discretionary lane change is desired due to higher potential speed in the adjacent lane, the subject vehicle must then find an appropriate gap before beginning the lane changing maneuver. (19)

### 2.3.3.2 CORSIM

CORSIM (CORridor SIMulation) is a microsimulation model originally developed by the Federal Highway Administration (FHWA) and consists of two main components, NETSIM and FRESIM. NETSIM provides traffic modeling in urban areas while FRESIM is designed to model freeway traffic flow. For the purpose of this study, the FRESIM component will be utilized as this study focuses on driver behavior on a freeway. CORSIM is a stochastic model which utilizes a link and node setup and calculates vehicle behavior on one-second time steps.

CORSIM's car-following logic follows the Pipes' model and assumes the following vehicle maintaining a desired headway between itself and the lead vehicle. This distance is dependent on both vehicle speed and driver type, each of the ten driver types within CORSIM has a designated following headway. When the headway between the subject and lead vehicle is greater than the desired headway, the subject vehicle will accelerate to reduce the headway, or until the subject vehicle is at free flow speed. If the following headway is less than the desired headway, the subject vehicle will decelerate.

CORSIM's lane changing logic is broken into two categories: mandatory and discretionary. A mandatory lane change is defined as a lane change required due to a changes in the geometry of the network, such as a lane drop or exit, which require the vehicle to change lanes to approach the vehicle's destination. On the other hand, a discretionary lane change is completed when vehicle speeds in neighboring lanes are more desirable than the speed in the current lane. Vehicles making mandatory lane changes will accept much higher deceleration rates than those performing discretionary lane changes. (20)

### 2.3.3.3 VISSIM

VISSIM is a microscopic traffic modeling package produced by Planning Transport Verkehr AG (PTV AG) which utilizes time steps up to the deci-second and a behavior based simulation to model urban traffic operations. VISSIM consists of two internal components, a traffic simulator and a signal state generator which communicate with each other to determine vehicle behavior.

The traffic simulator is the component which controls the microscopic vehicle interactions such as the car-following and lane changing actions. The traffic simulator determines these actions based off of input from the signal state generator. For each time step, the signal state generator detects values from the traffic simulator, determines signal status for the following time step, and provides this signal status to the traffic simulator. The traffic simulator using this input to determine vehicle actions for the following time step, records any analysis information for output files, and the process repeats.

The car-following logic in VISSIM is based on the psycho-physical driver behavior model produced by Wiedemann (1974). This model performs an iterative process of acceleration and deceleration to model driver car-following behavior. The basis for this iterative process is that a driver cannot determine the exact speed of a lead vehicle and thus when approaching a slower moving vehicle, will decelerate to a speed less than that of the lead vehicle followed by an acceleration to a speed greater than the lead vehicle. By continuing this process, the following vehicle can maintain an appropriate following speed. This model has been calibrated by multiple field measurements at the Technical University of Karlsruhe, Germany.

VISSIM's lane-changing logic is broken into two categories: necessary lane changes, and general lane driving behavior. This naming configuration differs from the other two models, but the intent of the lane changes is the same as mandatory and discretionary lane changes. Necessary lane changes are those needed to navigate to the desired destination while general lane driving behavior describes vehicles performing discretionary lane changes. In both cases, this behavior is controlled by the maximum and accepted deceleration rates by the subject and lead vehicle. In addition, VISSIM allows the user to define a lookback value to describe the distance upstream which the vehicle would begin to move to an appropriate lane anticipating a downstream movement such as a diverge area. (21)

### 2.3.4  Calibration and Validation Efforts

This section of the literature review will cover current and past studies on calibration and validation of microsimulation models.

The current practice for calibration and validation is generally based on characteristics such as congestion, maximum queue length, speed, travel time, and density rather than vehicle behavior and interaction. In addition, often times these variable are averaged over many simulations and only reviewed on specific links. (20) The reason why models are calibrated in this fashion is mainly due to the combination of lack of time and lack of proper data sources. Macroscopic data are easily collected through the use of items such as loop detectors (16) while sources of microscopic traffic behavior include video data. While loop detector data can easily produce aggregate recordings ready to use for calibration, video data contain thousands of still frames which need to be analyzed either with a video analyze algorithm or manually. Manual video inspection is often too time consuming and costly to implement, and image processing algorithms are often difficult to apply. (22)

To add another challenge to model calibration is that this calibration process is often a trial-and-error process or based on an educated estimation rather than an automated procedure. Due to this lack of an automated process, often times these models will have default values left for any value which the practitioner was unsure or did not have available data to analyze. (23) Common use of default parameters show that any problems with default model parameters may be introduced into simulation results and thus provide a flawed foundation for any decision-making process.

Microsimulation models can also produce unrealistic behavior on the microscopic level which may not translate to the macroscopic level. For instance, Gomes et al. (24) recommend setting VISSIM diffusion parameter from its default value of 60 seconds to 1 second to calibrate the model in their study. VISSIM's vehicle diffusion parameter allows a vehicle stopped for a specified time period to leave the network. In this case, Gomes' recommends that the vehicles will leave the network after being stopped for one second. While this may help create realistic travel times when comparing to field data, this is a completely unrealistic activity not seen in the real-world.

In addition, other studies have shown that while inputs and output values may seem to be accurate, without close inspection of the visualization, one cannot be sure of the validity of the simulation output. (25) As microsimulation models are inherently time consuming to code and calibrate, the step of reviewing the visualization creates an additional level of difficulty to utilizing such models, especially if the network is complex or many random seeds are simulated.

Many of these challenges with microsimulation models led Fox to write a report questioning the use of microsimulation models. (26) Fox highlights that microsimulation models can have challenges accurately portraying capacity, lane changing and car following behavior, and traffic assignment. Fox recommends neglecting microsimulation modeling in favor of an integrated approach which would combine attributes of both mesoscopic and microscopic models.

### 2.3.5   Model Challenges and Shortcomings

Both CORSIM and INTEGRATION appear to be more sensitive to improper roadway designs, such as improper freeway geometric characteristics, than VISSIM. For example, in both CORSIM and INTEGRATION, if the network is improperly designed the model will often provide an error message and refuse to run the simulation. While VISSIM does provide error messages as well, they did not seem to be as common as the other models. There are instances where VISSIM will begin a simulation although freeway geometries are not realistic, such as an improperly coded connector between links which routes vehicles to change lanes as they cross links when they should remain in their current lane. While it can be frustrating to receive a number of warning or error messages and failures when attempting to conduct the simulation, one of the most important functions of microsimulation models is the ability to properly estimate traffic behavior, and this cannot happen without realistic roadway networks for the traffic to transverse.

Another challenge regarding microsimulation models is required inputs. INTEGRATION seems to take the most logical approach by having the user input macroscopic traffic stream characteristics such as free-flow speed, speed at capacity, and jam density. Both CORSIM and VISSIM request that the user enter driver behavior parameters which are often adjusted so that the simulated traffic flow match observed macroscopic traffic characteristics. In addition, parameters used in both CORSIM and VISSIM are much more difficult to measure in the field as opposed to the macroscopic traffic parameters requested by INTEGRATION.

### 2.3.6   Summary of Microscopic Model Literature Review

This section of the literature review provides insight into microsimulation models, their components, and current practices for their usage. It is seen that many microsimulation models have the same general structure with regards to car-following and lane-changing logic. These models can vary in the ways of which data is input and the roadway network is designed. Models such as VISSIM and CORSIM utilize input parameters related to individual driver behavior and contain a GUI to assist in the modeling of the roadway network. On the other hand, INTEGRATION utilizes a more macroscopic approach allowing practitioners to input macroscopic traffic parameters.

In general, microscopic model calibration is often a time consuming trial and error type of process, specifically when practitioners are required to modify such driver behavior parameters not easily obtained from readily accessible data. Because of this challenge, often times practitioners leave default values in the model and this can lead to faulty model output.

Finally, literature has shown that even properly calibrated models are susceptible to unrealistic behavior and this should be noted and closely monitored. The goal of any microsimulation model is to portray realistic driver interactions and any simulation producing unrealistic behavior should be disregarded.

# Chapter 3 – Sensitivity Analysis

Much of the basis for this study was the realization that certain freeway and deceleration lane configurations created unexpected results when simulated in the three microsimulation models presented above. This chapter presents the results of a sensitivity analysis conducted with each of the three models to compare the models and understand how they are affected by the traffic volume, the number of lanes along the freeway, and the length of the deceleration lane.
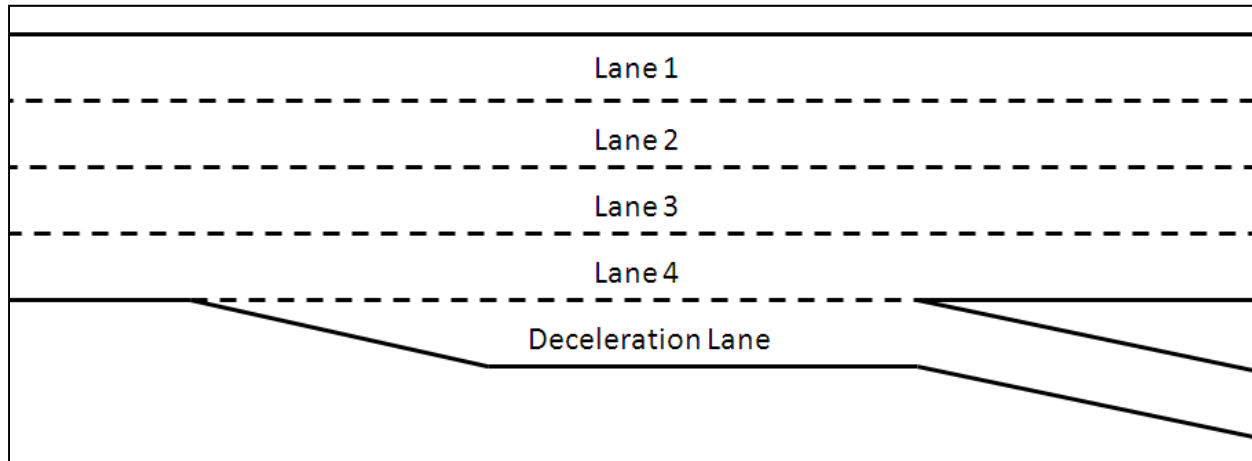
## 3.1    Model Development

Figure 2: Model Layout for Four Lane Freeway Scenario

A segment of freeway was modeled that was two, three, and four lanes of width. The notation for lane numbering began with lane one located adjacent to the median and the lane number increasing as the lane approached the deceleration lane, as seen in Figure 2. For example on the three lane freeway segment lane one would be adjacent to the median, lane two would be the center lane, and lane three would be the lane adjacent to the deceleration lane. Each scenario had the freeway modeled using a base capacity of 2,350 vehicles per hour per lane, a free-flow speed of 104.6 kilometers per hour (65 miles per hour), and deceleration lane speed of 72.4 kilometers per hour (45 miles per hour). Each segment of freeway was modeled with a configuration including either: no deceleration lane, a 50 meter, a 100 meter, a 150 meter, a 200 meter, and a 250 meter deceleration lane. In all configurations, different scenarios with off-ramp demand levels of 5%, 10%, 15%, 20%, and 23% of the total traffic volume were examined. The highest off-ramp demand, 23% of the total traffic volume, is the capacity of the off-ramp in the four lane freeway segment. Scenarios were also modeled for a freeway with a free-flow speed of 88.5 kilometers per hour (55 miles per hour) and ramp speed of 64.4 kilometers per hour (40 miles per hour). All scenarios were modeled using ten random seeds and results reported are the mean across these ten runs.

In addition to the above mentioned configurations, another set of models were created with a feature of INTEGRATION called the lane bias to over-ride the default lane biases within the

software. Lane bias allows specific groups of vehicles, in this case through or exiting traffic, to have a preferred lane of usage. For all scenarios with lane bias enabled, there is a bias for both the through and the exiting traffic. The through traffic had a bias against traveling in the lane adjacent to the deceleration lane, and this bias is constant from the beginning of the freeway segment until the exit. Exiting traffic was biased away from the lane adjacent to the median. The bias value increases as the exiting vehicles approach the diverge point, yet it remains constant for the through traffic. Because it is possible to relate this feature to driver's familiarity with the roadway, such as commuters, this feature was utilized to try to determine if there is a significant difference between driver behavior with and without familiarity of the roadway layout.

Similarly to how the scenarios were modeled in INTEGRATION with a lane bias, in VISSIM the scenarios were modeled with the lane change parameter in the exit ramp connector at the default (200 meters), and at a much higher value (1,000 meters). The 1,000 meter value allows the drivers to become aware of the exit ramp much earlier than they would have otherwise, and begin to change lanes anticipating the ramp. Again, each of these scenarios was modeled with ten random seeds.

One default setting in VISSIM not included in INTEGRATION or CORSIM is the ability for a vehicle stopped for a set period of time to diffuse, or disappear from the network. Because in reality vehicles do not disappear from the network after being stopped for a period of time, this setting has been modified so no vehicles will be removed during the simulations.

The results obtained from each model's output were reviewed to investigate the average delay of the vehicles as well as the distribution and number of lane changes which occurred.

## 3. 2   Results
This section summarizes the results of the simulation sensitivity analysis. Initially the results from the INTEGRATION runs are presented followed by the results from VISSIM and then CORSIM.

### 3.2.1   INTEGRATION Results
The average delay per vehicle was used to compare the simulated driver behavior for each of the freeway models. The results are shown in Figure 3, Figure 4, and Figure 5. For the majority of the scenarios, it can be seen that there was more delay produced with a 50 meter deceleration lane as opposed to a freeway configuration without a deceleration lane. In many scenarios, the 50 meter deceleration lane produced the highest delay. This high level of delay was more prominent as the off-ramp demand and number of lanes increased. In all scenarios, as the length of the deceleration lane increased, the average delay decreased, excluding the 50 meter deceleration lane configuration. A reason for this delay may be due to drivers attempting to minimize their personal delay by remaining in the left lanes followed by changing lanes to exit the freeway at the last opportunity creating a disruption in flow. This behavior should be further

investigated to determine if it is realistic. It should be noted at this point that the required deceleration lane length to decelerate from a speed of 104.6 to 72.4 kilometers per hour (65 to 45 miles per hour) is 108 meters per the AASHTO's *Policy on Geometric Design of Highways and Streets (Green Book)* so the 50 m deceleration lane would represent an under-designed facility.

The results indicate the following:

a. The delay increases as the proportion of exiting vehicles increases. This finding appears to be intuitive.
b. A substandard design deceleration lane can produce higher delays compared to the case with no deceleration delay. This finding may appear counter intuitive and thus will be investigated further.
c. The benefits of a deceleration lane are significant, however by increasing the length of the deceleration lane beyond the needed length the delay reductions diminish. These delay reductions are minimal especially for the three- and four-lane configurations.
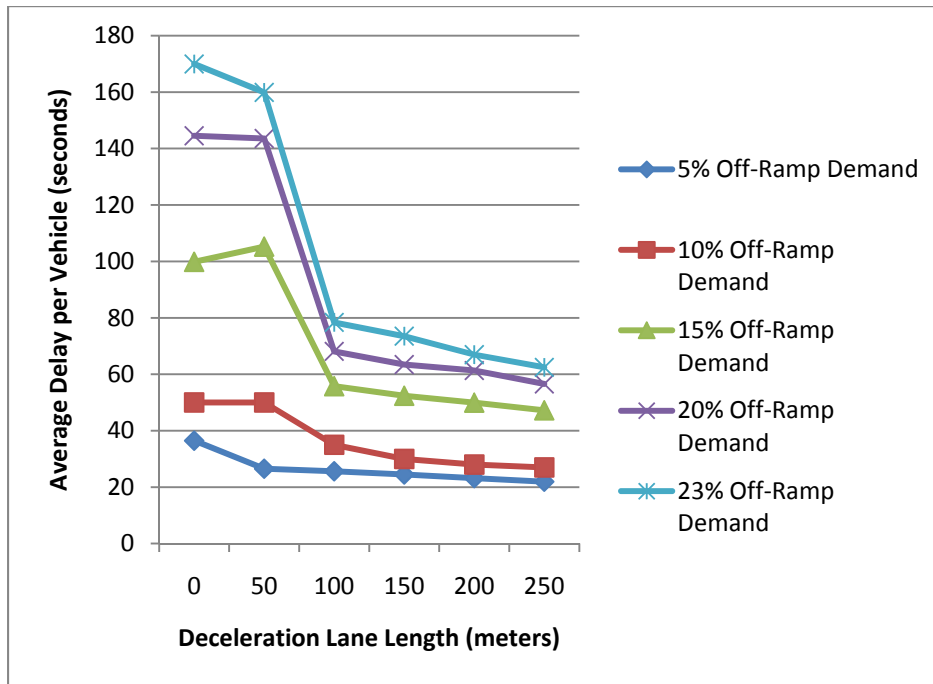


**Figure 3: INTEGRATION Results for a Two-lane Freeway**

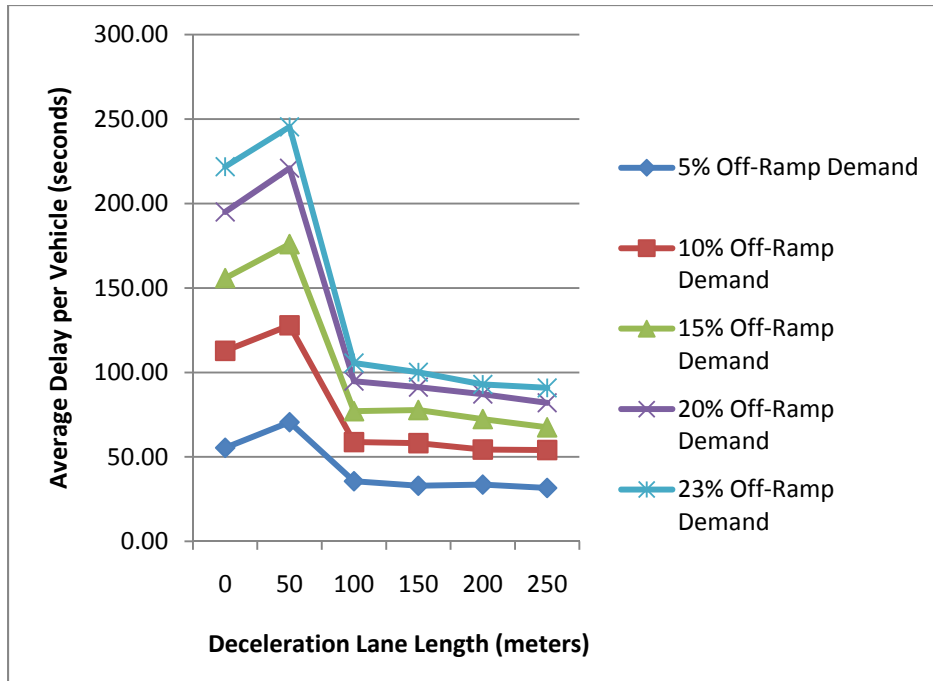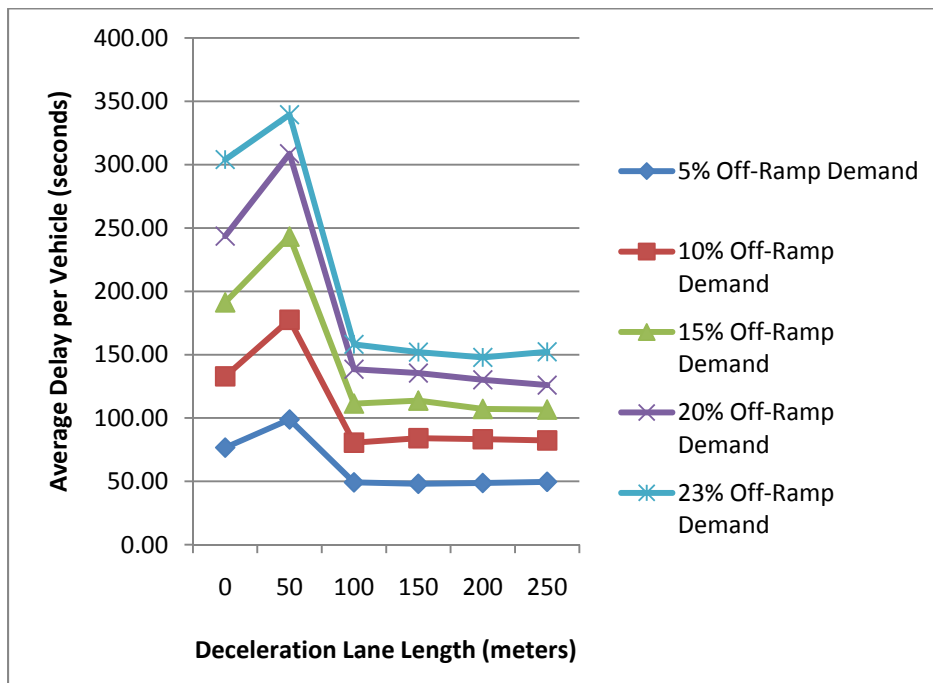**Figure 4: INTEGRATION Results for a Three-lane Freeway**



**Figure 5: INTEGRATION Results for a Four-lane Freeway**

It was hypothesized that this increase in delay for scenarios with the 50 meter deceleration lane was due to the lane-changing behavior within the INTEGRATION software. To further investigate these findings, time-space trajectories of each vehicle was extracted from the

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INTEGRATION model results, and the location, origin lane, and destination lane of each lane change was recorded. This information allowed the distribution of lane changes to be compared across the different scenarios. Figure 6 shows the typical lane-changing distribution for the no deceleration lane scenario.



**Figure 6: Typical Lane Changing Distribution for a Configuration without a Deceleration Lane**

Figure 6 shows the lane changing distribution for all vehicles in a typical INTEGRATION scenario of a three lane freeway segment with 15% off-ramp demand and no deceleration lane. The exit ramp is located in the 10th bin in the figure. Two important findings are portrayed in this figure, namely: how the lane changes are distributed, and where the majority of the lane changes to lane three occur. This figure shows that the lane changing distribution for this scenario is bi-modal in shape, with one peak approximately 300 meters prior to the exit, and the second approximately 100 meters prior to the exit. It is interesting to note that in the ninth bin, between 50 and 100 meters prior to the exit, the majority of the lane changes take place from lane two to lane three. Because this freeway configuration does not include a deceleration lane, vehicles exited the freeway directly from lane three. The majority of the lane changes prior to this point were vehicles moving away from the exit, either from lane two to lane one or lane three to lane two.

**Figure 7: Typical Lane Changing Distribution for a Configuration with a 50 meter Deceleration Lane**

Figure 7 shows the typical lane changing distribution for all vehicles in a typical INTEGRATION scenario with the same configuration as the previous example, except with the addition of a 50 meter deceleration lane. In contrast to the previous figure, the lane changing distribution was found to be skewed towards the exit. The vehicles were found to have performed a minimal number of lane changes, and waited much longer to make these changes in comparison to the configuration without a deceleration lane thus introducing additional delay. It should also be noted that in comparison with the previous example, there were very few lane changes noted from lane three to lane two.
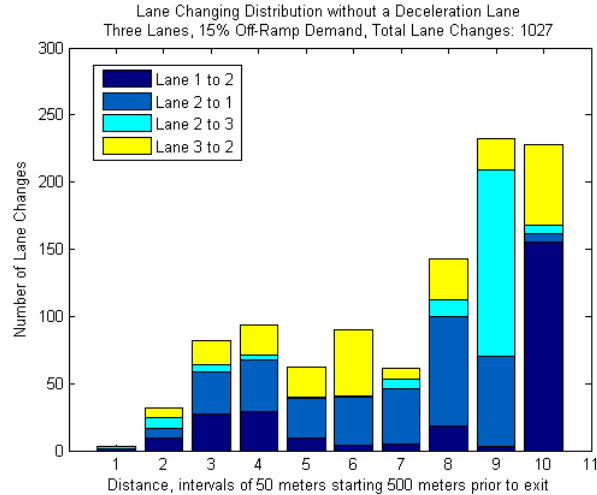


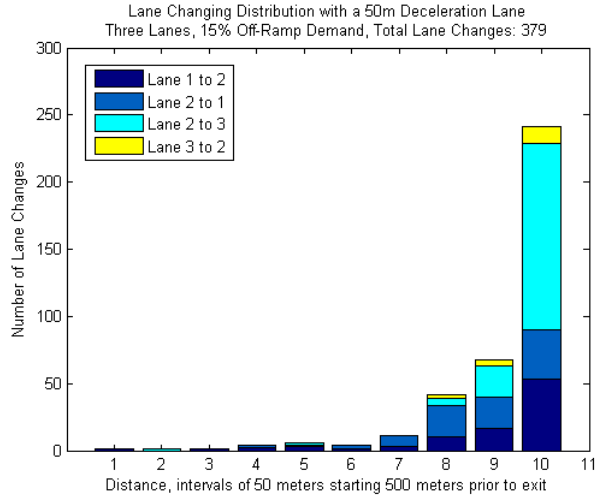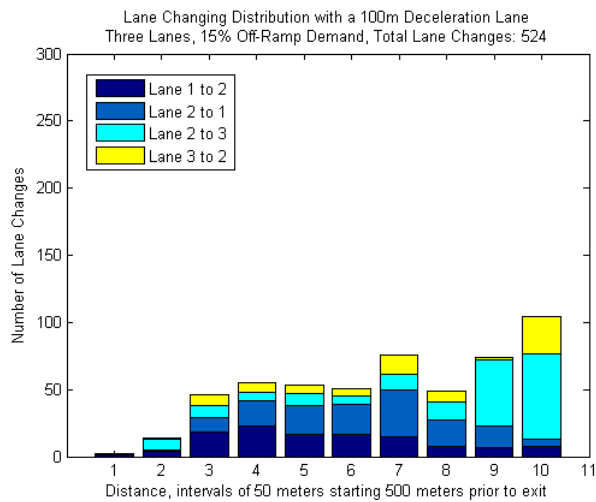**Figure 8: Typical Lane Changing Distribution for a Configuration with a 100 meter Deceleration Lane**

Figure 8 shows the lane changing distribution for all vehicles in a typical INTEGRATION scenario with the same configuration as the previous two examples, except with a 100 meter

deceleration lane. The addition of the 100 meter deceleration lane drastically changes the driver behavior in comparison to the scenario with the 50 meter deceleration lane. The lane changing distribution for the 100 meter deceleration lane is found to be much more uniform than the lane changing distribution of a 50 meter deceleration lane. This uniform distribution of lane changes results in a reduction in the system delay. It should also be noted that in comparison with the previous two examples, there were more vehicles changing into lane three farther from the exit.

The overall number of lane changes was often found to be greatest in scenarios without deceleration lanes and found to be least in scenarios with 50 meter deceleration lanes. The scenarios including the remaining deceleration lanes were often found to have a similar number of lane changes, but the number of lane changes did not seem to correlate with the length of remaining deceleration lanes.

Exiting vehicles were found to have made the majority of their lane changes much closer to the exit in the scenarios with the 50 meter deceleration lane. When there was a configuration with a longer deceleration lane, the distribution of lane changes was much more uniform over the course of the freeway. It is interesting to note that when comparing the lane change distribution of a freeway configuration with no deceleration lane to one with a 50 meter deceleration lane, INTEGRATION distributes the lane changes for the configuration with no deceleration lane in a more uniform pattern than that of the 50 meter deceleration lane. Because there is such a difference between the lane changing distribution between freeway configurations of a 50 meter deceleration lane and that without a deceleration lane, it is important to gather field data to characterize empirically how drivers behave in the vicinity of short deceleration lanes. It should be noted again, that the 50 meter deceleration lane is a substandard design given that the minimum length for this speed difference is 108 meters, per AASHTO's *Policy on Geometric Design of Highways and Streets (Green Book)*.

In an effort to determine the effect on this distribution of lane changes, all scenarios were modeled with the added lane bias parameter. It was found that with the lane bias, the scenarios including a configuration with a 50 meter deceleration lane often produced as much or more delay than the same scenario without a deceleration lane. This is similar to the results without the lane bias.

The distribution of lane changes have been plotted below to show how the distribution was affected by the lane bias. In comparison with Figure 7 and Figure 8, it can be seen that the vehicles began to change lanes earlier with the lane bias as opposed to the scenarios above without it. Configurations including a 50 meter deceleration lane were not affected to the same degree as the other configurations, and this is the reason why with the lane bias enabled, the configurations including a 50 meter deceleration lane still had more delay than a configuration without a deceleration lane.
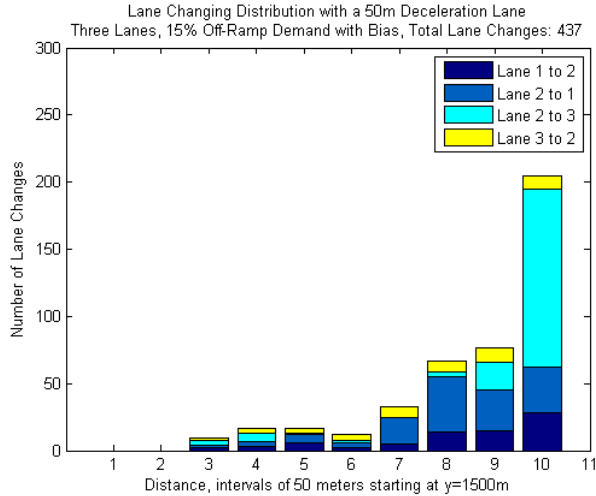
**Figure 9: Typical Lane Changing Distribution for a Configuration with a 50 meter Deceleration Lane and Lane Bias**
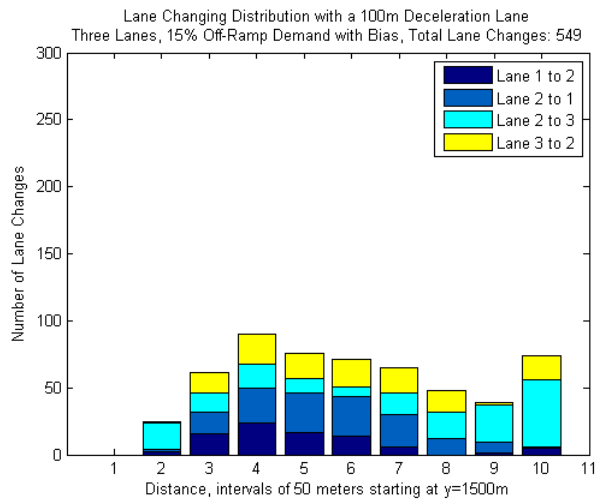


**Figure 9 Typical Lane Changing Distribution for a Configuration with a 100 meter Deceleration Lane and Lane Bias**

All scenarios were also modeled with freeway free-flow speeds of 88.5 kilometers per hour (55 miles per hour) and deceleration lane free-flow speeds of 64.4 kilometers per hour (40 miles per hour). The results were found to be consistent with the original results for the two lane scenarios. The 50 meter deceleration lane produced less delay than the case without a deceleration lane, but in the three and four lane scenarios, the 50 meter deceleration lane produced more delay than that of the configuration without a deceleration lane. In all scenarios, the amount of delay decreased as a function of the deceleration lane length, with an exception to the 50 meter deceleration lane configuration, which was an under-designed deceleration lane.

### 3.2.2   VISSIM Results

Results from VISSIM provided similar results in some cases and different results in other cases. Many of the scenarios produced more delay associated with a configuration having a sub-

standard 50 meter deceleration lane than a configuration without a deceleration lane, as illustrated in Figure 10, Figure 11, and Figure 12.

The findings can be summarized as follows:

a. As with the case with INTEGRATION a sub-standard deceleration lane design produces more delay compared to the base no deceleration lane configuration.

b. The delays increase by increasing the length of the deceleration lane beyond 200 m. This behavior appears to be counter intuitive and suspicious and thus will be analyzed further.

c. As was the case with the INTEGRATION model results, an increase in the volume of exiting vehicles results in an increase in the overall system delay.



**Figure 10: VISSIM Results for a Two-lane Freeway**

**Figure 11: VISSIM Results for a Three-lane Freeway**



**Figure 12: VISSIM Results for a Four-lane Freeway**
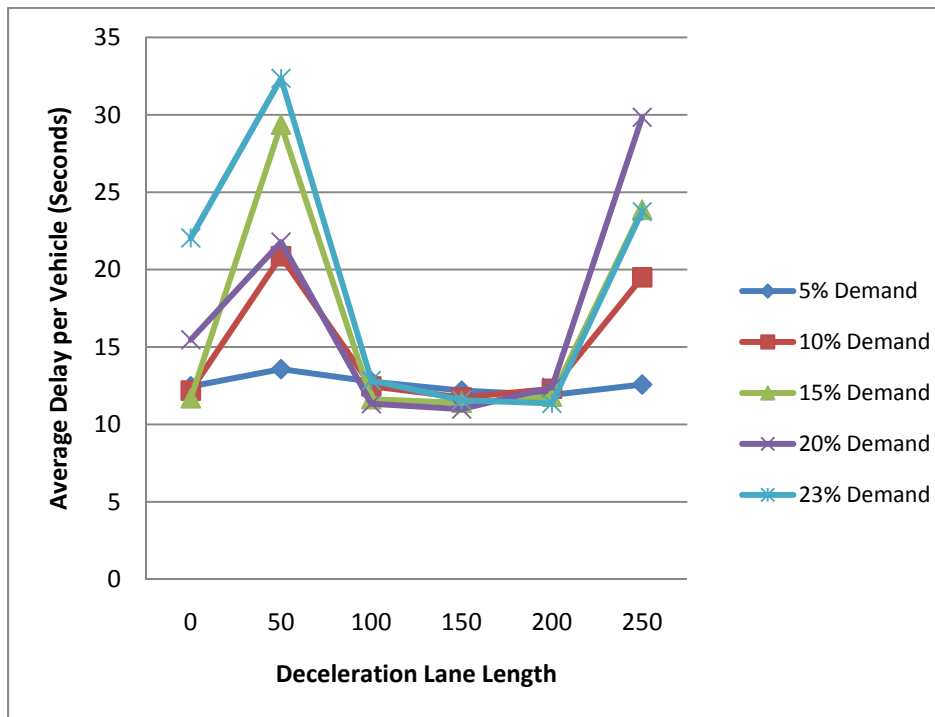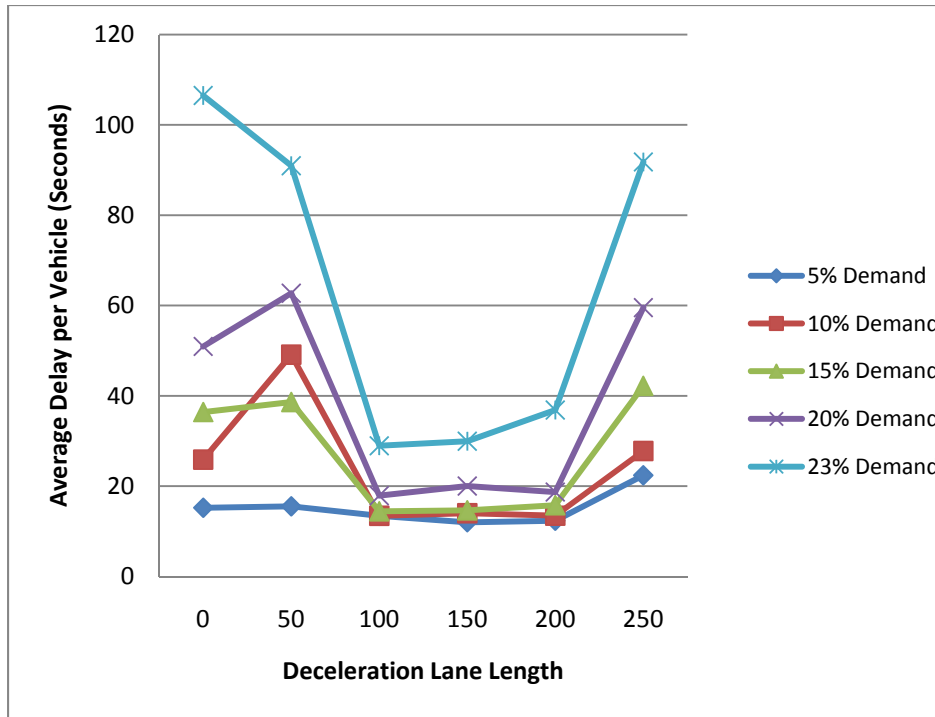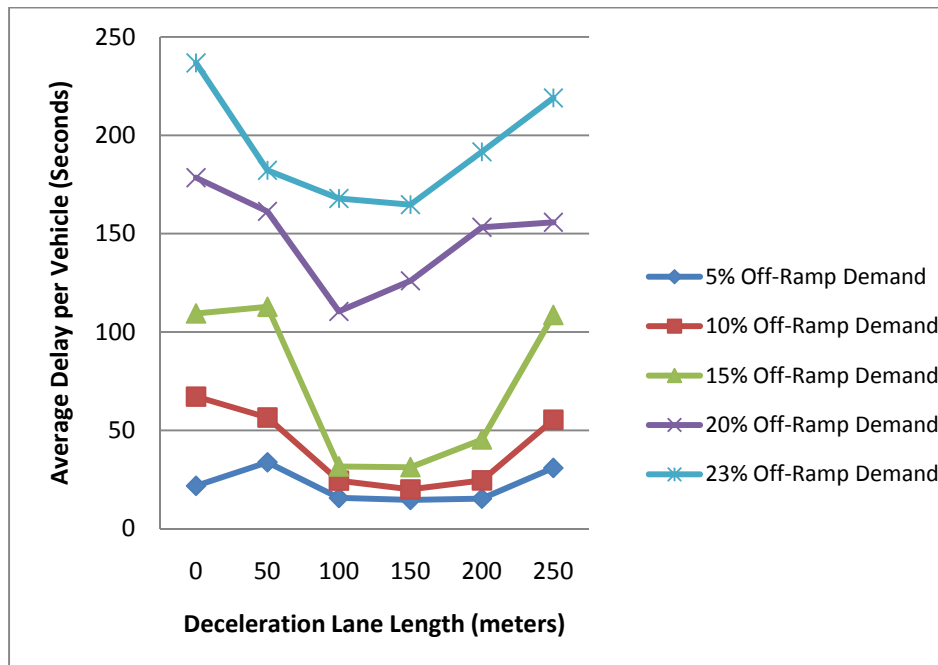
A major discrepancy exists between the results found with INTEGRATION and those found with VISSIM. In INTEGRATION, it was found that the delay associated with each scenario

decreased as the length of the deceleration lane increased, excluding the 50 meter length. The results from VISSIM show that in all scenarios, a 250 meter deceleration lane results in an increase of average delay.

A visual inspection of the VISSIM simulation provided a clue to the cause of this large increase of delay associated with the 250 meter deceleration lane configuration. It was seen that in scenarios with this configuration, often times vehicles would use the deceleration lane to attempt to pass mainline traffic. This behavior does not appear to be realistic as motorists do not general use deceleration lanes for discretionary lane changes. Vehicles attempting to exit the freeway would then come in conflict with through-vehicles using the deceleration lane to pass mainline traffic, and additional delays would ensue. During the INTEGRATION simulations, vehicles were not found to use the deceleration lanes to pass mainline traffic.

### 3.2.3   CORSIM Results

The results of the CORSIM sensitivity analysis can be seen in Figure 13, Figure 14, and Figure 15. Unlike both INTEGRATION and VISSIM, CORSIM estimates the delay to decrease as a function of the deceleration lane length with minimal variation. Of the three scenarios, the most interesting is the two lane freeway. CORSIM calculates an increase in delay in the 150 meter deceleration lane as opposed to the 50 meter deceleration lane. None of the other models displayed this characteristic. The results of CORSIM seem to imply that regardless of the length of the deceleration lane the delay remains fairly constant. This finding appears to be unrealistic as shorter deceleration lanes will cause drivers to decelerate on the mainline and cause delay to through vehicles. Additionally due to CORSIM's stochastic nature and lack of origin-destination tables, some simulation seeds had up to 10 percent of the exiting vehicles disregarding their destination and remaining on the mainline. These vehicles remaining on the mainline could also explain some of the differences in delay in comparison to the other models.

In summary the findings or CORSIM are:

a.  For the two-lane configuration the exiting volume has no impact on the overall system delay. This behavior is very suspicious.
b.  Increasing the length of the deceleration lane has no impact on the system delay in the case of the two-lane configuration and minimum effects for the three- and four-lane configurations.
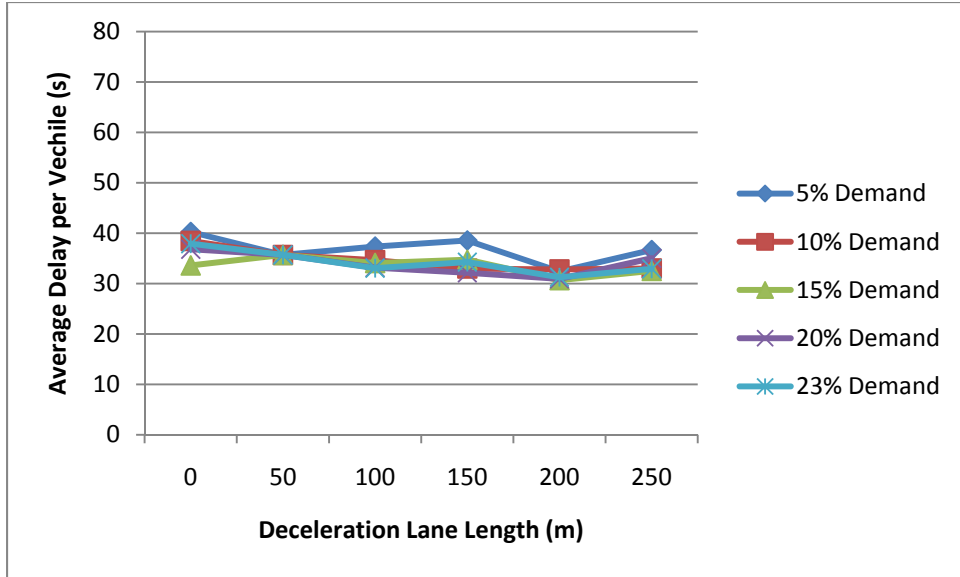
**Figure 13: CORSIM Delay for Two Lane Freeway**
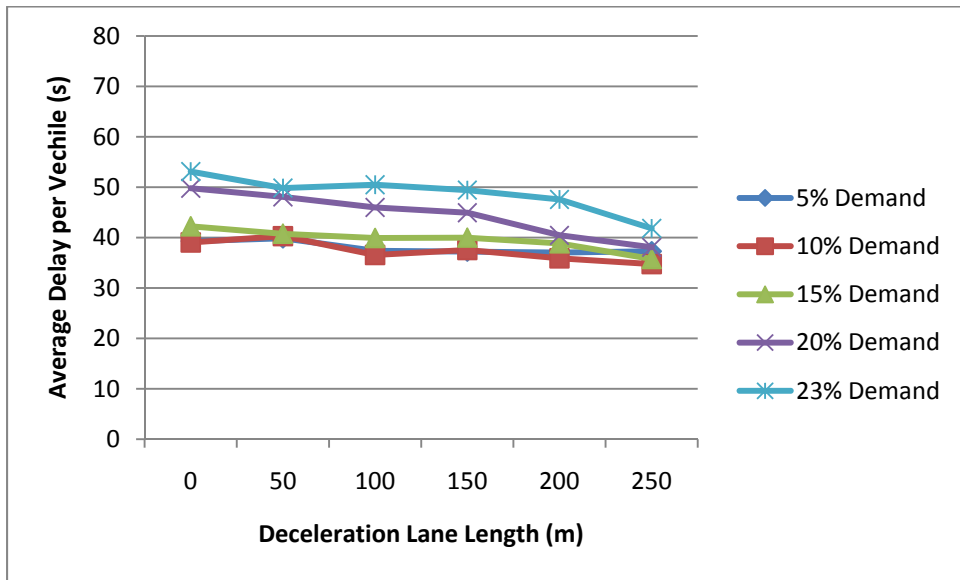


**Figure 14: CORSIM Delay for Three Lane Freeway**
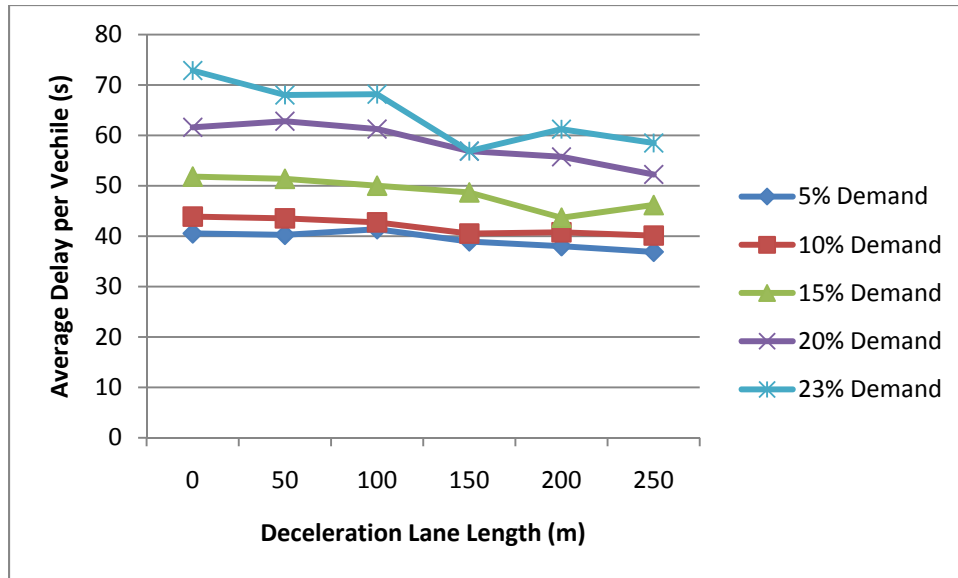
**Figure 15: CORSIM Delay for Four Lane Freeway**

## 3.3    Sensitivity Testing Results

The table below displays the relative change in delay between the configuration without a deceleration lane and each configuration of varying deceleration lane length.  All off-ramp demands for each freeway segment were averaged together to arrive at these values.  This table again shows the consistency of the INTEGRATION results.  A reason for VISSIM's lack of consistency may be due to the fact that the default VISSIM setting allowing vehicles to diffuse from the network was disabled.  With this setting disabled, it is possible that a vehicle may have become "trapped" while waiting to make a mandatory lane change.  If this happened, additional delay would have been added to the results.

Table 1 shows that as the number of lanes increase, INTEGRATION calculates that the percentage of additional delay added to the network due to a 50 meter deceleration lane in comparison to a scenario without a deceleration lane also increases.  VISSIM was found to have the largest percentage increase of delay for a scenario with a 50 meter deceleration lane in comparison to a scenario without a deceleration lane for the two lane freeway segment.  As the number of lanes increased, this increase in delay decreased.  As mentioned previously, Table 1 shows that the 250 meter deceleration lane is found to produce more average delay regardless of the number of lanes for VISSIM, and this greatly contrasts the findings in INTEGRATION.  INTEGRATION shows that a 250 meter deceleration lane will have nearly half the amount of average delay for all lane tests in comparison to a configuration without a deceleration lane.

There are two important items to note when reviewing the results from the CORSIM analysis.  The first item is that CORSIM estimates a decrease in delay for almost every deceleration lane length, as opposed to both INTEGRATION and VISSIM.  The only exception is the 200 meter

deceleration lane on the two lane freeway. The second item is that in general, CORSIM produces less significant savings for each deceleration lane length in comparison to those derived from INTEGRATION and VISSIM. For example, for a three lane freeway with a 200 meter deceleration lane, INTEGRATION calculates a reduction in delay of about 52%, VISSIM 50%, but CORSIM only calculates a reduction of delay of 11%.

Overall the results produced by the INTEGRATION and CORSIM software appear to be more realistic given that they do indicate

   (a) A decrease in system delay as the deceleration lane length increases,
   (b) The marginal benefits of increasing the length of the deceleration lane above the recommended value is minimal,
   (c) An under-designed deceleration lane can be worse than not providing a deceleration lane. This finding, however, needs further investigation using empirical data.

**Table 1: Relative Change in Average Delay**

|  |  | 0 Meter | 50 Meter | 100 Meter | 150 Meter | 200 Meter | 250 Meter |
|---|---|---|---|---|---|---|---|
| **INTEGRATION** | Two Lanes | 0% | -6% | -42% | -46% | -49% | -52% |
|  | Three Lanes | 0% | 16% | -48% | -49% | -52% | -54% |
|  | Four Lanes | 0% | 26% | -42% | -42% | -43% | -43% |
| **VISSIM** | Two Lanes | 0% | 64% | -13% | -17% | -14% | 53% |
|  | Three Lanes | 0% | 21% | -52% | -52% | -50% | 15% |
|  | Four Lanes | 0% | 2% | -46% | -47% | -37% | 1% |
| **CORSIM** | Two Lanes | 0% | -5% | -8% | -8% | -15% | -9% |
|  | Three Lanes | 0% | -2% | -6% | -6% | -11% | -16% |
|  | Four Lanes | 0% | -2% | -3% | -11% | -12% | -14% |

## 3.4   Sensitivity Testing Conclusions and Recommendations

This research presents the need to gather empirical data on driver behavior in the vicinity of off-ramps especially those that include very short deceleration lanes. It should be noted that because the 50 meter deceleration lane was less than the design length specified in AASHTO's *Policy on Geometric Design of Highways and Streets (Green Book)* for a freeway with the given design speed, it is unlikely that one would find deceleration lanes of this length in real-world situations.

The calculated optimal length of a deceleration lane as per the Green Book is 108 meters for the design speed of 104.6 kilometers per hour (65 miles per hour) and ramp speed of 72.4 kilometers per hour (45 miles per hour). (27)

Overall the results produced by the INTEGRAION and CORSIM software appear to be more realistic than those produced by VISSIM given that they do indicate:

(a) A decrease in system delay as the length of the deceleration lane increases,
(b) The marginal benefits of increasing the length of the deceleration lane above the recommended AASHTO value is minimal,
(c) An under-designed deceleration lane can be worse than not providing a deceleration lane. This finding, however, needs further investigation using empirical data.

## Chapter 4 – Data Collection and Modeling

### 4.1    Data Collection

To collect video data for this study, a research vehicle equipped with a telescoping arm and camera was used.  This vehicle can be seen in Figure 16.  This vehicle was utilized due to its mobility, ease in set-up, and availability.



**Figure 16: Research Vehicle with Camera in the Lowered Position**

Four potential test sites were located in the vicinity of Blacksburg, Virginia. Video data were recorded in multiple positions at each of these potential test sites and reviewed to ensure that the video recorded captured vehicle behavior as the vehicles approached the diverge area.  Instances of poor camera placement revealed that the captured video did not include adequate video to track each vehicle approaching the diverge area.   Examples of research vehicle placement included: on the shoulder downstream of the diverge point, on the shoulder upstream of the diverge point, on the opposite side of the freeway looking perpendicularly at the diverge area, and parked off of the freeway in adjacent parking lots.

Reviewing the video data at each of the potential locations revealed that there was difficulty selecting a proper location to record video data of vehicles approaching the freeway diverge. While setting the research vehicle downstream of the diverge area allowed for the collection of vehicles entering the deceleration lane, it was often difficult to observe vehicle behavior as they

approached the deceleration lane.  Locating the research vehicle on the opposite freeway approach only allowed the view of a very small section of freeway to be recorded due to the field of view and provided little to no value when trying to analyze vehicle behavior.

Locating the test vehicle on various parking lots adjacent to the freeway allowed for a wide view of vehicles as they approached the freeway diverge, but the long distance from the diverge made it difficult to track vehicle movements across roadway lanes.  In some cases, potential recording locations adjacent to the freeway were surrounded by trees which obscured the view of the freeway.

It was determined that the most practical video was collected when the research vehicle was parked on the shoulder with the camera looking upstream.  In this position, the camera was raised and aimed upstream to capture vehicle behavior as they approached the diverge area of the freeway.  Care was taken to follow guidelines on recording traffic video as documented in a whitepaper to the Florida Department of Transportation. (28)

One hour of video data was collected and analyzed at each of two sites during peak and non-peak periods, making a total of four hours of video data.  These sites were chosen due to a number of reasons including geometric design considerations and accessibility for the research vehicle.  With the camera positioned facing upstream, it was important that the selected locations have relatively little horizontal curvature.  Because the best field of view was obtained when the camera was faced upstream to the approaching motorists, the research vehicle needed to be parked on the roadway shoulder.  At both locations, there was adequate shoulder or clear-zone space where the vehicle could be parked with little to no disruption to passing motorists.  In addition, these test sites offered differing lengths of deceleration lanes.

### 4.1.1   Site A
Site A is located on U.S. 460 in Blacksburg, Virginia and included a lengthy deceleration lane which is estimated to be approximately 225 meters in length, including a taper.  This site was selected due to its wide shoulders and unobstructed view upstream.  This exit is used heavily during morning peak hours as it provides access to industrial and business park areas.  During the afternoon peak period, many Virginia Tech employees utilize the mainline of this route as they end their working day and return home.  At this location, the research vehicle was situated upstream of the diverge point.

### 4.1.2   Site B
Site B was also located on U.S. 460 and included a much shorter deceleration lane which was approximated as 150 meters in length, including the taper.  It is important to note that while this deceleration lane is estimated at 150 meters in length, the taper is very long in comparison to the deceleration lane which can make this lane appear shorter to the driver.  This site was primarily selected due to the short deceleration lane.  It was desirable to compare driver behavior near longer and shorter deceleration lanes. This exit is heavily used during the afternoon peak period

as it provides access to downtown Blacksburg. Because of the lack of shoulder upstream of the diverge point, the research vehicle was situated just downstream of the diverge area at this site.

## 4.2    Analysis Approach

### 4.2.1  Video Data Analysis

The video data collected from the two test sites were analyzed visually and information regarding origin-destinations and lane changing behavior was recorded. Counts and locations were recorded for each lane change, and these records were aggregated into approximately fifty meter increments to determine how vehicles were behaving prior to the diverge area. Because the video recorded at Site A where the research vehicle was positioned upstream of the diverge area did not include exiting vehicles, a manual vehicle count of the exiting vehicles was recorded during the data collection period.

### 4.2.2  Modeling

A model of a two lane freeway diverge section was created to match the conditions of the field data in each of the three microsimulation models used in this study: INTEGREATION, VISSIM, and CORSIM. Google Earth was used to determine estimates of geometric elements while observation of the data collected at each site provided the traffic volumes and origin-destinations.

As each of the three models had slight differences, precautions were taken to ensure that the results of each model were comparable to the others. For instance, CORSIM does not offer a specified capacity parameter for the freeway. Instead, the capacity was defined by calibrating vehicle headway and length parameters to match the capacity coded in the other two models. In addition, VISSIM's vehicle diffusion setting was adjusted to the maximum setting to prevent any vehicles from diffusing from the network.

## 4.3    Results and Discussion

All results discussed in this section consist of running each model ten times using different random seeds and averaging the data.

### 4.3.1  Overall

To get a better perspective of how the different models are calculating lane changes, Figure 17 shows the number of lane changes estimated by each of the three models for three kilometers prior to the diverge area, in bins of 200 meters using parameters similar to Site A. All lane changes from the mainline to the deceleration lane are not included in this figure, nor are they in any other figure or table in this study. This figure shows that VISSIM calculates a very high number of lane changes prior to the diverge area while CORSIM shows that the number of lane changes peak near 400 to 600 meters prior to the diverge area. These peaks are directly related to the lookback parameter in each of the models. This parameter allows the practitioner to determine where the motorists will learn of the diverge area.

Of the three models, both CORSIM and VISSIM utilize such a feature, whether it is VISSIM's lookback parameter of CORSIM's off-ramp reaction point. INTEGRATION is the only model which does not allow the entry of a single distance of which the vehicles learn of the upcoming change in freeway geometry. Instead, INTEGRATION allows the use of lane bias which entices the motorists to change lanes away from the lanes they are set to be biased against. Again, the lane bias parameter is different from the other two models as this bias can be changed to vary in degree and can span over the course of multiple links. The benefit of this, as opposed to determining a single value, is that it allows a more varied distribution of lane changes. The default value for this parameter is 200 meters (656 feet) in VISSIM and 762 meters (2500 feet) in CORSIM.
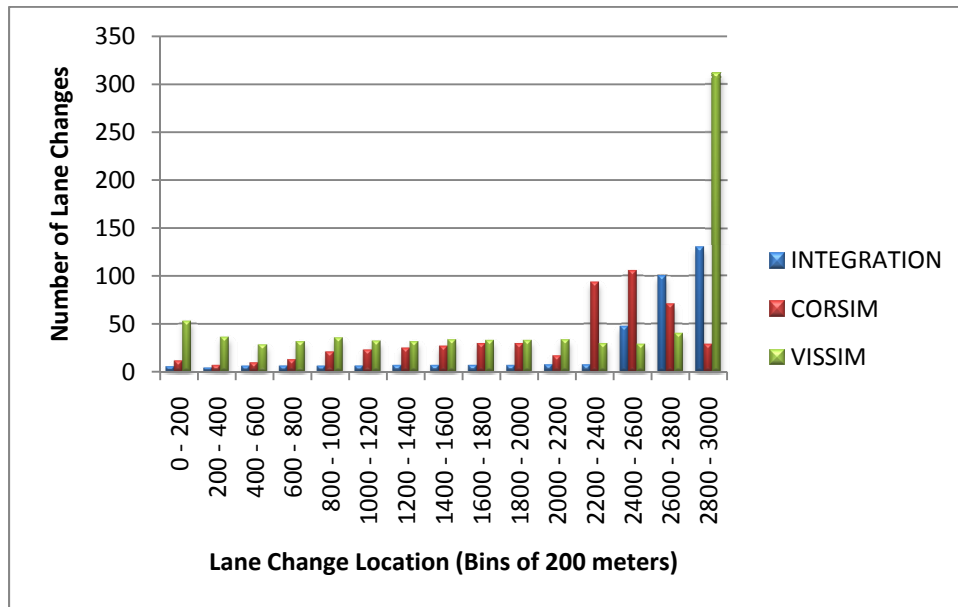


**Figure 17: Lane Changes Excluding Changes to Deceleration Lane**

The purpose of this research will not be to completely calibrate each model to the site conditions determined from the video data, but will be to validate the models against the field data.

## 4.3.2   Default Lane Changing Logic

### 4.3.2.1 Site A

Figure 18 illustrates the number of lane changes observed at Site A during the off-peak period in the field observations as well as in the three microsimulation outputs.
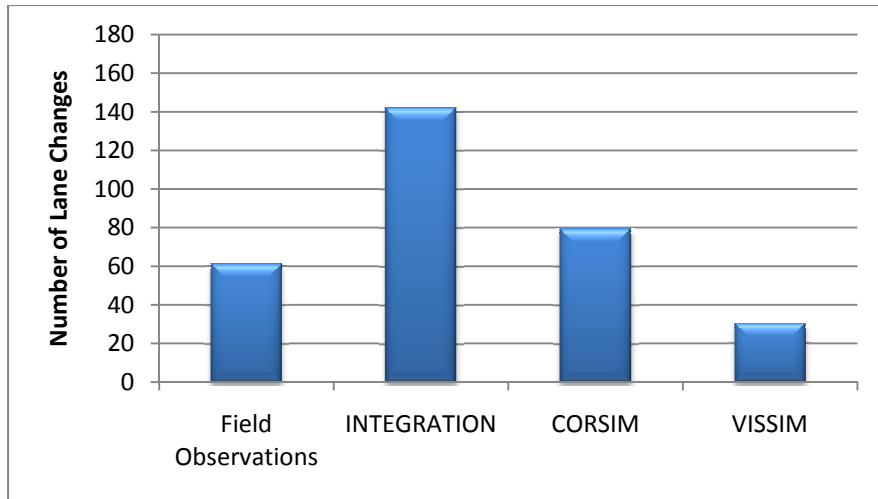
**Figure 18: Count of Lane Changes 200 Meters Prior to Deceleration Lane at Site A (Off-peak Period)**

As illustrated in Figure 18, the CORSIM output provided the most similar number of lane changes prior to the deceleration lane as observed in the field. VISSIM calculated a lower number of lane changes than what was observed while INTEGRATION calculated a greater number of lane changes.

Figure 19 illustrates the lane change count from Site A during peak periods. In this example, it can be seen that while all three models greatly overestimated the number of lane changes, VISSIM provided the closet estimate followed by CORSIM and finally INTEGRATION.



**Figure 19: Count of Lane Changes 200 Meters Prior to Deceleration Lane at Site A (Peak Period)**

To properly analyze Figure 18 and Figure 19, one must take into consideration two items: the location of field observations as well as the distribution of lane changes per model. Figure 17 shows that using INTEGRATION's default parameters, there is minimal lane changing

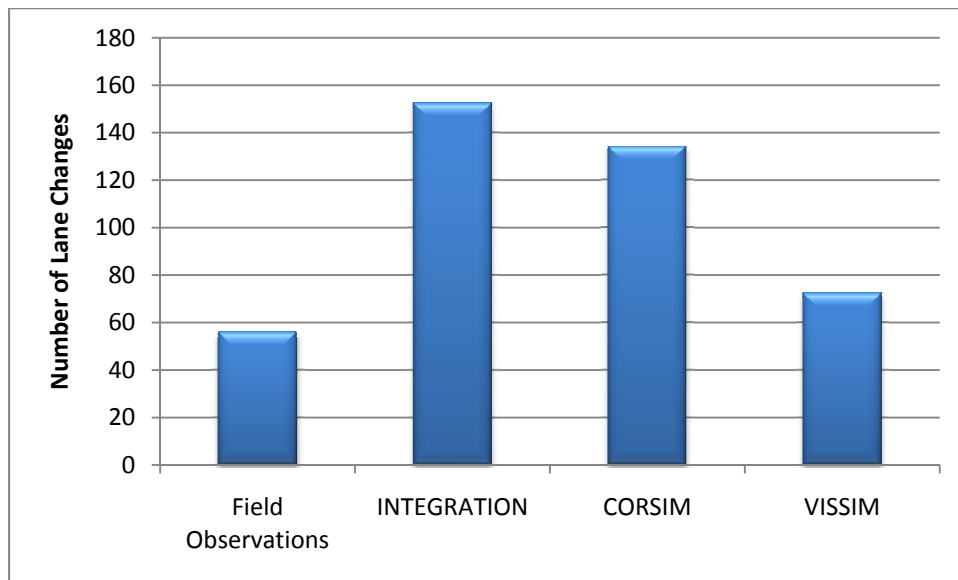occurring, in comparison to the other two models, until around 500 meters prior to the diverge point where the intensity of lane changing begins to increase. On the other hand, CORSIM estimates that in this scenario the greatest number of lane changes occur between 400 and 600 meters prior to the diverge area, and the lane changing intensity decreases closer to the diverge point. Finally, VISSIM estimate a fairly even number of lane changes over the course of the freeway with a significant increase in the number of lane changes within the last 200 meters of the freeway.

With this information in mind, one can see that Figure 18 and Figure 19 represent an overestimate by INTEGRATION as the field observations were captured in the location to where INTEGRATION began to increase lane changing intensity. Much to the same effect, VISSIM is shown to underestimate the number of lane changes because the field observations were taken in an area upstream of the area where VISSIM calculates the highest number of lane changes.

### 4.3.2.2 Site B

Figure 20 displays the lane change count from Site B during the off-peak time period. All three models were found to overestimate the number of lane changes.
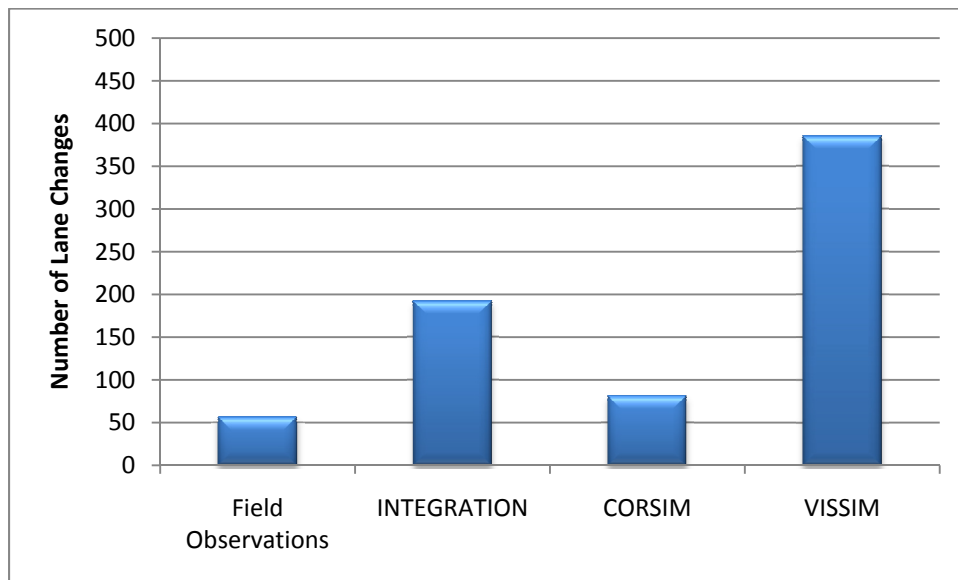


**Figure 20: Count of Lane Changes 150 Meters Prior to the Diverge Area at Site B (Off-peak Period)**

Figure 21 displays the lane change count from Site B during the peak time period. In this example, all three of the models overestimated the number of lane changes. Again, all three of the models overestimate the number of lane changes occurring in this area.
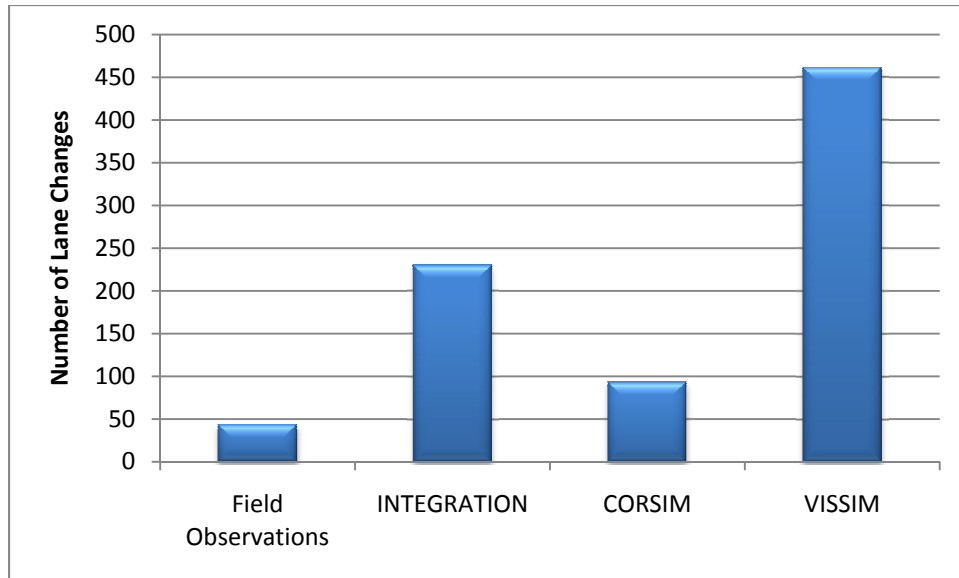
**Figure 21:  Count of Lane Changes 150 Meters Prior to the Diverge Area at Site B (Peak Period)**

It is interesting to note that in both instances, fewer lane changes were noted in the vicinity of the diverge area in the peak period in comparison to the off-peak period from the field observations. None of the models reviewed in this study exhibited similar behavior.  From the author's observations and passive driver behavior witnessed in the study area, this decrease in lane changes observed in the field immediately prior to the diverge area signifies that these motorists change lanes a distance upstream of the diverge area.  With this being the case, it is easy to see why CORSIM most accurately predicted the number of lane changes in each of the four cases; CORSIM's default lane changing logic notifies drivers of diverge areas the farthest upstream out of the three models.

### 4.3.3   Modified Lane Changing Logic

In order to more accurately compare these models on the number of lane changes in the area immediately prior to the diverge area, both INTEGRATION and VISSIM had their lane changing logic adjusted to mimic the logic of CORSIM.  This adjustment was a simple change of VISSIM's lookback value to 762 meters, the same value which CORSIM uses, and the addition of a lane bias in INTEGRATION.  No other parameters were modified in any of the models. This adjustment is an attempt to persuade each model to simulate lane changes in a similar fashion and observe the overall outcomes.

### *4.3.3.1 Site A*

Figure 22 below illustrates the number of lane changes estimated prior to the diverge area in addition to the number observed in the field for the off-peak time period.  It can be seen that the addition of a lane bias to the INTEGRATION model as well as a modification of the lookback parameter in VISSIM drastically changed the number of lane changes and all three models now produce  much  closer  estimations  to  that  of  the  field  observations.    For  this  scenario,

INTEGRATION's estimation was exactly that of the field observations, CORSIM overestimated, and VISSIM underestimated.
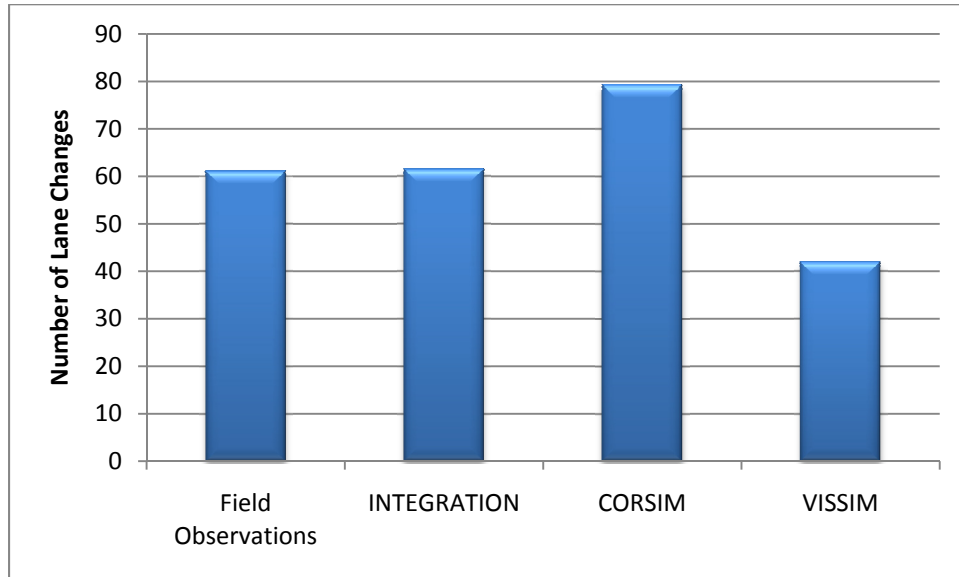
**Figure 22: Count of Lane Changes 200 Meters Prior to Deceleration Lane at Site A (Off-peak Period) With Lane Changing Logic Adjustment**

Figure 23 illustrates the number of lane changes estimated prior to the diverge area in addition to the number observed in the field for the peak time period.  In this scenario, each of the three models once again overestimates the number of lane changes in comparison to the field observations.  In comparison to the estimations without modifications to the lane changing logic, presented in Figure 19, each of the three models produce similar estimates with one and another.
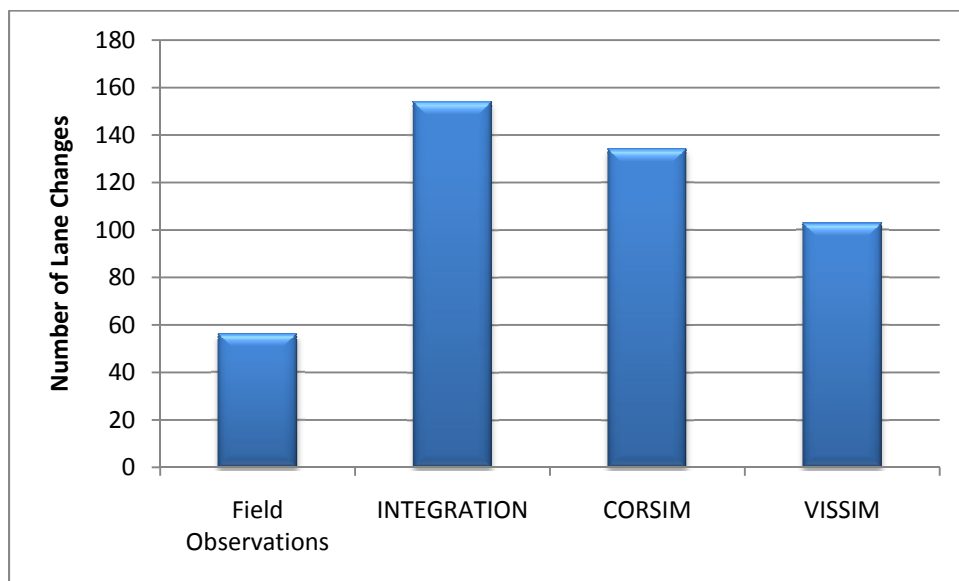
**Figure 23: Count of Lane Changes 200 Meters Prior to Deceleration Lane at Site A (Peak Period) With Lane Changing Logic Adjustment**

### 4.3.3.2 Site B

Figure 24 illustrates the number of lane changes estimated prior to the diverge area of Site B in addition to the number observed in the field for the off-peak time period.  It can be noted that although the lane change logic modifications did reduce the estimations produced by both INTEGRATION and VISSIM, they still overestimate the number which was observed in the field.



**Figure 24: Count of Lane Changes 150 Meters Prior to the Diverge Area at Site B (Off-Peak Period) With Lane Changing Logic Modifications**

Figure 25 illustrates the number of lane changes estimated prior to the diverge area of Site B in addition to the number observed in the field for the peak period.  Again, both the estimations produced by INTEGRATION and VISSIM have decreased from the estimations produced using the default lane changing logic, they still overestimate the number of lane changes in comparison to what was seen in the field data.

In both scenarios for Site B, the lane changing logic modification greatly improved the estimation produced by VISSIM in comparison to the field data and created some consistency between INTEGRATION and VISSIM's estimation.
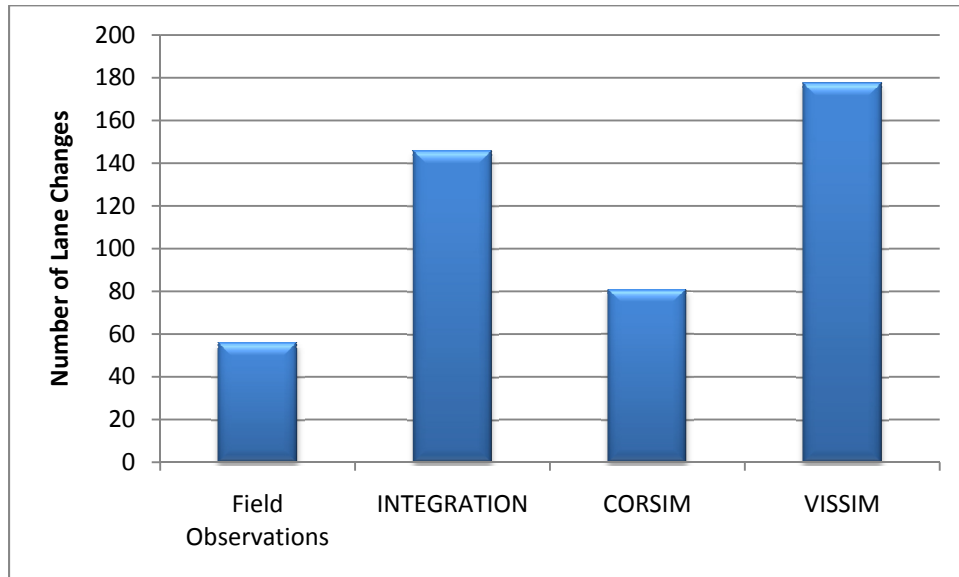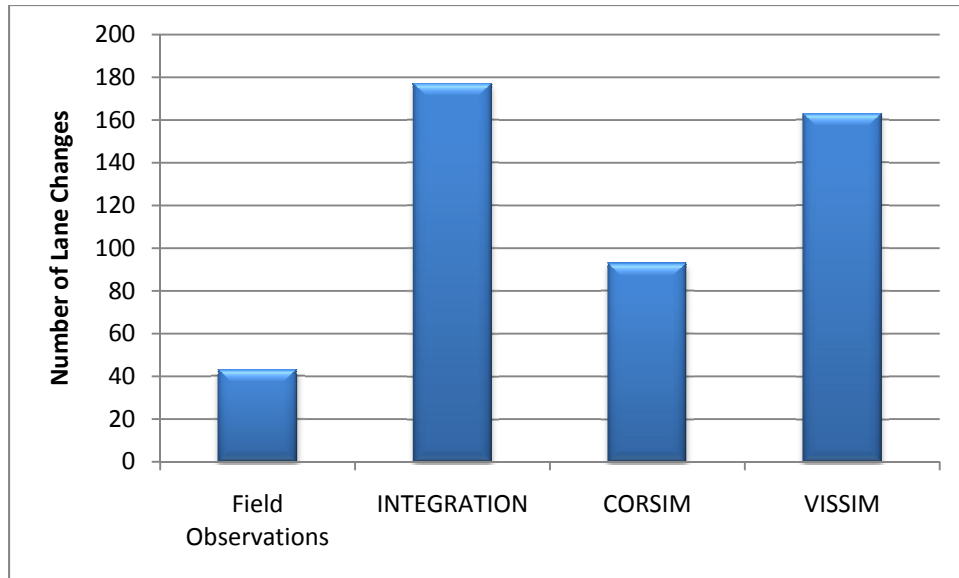
**Figure 25: Count of Lane Changes 150 Meters Prior to the Diverge Area at Site B (Peak Period) With Lane Changing Logic Modifications**

### 4.3.4  Comparison of Lane Distribution

The lane distributions were obtained from the video data at each site and compared to the results from each of the three models, using default and modified lane changing logic. The field lane utilization values were determined from the number of vehicles leaving the screen per lane. Simulation values were extracted from model output at points representing the same locations as were used in the field data analysis.

Table 2 illustrates the lane distribution values for all three models as well as both the default and modified lane changing logic. It can be seen that CORSIM does not have a modified lane changing logic listed as the results of the previous section demonstrated that the default CORSIM lane changing logic was appropriate for this case study and that the other two models had their lane changing logic adjusted in an attempt to match CORSIM's. The root mean square error (RMSE), as defined in Equation 1, for each of the models is listed in the rightmost column. It should be noted that in this table, the lane use percentages have been rounded to the nearest percent, but the computation of the RMSE uses the entire unrounded percentage taken as an average over each of the ten random seeds.

**Equation 1: Root Mean Square Error**

$$RMSE = \sqrt{\frac{1}{3}\sum_{i=1}^{2}\left(Y_i^{sim} - Y_i^{obs}\right)^2}$$

*where:*
*i is the lane, 1 equal to the left lane and 2 equal to the right lane,*
*$Y_i^{sim}$ and $Y_i^{obs}$ are the observed and simulated percentage of vehicle lanes distributions on lane i.*

Table 2 shows that the models tend to overestimate the utilization of the left lane in both the off-peak and peak periods.  In the off-peak period, INTEGRATION with the default lane changing logic is found to produce the least RMSE in comparison to the field data.  For the peak period of Site A, it is found that CORSIM produces the least RMSE in comparison to the field data.

**Table 2: Site A Lane Distribution**

| Site A - Off-Peak | | | | |
|---|---|---|---|---|
| Model | Lane Changing Logic | Lane 1 (Left) | Lane 2 (Right) | RMSE |
| Field, Off-Peak | N/A | 42% | 58% | N/A |
| INTEGRATION | Default | 41% | 59% | 0.011 |
| INTEGRATION | Modified | 51% | 49% | 0.090 |
| CORSIM | Default | 45% | 55% | 0.031 |
| VISSIM | Default | 50% | 50% | 0.079 |
| VISSIM | Modified | 38% | 62% | 0.045 |

| Site A - Peak | | | | |
|---|---|---|---|---|
| Model | Lane Changing Logic | Lane 1 (Left) | Lane 2 (Right) | RMSE |
| Field, Peak | N/A | 40% | 60% | N/A |
| INTEGRATION | Default | 47% | 53% | 0.066 |
| INTEGRATION | Modified | 50% | 50% | 0.098 |
| CORSIM | Default | 45% | 55% | 0.047 |
| VISSIM | Default | 50% | 50% | 0.104 |
| VISSIM | Modified | 45% | 55% | 0.052 |

Again, Table 3 shows that the models tend to overestimate the utilization of the left lane in both the off-peak and peak periods.  In both the off-peak and peak periods, it was found that the INTEGRATION with the default lane changing logic produced the least RMSE related to the lane utilization in comparison with the field observations.

**Table 3: Site B Lane Distribution**

| Site B - Off-Peak | | | | |
|---|---|---|---|---|
| Model | Lane Changing Logic | Lane 1 (Left) | Lane 2 (Right) | RMSE |
| Field, Off-Peak | N/A | 43% | 57% | N/A |
| INTEGRATION | Default | 45% | 55% | 0.019 |
| INTEGRATION | Modified | 50% | 50% | 0.064 |
| CORSIM | Default | 54% | 46% | 0.111 |
| VISSIM | Default | 45% | 55% | 0.015 |
| VISSIM | Modified | 53% | 47% | 0.101 |

| Site B - Peak | | | | |
|---|---|---|---|---|
| Model | Lane Changing Logic | Lane 1 (Left) | Lane 2 (Right) | RMSE |
| Field, Peak | N/A | 45% | 55% | N/A |
| INTEGRATION | Default | 46% | 54% | 0.007 |
| INTEGRATION | Modified | 49% | 51% | 0.037 |
| CORSIM | Default | 54% | 46% | 0.094 |
| VISSIM | Default | 43% | 57% | 0.016 |
| VISSIM | Modified | 54% | 46% | 0.087 |

It is interesting to note that the modified lane changing logic generally increased the models accuracy to the field data when reviewing the lane change counts, but this same adjustment is found to decrease the lane utilization accuracy to the field data. With a sample of eight observations, two sites with two time periods each containing two models with modified lane changing logic, only twice did the use of the modified lane changing logic decrease the RMSE. This decrease can be seen in VISSIM from both the off peak and peak period at Site A.

### 4.3.5  Total Number of Lane Changes

Because the scope of this study did not allow for the collection of field video data over the course of the entire freeway section, this section will provide simulation results for analysis without corresponding field data.

Table 4 illustrates the total number of lane changes estimated over the course of the three kilometer freeway section in Site A for a duration of one hour. In all cases, INTEGRATION produces the least number of lane changes while VISSIM produces the largest number of lane changes.

<p align="center">Table 4: Total Number of Calculated Lane Changes, Site A</p>

| Site A - Off-Peak | | |
|---|---|---|
| Model | Lane Changing Logic | Total Number of Lane Changes |
| INTEGRATION | Default | 346 |
| INTEGRATION | Modified | 454 |
| CORSIM | Default | 464 |
| VISSIM | Default | 781 |
| VISSIM | Modified | 691 |

| Site A - Peak | | |
|---|---|---|
| Model | Lane Changing Logic | Total Number of Lane Changes |
| INTEGRATION | Default | 596 |
| INTEGRATION | Modified | 711 |
| CORSIM | Default | 810 |
| VISSIM | Default | 1793 |
| VISSIM | Modified | 1449 |

Table 5 illustrates the total number of lane changes occurring over the 1.5 kilometer freeway segment at Site B for a duration of one hour.  Again, INTEGRATION is found to produce the least number of lane changes while VISSIM produces the largest number of lane changes.

**Table 5: Total Number of Calculated Lane Changes, Site B**

| Site B - Off-Peak | | |
|---|---|---|
| Model | Lane Changing Logic | Total Number of Lane Changes |
| INTEGRATION | Default | 421 |
| INTEGRATION | Modified | 523 |
| CORSIM | Default | 456 |
| VISSIM | Default | 924 |
| VISSIM | Modified | 758 |

| Site B - Peak | | |
|---|---|---|
| Model | Lane Changing Logic | Total Number of Lane Changes |
| INTEGRATION | Default | 465 |
| INTEGRATION | Modified | 566 |
| CORSIM | Default | 498 |
| VISSIM | Default | 1056 |
| VISSIM | Modified | 858 |

### 4.3.6  Observations

Aside from the quantitative results presented above, a qualitative review of both the simulation's visual output and the field data was conducted.  Reviewing the video data revealed that, especially during peak periods, very few exiting vehicles used the left lane to overtake slower vehicles prior to exiting the freeway.  When this event did occur, it was generally due to the passing of a slower moving vehicle without the presence of other vehicles.  This is another indication that the exiting vehicles prepare for the diverge area upstream of the deceleration lane.  Also, this is an indication of the passive nature of the drivers in the study area.

A benefit of microsimulation modeling is that most models include some sort of visualization feature allowing the practitioner to view vehicle interactions which were estimated by the model.  As mentioned in the literature review, reviewing the visualization is vital to proving the validity and realistic nature of any microsimulation result.  When reviewing the visualizations produced by all three models, the author noted events of unrealistic lane changing behavior occurring in multiple VISSIM scenarios.  Figure 26 illustrates one of these unrealistic lane changes.  This figure shows a vehicle in the left lane trying to exit the freeway.  In order to exit the freeway, this vehicle must make a lane change to its right.  This vehicle is still in the left lane near the end of the deceleration lane without finding any gaps and thus slows to a complete stop to wait for an appropriate gap.  The action causes queuing as through traffic in the left lane cannot pass the

stopped vehicle. In addition, one can see that the white vehicle, fourth in queue, has its turn signal on indicating that it is also trying to change lanes.

When reviewing the VISSIM simulation visualization it was found that vehicles attempting to change out of the left lane often remained at a complete stop for over ten seconds while waiting for an acceptable gap to complete their lane change. While vehicles may find themselves needing to make a last second maneuver to maintain their route in real-world conditions, it appears to happen too often in the VISSIM simulation. Possibly the most unrealistic component of this observation is the duration of time which the vehicles were observed stopping in the VISSIM simulation. It would be a challenge to find an example of a real-world driver coming to a complete stop in the left lane of a freeway and remaining stopped for over ten seconds while other vehicles are driving at nearly 104.7 kilometers per hour (65 miles per hour).
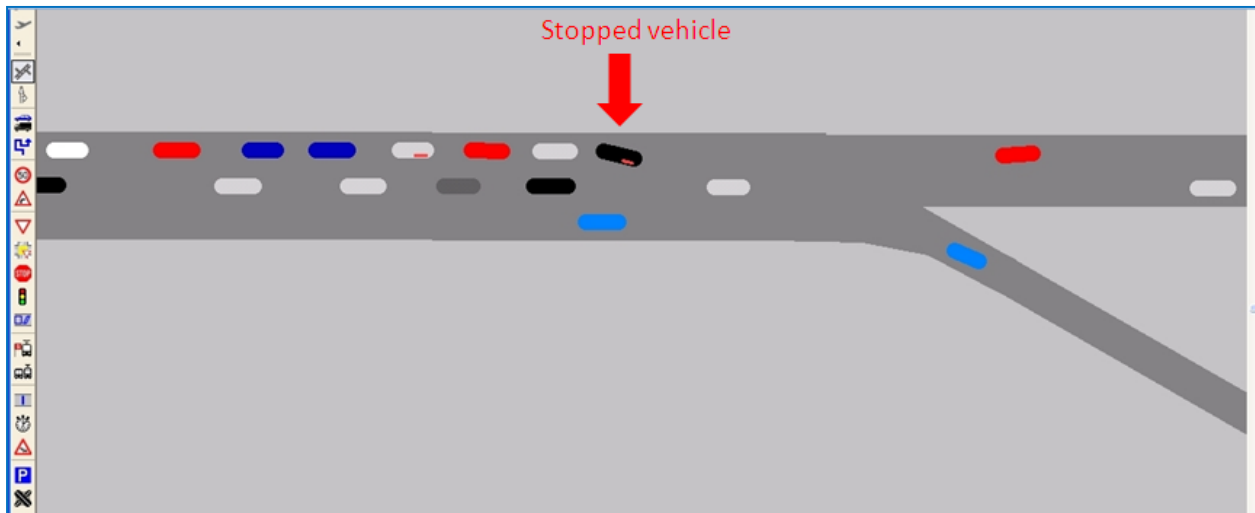


**Figure 26: Unrealistic Lane Change in VISSIM**

### 4.3.7   Discussion

#### 4.3.7.1 Lane Change Count

As seen above, although all three models generally overestimated the number of lane changes CORSIM usually provided the best estimation of the number of lane changes in the vicinity of the deceleration lane in each scenario using default lane changing logic. It is important to note that the combination of CORSIM's stochastic nature with the fact that CORSIM does not use origin-destination pairs for each vehicle allow vehicles to deviate from their intended path. For example, practitioners input the intended percentages at freeway diverge areas for through and exiting traffic, but simulation results generally do not match these percentages. Reviewing each of the CORSIM simulation output files reveal that similarly to the results in the sensitivity analysis, there were instances of up to 10 percent of vehicles intending to exit were unable to do so and thus remain on the freeway. This large number of vehicles remaining on the freeway attributed to the lower estimation of lane changes in the CORSIM results as compared to both the

INTEGRATION and VISSIM results. However, this behavior is unrealistic as vehicles which have a destination to exit the freeway would generally not continue on the mainline.

A major pattern recognized in the majority of the scenarios was that all of the models overestimated the number of lane changes in comparison to the field observations. With the exception of CORSIM, there were generally more lane changes estimated in the vicinity of the deceleration lane which were not seen in the field observations. Interestingly enough, in the sensitivity analysis it was found that the examples with higher than expected delay, also contained a large number of lane changes very near the freeway diverge.

When viewing the total number of lane changes calculated over the course of a simulation, INTEGRATION, using the default lane changing logic, generally calculated the least number of lane changes, followed by CORSIM, and lastly VISSIM. When the lane bias was added to INTEGRATION, it was found in some cases INTEGRATION calculated slightly more lane changes than CORSIM. In all cases, VISSIM calculated a significantly higher number of total lane changes, often more than doubling that of INTEGRATION and doubling the amount calculated by CORSIM.

### 4.3.7.2 Lane Utilization

There were multiple patterns which emerged from the analysis of the lane use utilization. First, INTEGRATION without the modified lane changing logic performed well in every scenario. INTEGRATION without the lane changing logic modification had the least RMSE compared to the field observations in two of the four scenarios. In the remaining two scenarios, one case had INTEGRATION's lane utilization percentage within one percent of the field observation, while the second was within two percent of field observations.

CORSIM produced better lane use distributions during both the peak and off-peak periods of Site A than it did for site B. CORSIM was found to produce the least RMSE in the peak period of Site A and was within three percent of the percentage of lane use distribution in Site A during off-peak periods. On the other hand, CORSIM was found to produce the most RMSE in both off-peak and peak periods at Site B.

Similarly to CORSIM, VISSIM more closely matched the lane use distribution at Site B than it did for Site A. VISSIM using the modified lane changing logic was found to produce the least RMSE in the off-peak period of Site B, and produced a lane use distribution percentage within two percent of the field observations in the peak period of Site B. Unlike the other models, VISSIM's lane distribution decreased in RMSE when the modified lane change logic was applied in Site A. This was not seen in Site B.

### 4.3.7.3 Sources of Uncertainty

VISSIM, as described in its user manual, is designed to model urban traffic. While this study shows a very simple application of VISSIM, it should be noted that the study area model is a rural area. Many drivers in the study area have short commutes and portray less aggressive

driving behaviors than what would be observed in a dense metropolitan area. The study area may explain some of the difference between VISSIM's estimation in comparison to the field observations.

The FHWA publication containing guidelines for CORSIM usage contains a section on limitation and notes multiple limitations which may be involved in this study.  In general, CORSIM has been designed to quickly and accurately model overall link flows as opposed to second-by-second vehicle interactions.  Secondly, lane changes calculated in CORSIM are based solely on the current link and lane of the subject vehicle.  (20)

As shown in this study, the lookback parameter included both in VISSIM and CORSIM is a source of uncertainty.  There is merit in allowing practitioners the ability to specify when motorists learn of the upcoming diverge area, and as with all parameters this should be calibrated in the model.  While the freeway modeled in this study was very basic, often times planners will need to model sophisticated and complex freeway sections with multiple diverge areas.  By introducing the lookback value for each diverge area planners will require significant effort to calibrate the value for each area.  Similarly, VISSIM offers great flexibility by providing practitioners with an array of parameters to control driver behavior.  The disadvantage of this flexibility is again the effort and time needed to properly design and calibrate a model.

When combining the results from the lane change count with that of the lane distribution, one can see that while modifying the lane changing logic of each simulation model generally increases the accuracy in comparison to the field observations for the lane change count, it decreases the accuracy to field observations in the lane use distribution.  This balancing act between different measures within a microsimulation model is something which should be taken into consideration when calibrating a microsimulation model with macroscopic data.  Just because a model matches macroscopic traffic behavior, it is not inherent that the model will still match disaggregate data.

Although the results presented in this thesis cover very basic freeway networks, there is concern that any poor estimation calculated by microsimulation model on a very basic network can be compounded in a much larger network. This shows the need for better calibration techniques on the microscopic level.

### 4.3.7.4 Limitations
Effort was made to match each microsimulation model as closely to the field data as possible. Google Earth was utilized to determine freeway dimensions and traffic volumes and distributions were determined through a combination of visual analysis of the video data as well as manual recording while in the field.  The research vehicle was located as close as possible to a reference point such as the start of the deceleration lane or the freeway diverge point.  Obtaining this reference point in combination with visual analysis of the field observations provided the viewing area at each site.  This area was then defined in the simulation output and all lane

changes occurring in this area were extracted.  Because of limitations with the camera, only a small viewing area was usable for each site and therefore the results only capture a snapshot of the vehicle behavior in the vicinity of the freeway diverge.

# Chapter 5 – Conclusions

## 5.1    Conclusions

The purpose of this study was to model simple diverge areas along a freeway and using three microsimulation tools and to validate the results against field observations.  Findings from this study highlight the strengths and weaknesses of various aspects of microsimulation modeling and should be used to further advance such models.  This analysis found that all three models tend to overestimate the number of lane changes during higher demands and at Site B, in comparison to field observations.   The results of the lane distribution were mixed with INTEGRATION performing best in two scenarios, CORSIM in one, and VISSIM in one.   Across all four scenarios, INTEGRATION consistently had low RMSE in regards to lane use distribution.  Both CORSIM and VISSIM were found to perform well in a particular scenario and poorly in others.

Each of the three models presented in this study offer advantages and disadvantages.   For instance, VISSIM offers a very detailed visualization component, but also has a wide range of parameters which must be calibrated for proper model running.   Also, VISSIM was found to produce the most lane changes out of any of the models as well as the only model to produce unrealistic driver behavior.  An example of this unrealistic behavior would be vehicles coming to a complete stop on a freeway while waiting for a gap to change lanes.

With limited time for microscopic analysis, CORSIM stands out as it takes the least amount of time to run the model.  A disadvantage to CORSIM is that it focuses on overall traffic flows on links and can neglect low level interaction between vehicles as well as lacks set origin-destination pairs.   This lack of set origin-destination pairs creates difficulty in setting vehicle routes and maintaining consistent methods of evaluation across random seeds or other models.

While the lack of a GUI may cause some users the need to spend more time becoming accustomed to INTEGRATION's usage than the other models, it uses macroscopic traffic stream parameters as input which are more readily available and easily input into the model. INTEGRATION proved to provide accurate and consistent lane distributions when compared to field observations.

Microsimulation models have importance to the future of transportation modeling, but care should be taken so that the future of these models offers a balance of accuracy and applicability. While offering dozens of parameters to control every aspect of driver behavior may assist in matching desired conditions, if the level of effort needed to accurately determine and calibrate these parameters is too great, there will be limited use for such a model.

## 5.2    Recommendations for Further Research

There were many challenges and limitations when conducting this study.  The first and foremost challenge was the single camera to collect video data.  Because of only one camera, the analysis

of vehicle behavior was limited to the section of freeway which camera focused on.  Because of this, the field observations were in essence a snapshot of the traffic behavior.  A future study utilizing multiple cameras would allow researchers to have knowledge of vehicle behavior many locations along the freeway and will be better able to validate the microscopic interactions modeled.

While having both test sites on the same roadway allows a closer comparison of behavior in regard to differing deceleration lane lengths, it would be beneficial to include additional test sites with varying deceleration lane lengths, similarly to what was done in the sensitivity analysis chapter of this thesis.  In combination with that, it would be interesting to obtain data from a three or four lane freeway and compare it with the microsimulation output.  Adding to this complexity, it would be useful collect data on diverge sections with multiple lane exits.  Specifically, it would be worth investigating how microsimulation models compare to field observations on option lanes.  An option lane is a lane on the mainline which the driver can maintain on the mainline or exit the freeway.  These option lanes can be confusing to drivers (29) and how this is implemented into microsimulation modeling as well as how these models simulated motorist behavior would be worthy of future investigation.

Motorists in the rural environment, which this study was conducted, are generally more passive than drivers in a more urban area.  It would beneficial to conduct a similar study in a more urban environment to determine the difference in behavior due to the more aggressive driving behavior.  For the purpose of this study, it the 762 meter (2500 feet) lookback value used by CORSIM as a default more closely matched field conditions than the 200 meter (656 feet) lookback value used by VISSIM as a default.  This finding recommends that in rural areas with similar characteristics to this study site, practitioners should ensure that longer lookback values are used and warrants further analysis on lookback values in urban areas.

Finally, while there may be a lack of currently available and easily accessible data to calibrate microsimulation models down at the microscopic level, a new program from FHWA may be able fill this gap.  FHWA and the U.S. Department of Transportation's (USDOT) Research and Innovative Technology Administration are currently in the midst of launching their Connected Vehicle program which will include vehicle-to-vehicle communications.  One of the key components of this program is the ability for all intelligent vehicles to transmit a "here-I-am" message to other intelligent vehicles. (30)  This message is planned to include a number of factors such as GPS coordinates as well as vehicle speed and sensor data.  What this means is that every vehicle outfitted with this technology could be used as a probe in the traffic stream.  If this data can be collected and analyzed, it may provide the information needed to advance or validate many of the microscopic aspects of microsimulation modeling.

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