University of Nevada, Reno

Modeling the Temporal Priority Reversal Phenomenon at Roundabouts

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in
Civil and Environmental Engineering

By

Samuel Kofi Ahiamadi

Dr. Zong Z Tian/Dissertation Advisor

December, 2013

UNIVERSITY OF NEVADA RENO

THE GRADUATE SCHOOL

We recommend that the dissertation
prepared under our supervision by

SAMUEL KOFI AHIAMADI

entitled

Modeling the Temporal Priority Reversal Phenomenon at Roundabouts

be accepted in partial fulfillment of the
requirements for the degree of

DOCTOR OF PHILOSOPHY

Zong Z Tian, Ph.D., Advisor

Adrain R Gibby, Ph.D., Committee Member

Elie Hajj, Ph.D., Committee Member

Raj Siddharthan, Ph.D., Committee Member

Ilya Zaliapin, Ph.D., Graduate School Representative

Marsha H. Read, Ph.D., Dean, Graduate School

December, 2013

ABSTRACT

Roundabouts are a popular intersection control in the United States with over 2000 constructed in more than 45 states after their introduction in 1990. They have become a preferred choice over stop-controlled and signalized alternatives at low to medium traffic volumes for some jurisdictions. The number of roundabouts in the U.S is progressively increasing annually because of the safety and operational performances obtained with their installation. Procedures for roundabout analyses and evaluation in the 2010 U.S. Highway Capacity Manual are based on the assumption of absolute priority to circulating traffic: meaning entering drivers have to seek for gaps of sufficient size in order to merge with the circulating traffic. However observations at roundabouts operating at or near capacity show periods of priority reversal or shared priority between entering and circulating vehicles. Other studies of the priority reversal phenomenon have reported significant influence on the capacity, delay and queue length at roundabouts. To study the effects of priority reversal on the performance of roundabouts in the U.S., a roundabout in Fernley, Nevada, operating at capacity during the P.M. peak period was observed. The driver behavior characteristics were extracted from video recordings and the geometric parameters were obtained from the site. Based on the observed driver behaviors and traffic flow characteristics, four scenarios were modeled in the micro-simulation software VISSIM.

Results obtained after multiple simulation runs showed improvements in the performance of roundabouts as the periods of priority reversal increased: delay reduced by 8-16 percent and queue length reduced by 10-20 percent for every 10 percent increase in “reversed priority periods”. It was also shown that, as the priority reversal period increased, the influence of the size of the inscribed diameter decreased even though an improvement in performance was observed. When the intersection experienced a traffic volume increased, the performance of the roundabout decreased until it reached a threshold level where it appeared to remain constant. These modeling results were incorporated into the Analytical Hierarchy Approach, a multi-criteria decision based application to develop a tool that can be used to compare roundabouts to other intersection control options. This tool revealed a potential to enable better comparison devoid of biases and decision makers’ preferences.

DEDICATION

I dedicate this Dissertation to my parents, Mr. and Mrs. S.K Ahiamadi for all the skills of life they taught me.

ACKNOWLEGEMENT

I wish to express my sincere gratitude to Dr. Zong Z. Tian my advisor who was very patient and supportive throughout my studies. Through his patience and guidance, this day has become a reality. I want to thank him very much for all the research skills he guided me through, not to mention his support and encouragement through some of the difficult times. My thanks also go to members of my PhD committee (Dr Adrian Gibby, Dr Elie Hajj, Dr Raj Siddharthan and Dr Ilya Zaliapin) who in various ways gave suggestions and direction that made this successful. My next appreciation goes to my colleagues in the program for the various ways in which they assisted me. My special thanks goes to my siblings Bright, Benjamin, Moses, Beatrice, Francis and Michael for the great support and encouragement they gave me at various times. Last but not least, I also want to mention my friends who in various ways supported me and made Reno a welcoming environment. To all I say a very big thank you and may God bless you. My final thanks go to the Lord God Almighty, creator of heaven and earth, for his guidance and protection throughout my life.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 CHAPTER ONE - INTRODUCTION

1.1 INTRODUCTION

Roundabouts are a popular intersection control in the United States with over 2000 constructed in more than 45 states after their introduction in 1990. They have become a preferred choice over stop-controlled and signalized alternatives at low to medium traffic volumes for some jurisdictions in the U.S. Countries such as United Kingdom, France, Germany, and Australia have a longer history of roundabout use. The many advantages that roundabouts provide led to their introduction in the U.S. in 1990. Research shows roundabouts offer several advantages over signalized and stop-controlled alternatives at low to medium traffic volumes (*1*,*2*). The advantages include lower maintenance and operating costs (*3*,*4*), better overall safety performance (*5*,*6*), reduction in delay, reduction in service time (*7*), and shorter queues especially during off-peak hours. Roundabouts additionally provide better speed management, reduced air and noise pollution and create opportunities for community enhancement features like landscaping. They also operate efficiently and safely under a wide variety of conditions such as wide variations in peak and off-peak traffic volumes and skewed approaches (*8*).

As with other intersection controls the process for roundabout selection, design and installation involves several factors, some of which have conflicting requirements. The critical factors include safety, capacity, delay, queue, level of service (LOS) and cost. National research into roundabout design and installation guidance in the U.S. has resulted in several publications and, prominent amongst them are: 1) NCHRP 672 Report titled, Roundabouts: An Information Guide second edition (*9*) (first edition is FHWA-RD-0067 (*10*)), 2) NCHRP 572 Report titled: Roundabouts in the United States (*11*), 3) 2010 Highway Capacity Manual (HCM) (*12*) (chapters 21 and 33).

Several states have also developed their state specific roundabout guidance manuals, which mostly adopt the recommendations in the national reports. As part of the process for roundabout selection and installation, transportation professionals have to maintain a good balance of all the factors which sometimes prove to be a challenging task. An area with significant variations in individual states roundabout guidelines is the selection and installation requirements. A potential problem that might result is non-uniformity in the selection/installation of roundabouts as one travels across different states. A comprehensive guide for comparison between intersection controls would help eliminate such a potential problem.

Roundabouts operate on the same principle as priority junctions with priority given to the circulatory traffic. The priority assignment principle is applied in the two main roundabout analysis model categorizations: regression and analytical models. Regression models use field observation data to derive a relationship between geometric features and performance measures whereas analytical models use traffic flow theory combined with field measures of driver behavior data. Gap acceptance theory is applied in analytical models in which the entering traffic needs to find acceptable gaps within the circulatory traffic. However in situations where entering motorists experience long delays due to high circulating traffic flow volume, they may force themselves into the circulating traffic, a phenomenon known as “priority reversal” (*13,14*). Troutbeck and

Kako (13) showed that there is a significant effect on the entry capacity of double-lane roundabouts with limited priority merges occurring. The impacts of priority reversal on the performance of roundabouts have not been well studied in the U.S. Since capacity and delay play significant roles in the selection process for roundabouts, it was necessary to study the effect of priority reversal on roundabout capacity and delay models used for design (*15*,*16*,*17*).

1.2 BACKGROUND

Capacity and delay are two of the critical factors that affect the selection process of roundabout. Studies have shown that roundabout operations can be affected by priority reversal under heavy traffic flow conditions. Kimber (15) noted that during at-capacity operations, there are significant periods where entering vehicles edge forward and progressively distort the paths of circulating vehicles until one yields, or decelerates sufficiently to “create” a gap and allow one or more vehicles to enter the circulating traffic flow. Horman and Turnbull (*18*) in their study of priority reversal, estimated the proportion of circulating drivers who yield priority to entering traffic to be 7.6 percent. They showed that some circulatory drivers may merely slow down to allow entry drivers to enter. Troutbeck (*19*) found that entering vehicles who departed before a circulating vehicle had a margin of 0.80 seconds and those that departed after the circulating vehicle had a margin of 1.27 seconds. These gaps affect the ability of entering drivers to force priority reversal.

The 2010 HCM (12) estimates the capacity of a single lane entry conflicted by one circulating lane using Equation (1) as illustrated in Figure 1:

$$C_{pce} = 1{,}130e^{(-1.0\times10^{-3})v_{c,pce}} \tag{1}$$

Where;

C_{pce} = lane capacity, adjusted for heavy vehicles, pc/h, and

$V_{c,\ pce}$ = conflicting flow pc/h.

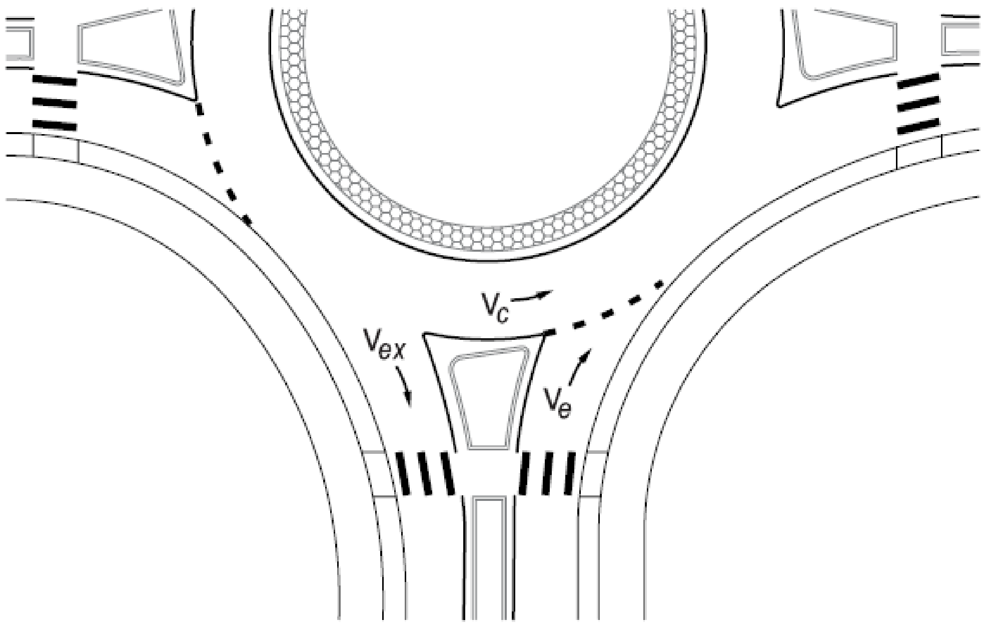

Figure 1 Example of One-Lane Entry Conflicted by One Circulating Lane

The relationship in Equation 1 is based partly on the typical gap acceptance theory where the major traffic flow has absolute priority over minor traffic flow, which accepts gaps equal or greater than the critical headway. The assumption implies the minor flow experiences all the delays (*20*). However, Kimber (*21*) and Troutbeck (*22*) have shown that minor traffic flow can affect the major traffic stream especially when they operate at high traffic flow conditions or with excessively long delays at the entry. This affects the capacity of the entry lanes and general operations of the roundabout. There is therefore a need for further studies to understand the magnitude of these effects since the performance indicators play a key role in the selection of roundabouts.

Transportation professionals consider several factors before selecting the optimal control for any intersection which sometimes results in trade-offs between requirements for two opposing factors. Due to the number of factors for consideration, the process can be very challenging and might result in inconsistent decisions. For such processes a Multi-Criteria Decision Analysis (MCDA) approach is ideal for a good resolution. Multi-Criteria Decision Analysis is a simple decision making tool for structuring and solving problems involving multiple criteria (*23*,*24*).They are typically applied when a unique optimal solution for the problem is non-existent and involves relying on decision makers' preferences to choose the most preferred alternative. The difficulty lies in the presence of more than one criterion for decision making. MCDA therefore establishes preferences between options using a set of explicit objectives that have been identified for which measurable assessment criteria have been established. The key features of MCDA are its emphasis on establishing objectives and criteria, estimating relative weights and judging the contribution of each performance criterion (23). A standard feature of MCDA is a performance matrix or consequence table, in which each row describes an option and each column the performance of the options against the criterion. Usually the performance assessments are numerical but can also be expressed as a score. The MCDA process has several advantages including:

1) Being transparent and definite,

2) The objectives and criteria are open to analysis and change,

3) Score and weight used are explicit and developed according to established techniques and can be adjusted, and

4) There is an audit trail that can be verified for each decision weight and score.

The challenge therefore was to use an MCDA procedure to assist in the selection/installation of roundabouts. The Analytical Hierarchy Process (AHP) developed by Thomas L Saaty (*25*) was selected as the preferred method. This method develops a linear additive model and derives the weights and scores achieved by the alternatives to be considered based on pair-wise comparisons between criteria and options. AHP helps order the alternatives (roundabouts, signals, and stop controls) from the most preferred to the least. AHP can also be used in combination with other MCDA procedures. With the knowledge of the strengths and limitations of AHP, a tool was designed for comparing roundabouts to the other controls.

1.3 PROBLEM STATEMENT

1) The 2010 U.S. HCM (12) performance analysis models are based on a combination of simple lane-based regression and gap acceptance models. A limitation with the current procedure is the lack of examples in which priority reversal occurs during situations such as unusual forced entry under extremely high flows (12). Under such circumstances, the HCM recommends alternative tools for analysis.

2) The three major roundabout research publications (9,11,12) give guidance on roundabout selection criteria and installation procedure, but the interpretation has led to various states having different factor considerations with varying levels of emphasis on

the factors. Therefore, the justification process for roundabouts in terms of location selection criteria and installation are significantly different as one travels across the U.S. To address this issue, there is a need to develop a comprehensive selection process that is easy, acceptable and applicable across multiple states.

1.4 OBJECTIVES OF THE RESEARCH

This research had two primary objectives: 1) to investigate the effects of priority reversal on roundabout capacity and delay, and 2) to develop a Multi-Criteria Decision Analysis (MCDA) framework for facilitating the roundabout selection/installation process. The research focused on the following areas: 1) measure the frequency of priority reversal occurrences during periods of high traffic flows and its effects on the circulating vehicles headways; 2) measure critical headways and follow-up headways during periods of priority reversal and evaluate their effect on roundabout capacity and delay; 3) explore the use of Analytical Hierarchy Process (AHP) and/or other suitable MCDA methodologies for developing a roundabout selection procedure; and 4) suggest new performance models to reflect situations of high traffic flow as an improvement over existing models.

1.5 SCOPE OF STUDY

The scope of this research was limited to exploring priority reversal occurrences at single-lane roundabouts in the U.S. and their effect on capacity and delay. Results from here were used in the development of an MCDA tool that allows a good comparison of roundabouts to signals and stop-controls in the U.S. The priority reversal study focused mainly on single-lane roundabouts because of the difficulty in identifying a double-lane roundabout with heavy flows for data acquisition; however, the knowledge is also applicable to double-lane roundabouts. The behavior of and interaction between circulatory and entry motorists during high flow periods was studied specifically. The data obtained was compared to the capacity and delay models to reflect the priority reversal effect.

1.6 TASKS PERFORMED

1.6.1 Literature Review

A comprehensive literature review was carried out on 1) priority reversal occurrence at roundabouts and its effects on performance/selection consideration and 2) multi-criteria analysis applications in transportation engineering.

1.6.2 Data Collection, Extraction and Model Development

This involved field data collection at a roundabout in Fernley, NV that operates with high traffic volume and long queue during the PM peak period. Three video camcorders mounted on tripods were positioned at different angles around the subject roundabout approach to record the data. Data of interest were: 1) frequency of occurrence of priority reversal; 2) the critical headways and follow-up headways that non-priority vehicles have during the reversed priority periods; 3) the headways between circulatory vehicles before and after priority reversal occurrences. Data was extracted using a software originally developed at the University of Idaho (*26*) and modified by UNR researchers. VISSIM simulation software (*27*) was used to develop a micro-simulation model.

1.6.3 Simulation Model Data Acquisition

Four main VISSIM simulation model scenarios were developed and multiple runs performed. Delay, queue length, and travel time data were extracted for analyses. Comparisons were made between the simulation results and results obtained using the models from the 2010 U.S. HCM (*28*).

1.6.4 Multi-Criteria Analysis Decision Tool

Using Analytical Hierarchy Process (AHP), a multi criteria selection tool was developed. These steps were followed for the tool development: 1) the critical variables were identified; 2) the weights and scores for the critical variables were selected based on literature and in consultation with roundabout experts at the Nevada Departments of Transportation; 3) the weights and score for each option were combined to achieve the overall value. The end product is a user friendly and reliable tool that can reach to a broad range of practitioners across the United States.

1.7 ORGANIZATION OF THE DISSERTATION

This dissertation consists of seven chapters. Chapter one provides a general overview of the study background, objectives, and the task undertaken for the research. Chapter two covers a comprehensive literature review which discusses issues related to priority reversal and multi-criteria decision analysis. Chapter three provides the methodology used for the research. Chapter four discusses the results obtained from the three simulation scenarios and the models developed. Chapter five discusses the results obtained from the sensitivity analysis. Chapter six discusses the multi-criteria analysis decision tool developed. Chapter seven presents the summary and conclusions drawn from the research.

2 CHAPTER TWO - LITERATURE REVIEW

Modern roundabouts evolved when the “old traffic circles” experienced operational failures such as grid locks and high crash rates with increased traffic volumes. The decision to assign priority to circulating traffic with entering vehicles seeking appropriate gaps to enter at roundabouts is referred to as “priority rule”. The assignment of priority to the circulating traffic which transformed the old traffic circles into an efficient intersection control was first introduced in the United Kingdom in 1960 (*29*). The priority rule together with the “Yield” sign resulted in improved operations at modern roundabouts. With the operations and safety improvement recorded in U.K., modern roundabouts spread to France, Germany, Australia and other countries (*30*). Over the years and with several research findings, roundabouts are known to offer several advantages over signalized and stop-controlled alternatives at low to medium traffic volumes. Advantages of roundabouts include lower maintenance and operating costs, better overall safety performance (40 percent reduction for all crashes and 80 percent reduction for injury crashes) (*31*), reduction in delay (from 7.2 seconds to 1.3 seconds per vehicle) (*32*) and reduction in service time (from 18.1 s to 0.53 seconds per vehicle) (32). Roundabouts result in shorter queues compared to other controls especially during off-peak hours (*33*). They also provide better speed management, reduce air and noise pollution and create opportunities for community enhancement features like landscaping (*34*).

The main objectives of this research were to study the impact of temporal reversed priority on delay and queue at a roundabout and to develop a multi-criteria framework for facilitating roundabout selection/installation process. Accordingly, the literature review focused on these major aspects: (1) delay and capacity models for roundabouts; (2) reversed priority and its impact on roundabout performance; (3) microscopic simulation application in modeling and evaluating roundabouts; (4) multi-criteria approach to traffic engineering studies.

2.1 CAPACITY AND DELAY MODELS FOR ROUNDABOUTS

An important factor for intersection evaluation is the estimated capacity and level of service (LOS). Roundabout capacity and performance estimation are estimated using either regression/empirical or analytical models (21,*35*). Regression models use field data to develop a relationship between geometric features and performance measures. Analytical models are based on traffic flow theory and the use of field measures of driver characteristic to develop a relationship with the performance measures. Models that use a combination of the two approaches have also been developed. The common roundabout analysis models in use include the TRRL model (U.K.), GIRABASE (France), German model, Australian model, Swiss model and the HCM model (U.S.). The models fall into one of the two categories described above and are discussed below.

2.1.1 TRRL Formula (United Kingdom Model)

The formula for estimating the capacity of a roundabout was developed by Transportation and Road Research Laboratory (TRRL now TRL) using experimental observations from a large number of roundabouts in U.K. The capacity of the entry is computed as a function of the entry leg, circle geometric parameters and the circulating flow in front of the entry lane. The formula is also generally referred to as Kimber's roundabout formula because of his contribution to the research. The capacity C (pcu/h) is expressed linearly as (*36*):

$$C = k \cdot (F - f_c Q_c) \tag{2}$$

Where,

$F = 303x_2$

$f_c = 0.210\ t_D\ (1 + 0.2\ x_2)$

$k = 1 - 0.00347\ (\phi - 30) - 0.978\ (1/r - 0.05)$

$$t_D = 1 + \frac{1}{2\left[1 + e^{\frac{D-60}{10}}\right]}$$

$$x_2 = v + \frac{e - v}{1 + 2 \cdot S}$$

$$S = 1.6\frac{e - v}{l'} = \frac{e - v}{l}$$

Table 1 gives the range of the geometric parameters used in the U.K. procedure. The parameters are illustrated in Figures 4 - 6 (*37*). It must be noted that the figures show the left-side driving in the U.K. which requires drivers to travel clockwise around the central island.

Table 1 **Geometric Parameters used by the TRRL Formula**

Parameter	Description	Range values
e	Entry width	3.6–16.5 m
v	Lane width	1.9–12.5 m
e′	Previous entry width	3.6–15.0 m
v′	Previous lane width	2.9–12.5 m
u	Circle width	4.9–22.7 m
ℓ, ℓ'	Flare mean length	1–∞ m
S	Sharpness of the flare	0–2–9
r	Entry bend radius	3.4–∞ m
Φ	Entry angle	0–77°
$D = D_{ext}$	Inscribed circle diameter	13.5–171.6 m
W	Exchange section width	7.0–26.0 m
L	Exchange section length	9.0–86.0 m

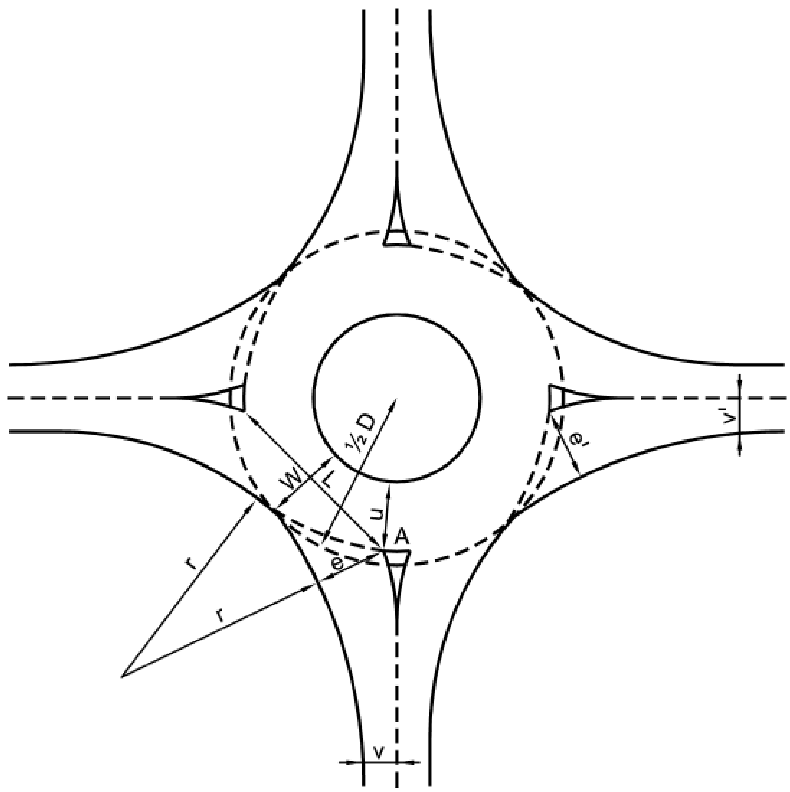

Figure 2 **Geometric Elements Used in the TRRL Formula**

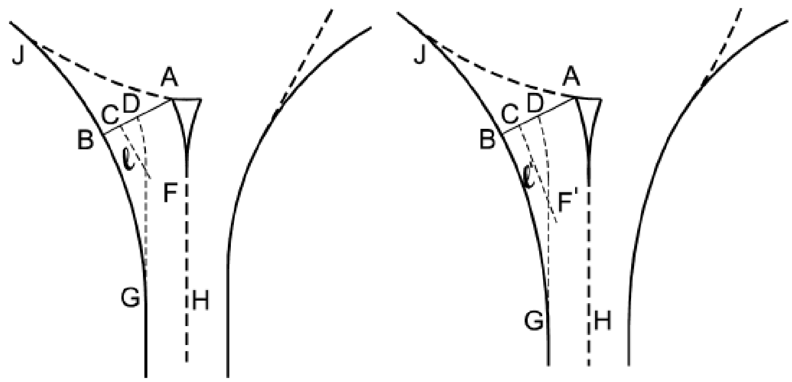

Figure 3 **Geometric Constructions for the Determination of *l* and *l'***

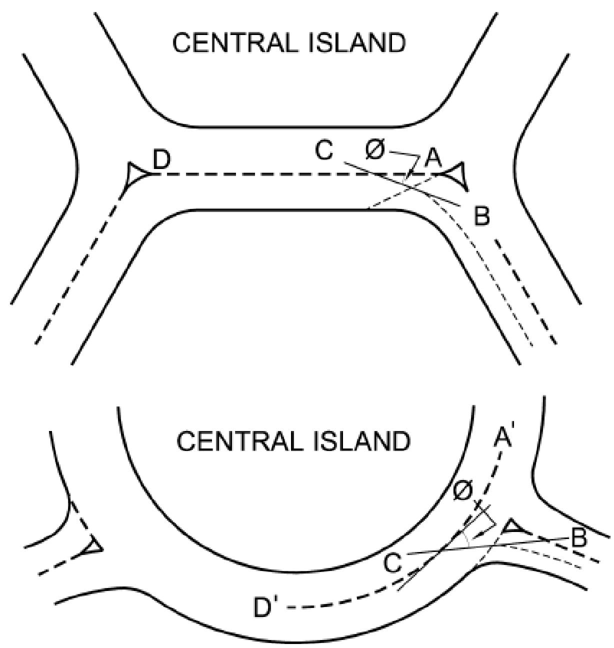

Figure 4 **Geometric Constructions for the Determination of the Entry Angle ϕ**

The delay model (*38*) is shown in the Equation (3).

$$D_v = 0.5 \times ((J^2 + K)^{0.5} - J) \tag{3}$$

Where,

$J = \frac{t}{2}(1-\rho) - \frac{1}{\mu}(L_0 - C + 2),$

$K = \frac{4}{\mu}\left[\frac{t}{2}(1-\rho) + 0.5\rho t C - \left(\frac{L_0+1}{\mu}\right)(1-C)\right],$

D_v = delay per arriving vehicle,

t = time,

L_0 = number of vehicles waiting at time t=0,

μ = available capacity (veh/sec),

q = traffic demand in a traffic stream (veh/sec),

ρ = traffic intensity = q/μ, and

C = is a constant depending on the arrival and service patterns; for regular arrivals and service C=0, for random arrivals and service C=1

2.1.2 Brilon, Wu and Bondzio Formula (German Model)

The current model used for roundabout capacity estimation in Germany was developed by Brilon, Bondzio and Wu (*39*). The formula is based on Tanner's capacity equation, modified for roundabouts.

$$C = 3600 \cdot \left(1 - \frac{t_{min} \cdot q_c}{n_c \cdot 3600}\right)^{n_c} \cdot \frac{n_e}{t_f} \cdot e^{-\frac{q_c}{3600}\cdot\left(t_c - \frac{t_f}{2} - t_{min}\right)}$$

(4)

Where,

C = basic capacity of one entry lane (pcu/h),

q_c = circulating flow in front of the entry (pcu/h),

n_c = number of circulating lanes,

n_e = number of entry lanes,

t_c = critical headway (sec),

t_f = follow-up headway (sec), and

t_{min} = minimum headway between the vehicles circulating in the circle (sec)

Equation (4) is based on the gap acceptance theory and for the basic parameters t_c, t_f and t_{min} the values used are:

t_c = 4.1 seconds,

t_f = 2.9 seconds, and

t_{min} = 2.1 seconds.

From the capacity Equation (4) above, a series of curves for estimating the capacities were obtained for any combination of entry lanes and circulating lanes as shown in Figure 2. Computer programs for ease of capacity computation have also been developed and are currently in use.

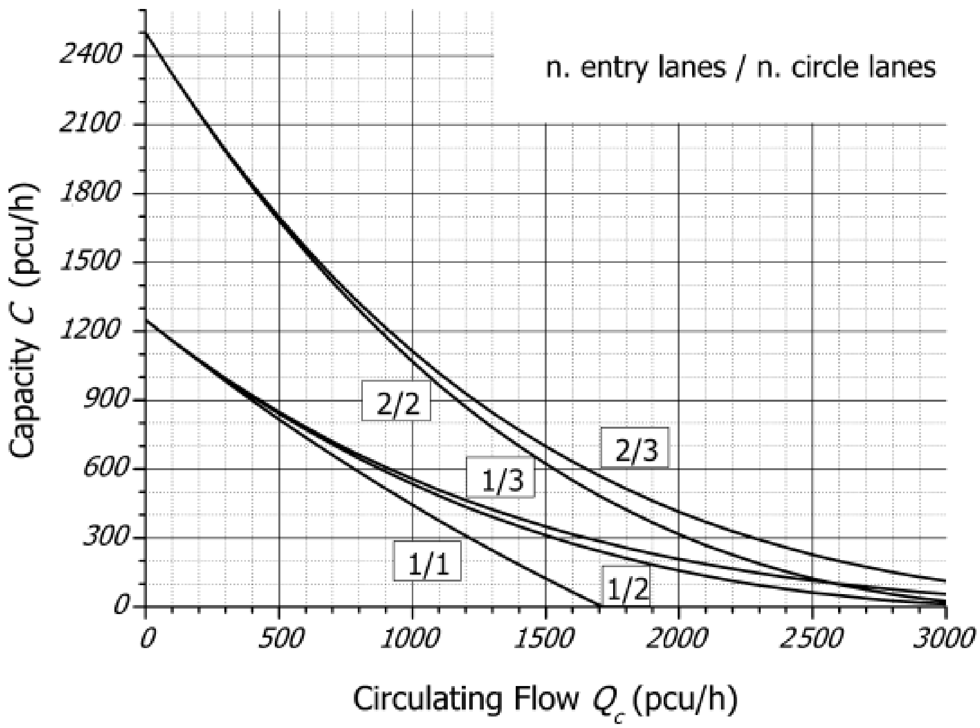

Figure 5 Capacity of Roundabout Entry According to the German Highway Capacity Manual (HBS 2001)

A further research of the capacity estimation in Germany recommended that Equation (4) be used for the case of a single entry lane conflicted by a single circulating lane (*40*). For other roundabout configurations, equation (5) was recommended for the capacity determination of an entry lane.

$$C = 3600 \cdot \frac{n_e}{t_f} \cdot e^{\left[-\frac{q_c}{3600} \cdot \left(t_c - \frac{t_f}{2}\right)\right]} \tag{5}$$

Where,

q_c = circulating flow in front of the entry (pcu/h),

n_e = parameter connected to the number of entry lanes; equal to 1 for single-lane entries and 1.4 for double-lane entries,

t_c = critical gap = 4.3 seconds, and,

t_f = follow-up time = 2.5 seconds.

For delay estimation, Germany adopts the U.K model developed by Kimber and Hollis (**Error! Bookmark not defined.**).

2.1.3 GIRABASE Model (France)

The capacity model adopted by France is based on 5-10 minute observations at entries of different roundabouts operating at saturated conditions, developed by statistical regression method. The formula was known to have been tested by Urbahn in Germany 1996 and updated by Guichet in 1997 (*41*,*42*). The procedure is useful for all types of roundabouts in both urban and rural locations. The French model was developed into the computer software named GIRABASE which is commercially available and widely used in France for roundabout capacity estimation. The formula for estimating the entry capacity (pcu/h), based on the exponential regression technique is given in Equation (6):

$$C = A \cdot e^{-C_B \cdot Q_d} \tag{6}$$

With

$$A = \frac{3600}{t_f}\left(\frac{L_e}{3.5}\right)^{0.8} \tag{7}$$

t_f = follow-up time = 2.05 seconds

Le = width of the entry in proximity to the roundabout, determined perpendicularly to the entry direction (m), and

C_B = coefficient that is 3.525 for urban areas and 3.625 for rural areas

Figure 3 gives an illustration of the geometric parameters used for capacity computation and Table 2 give the ranges of the values using Equation 6.

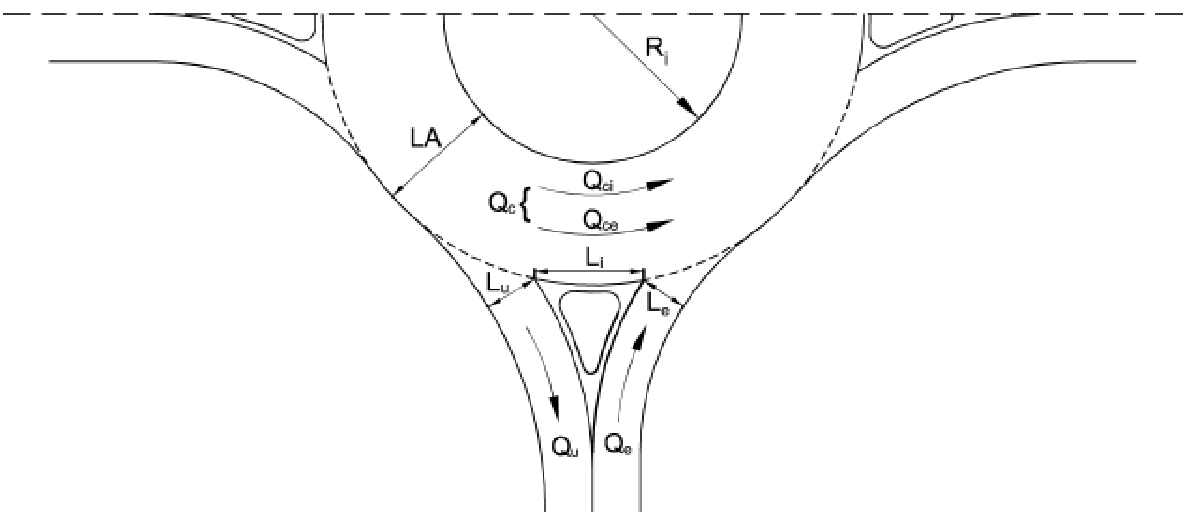

Figure 6 Traffic Flow and Geometric Elements for the GIRABASE Formula

Table 2 Range of the roundabout geometric elements for the application of the GIRABASE procedure

Parameter	Description	Range values
L_e	Entry width	3–11 m
L_i	Splitter island width	0–70 m
L_u	Exit width	3.5–10.5 m
LA	Circle width	4.5–17.5 m
R_i	Central island radius	3.5–87.5 m

$$Q_d = Q_u \cdot k_a \left(1 - \frac{Q_u}{Q_c + Q_u}\right) + Q_{ci} \cdot k_{ti} + Q_{ce} \cdot k_{te} \tag{8}$$

Where,

Q_d = disturbing flow in front of the entry (pcu/h)

Q_u = exiting flow (pcu/h)

$Q_c = Q_{ci} + Q_{ce}$ = circulating flow in front of the entry (pcu/h)

Q_{ci} = traffic rate Q_c on the inner circle lane (pcu/h), and

Q_{ce} = traffic rate Q_c on the outer circle lane (close to the entry) (pcu/h)

$$k_a = \begin{cases} \dfrac{R_i}{R_i + LA} - \dfrac{L_i}{L_{imax}} & per\ L_i < L_{imax} \\ 0 & in\ the\ other\ cases \end{cases}$$

Where,

R_i = central island radius (m),

LA = circle width (m),

L_i = splitter island width at legs (m),

$$L_{imax} = 4.55 \cdot \sqrt{R_i + \frac{LA}{2}}$$

$$k_{ti} = min \begin{cases} \dfrac{160}{LA \cdot (R_i + LA)} \\ 1 \end{cases}$$

$$k_{te} = min \begin{cases} 1 - \dfrac{(LA - 8)}{LA} \cdot \left(\dfrac{R_i}{R_i + LA}\right)^2 \\ 1 \end{cases}$$

2.1.4 Australian Model

The Australian model was developed by Troutbeck (*43*) based on Tanner's capacity model developed from the Cowan's M3-distribution. Troutbeck's roundabout capacity model is expressed as:

$$Q_e = \frac{3600(1-\theta)q_c e^{-\lambda(t_c-\Delta)}}{1-e^{-\lambda t_f}}$$

(9)

Where,

Q_e = entering capacity (veh/h),

q_c = conflicting flow (veh/h),

θ = percentage of vehicles following a leading circulating vehicle,

Δ = minimum headway in the circulating volume is equal to 1 sec for multi-lane roundabouts and 2 seconds for one-lane roundabouts (s),

t_c = critical headway (s),

t_f = follow-up headway (s), and

$$\lambda = decay\ parameter = \frac{(1-\theta)q_c}{1-\Delta \mathrm{q_c}}$$

In his study of single and multi-lane roundabouts in Australia, Troutbeck (43) developed regression models for estimating the critical headway and follow-up headway as a function of the roundabout geometry and circulating flow. Equation (10) is used to estimate the follow-up headway (t_f) on single-lane roundabout or the lane with the higher traffic volume in the case of a double-lane roundabout. Equation (11) is used to estimate the follow-up headway (t_f) for the lane with the lower traffic flow on a double-lane roundabout. Troutbeck (43) related the critical headway (t_c) to the follow-up headway, conflicting flow, number of circulating lanes and number of entry lanes.

$$t_{f,dom} = 3.37 - 0.000394Q_c - 0.0208D_i + 0.0000889D_i^2 - 0.395n_e + 0.388n_c \tag{10}$$

Where,

$t_{f,dom}$ = follow-up time in the domain lane (s),

Q_c = conflicting flow (veh/h),

D_i = inscribed diameter, or the largest diameter that can be drawn inside the roundabout (m),

n_e = number of entry lanes, and

n_c = number of circulating lanes.

$$t_{f,sub} = 2.149 + 0.5135t_{f,dom}\frac{Q_{dom}}{Q_{sub}} + 0.8735\frac{Q_{dom}}{Q_{sub}} \tag{11}$$

Where,

$t_{f,dom}$ = follow-up time in the sub domain lane (s),

$t_{f,sub}$ = follow-up time in the domain lane (s),

Q_{dom} = vehicle flow in the domain lane (veh/h), and

Q_{sub} = vehicle flow in the sub domain lane (veh/h).

$$\frac{t_c}{t_f} = 3.6135 - 0.0003137Q_c - 0.3390n_e - 0.2775n_c$$

(12)

Where,

t_c = critical headway (s)

t_f = follow-up headway (s)

n_e = number of entry lanes, and

n_c = number of circulating lanes

The minimum delay (43) is given by:

$$D_{min} = \frac{e^{\lambda(t_c - \Delta)}}{\alpha q} - t_c - \frac{1}{\lambda} + \frac{\lambda \Delta^2 - 2\Delta + 2\Delta\alpha}{2(\lambda \Delta + \alpha)}$$

(13)

Where,

α = Proportion of free vehicles in the circulating flows

q = flow of vehicles in the circulating flows

t_c = Critical headway (s)

Δ = Minimum headway in the circulating flows, and

$$\lambda = \frac{\alpha q_c}{1 - \Delta q_c}$$

But for practical purposes, the average delay (**Error! Bookmark not defined.**) is given by:

$$D = D_{min}\left[1 + \frac{ex}{1 - x}\right] \tag{14}$$

Where,

x = degree of saturation, and

e = form factor, which can be generally set to 1.0 if a better value us not available

2.1.5 Swiss Model (Bovy et al Formula)

The Swiss model was developed by Bovy et al (*44*) and is expressed as a linear relation between the entry capacity and the vehicle distribution. It is suggested to be used in urban and suburban environments with non-mountable Central Island of diameter 18-20m. The capacity of an entry in pcu/h is given as:

$$C = \frac{1}{\gamma} \cdot \left(1500 - \frac{8}{9} \cdot Q_d\right) \tag{15}$$

γ = parameter taking into account the number of entry lanes

$$\gamma = \begin{cases} 1, & for\ one\ lane \\ 0.6 \leq \gamma \leq 0.7, & for\ two\ lanes \\ 0.5\ , & for\ three\ lanes \end{cases}$$

Q_d = disturbing traffic determined as (pcu/h):

$$Q_d = \alpha Q_u + \beta Q_c \tag{16}$$

Where,

Q_u = exiting traffic

Q_c = circulating traffic in front of the exit being considered

α and β = coefficients related to the geometry of the roundabout and are related to the distance ℓ between the exiting and entering conflict points as shown in the Figures 7.

$$\beta = \begin{cases} 0.9 - 1.0, & for\ one\ lane \\ 0.6 - 0.8, & for\ two\ lanes \\ 0.5 - 0.6\ , & for\ three\ lanes \end{cases}$$

Coefficients α and β are related to the geometry of the roundabout, the distance between the exiting and entering conflict points (ℓ) and the number of circulating lanes.

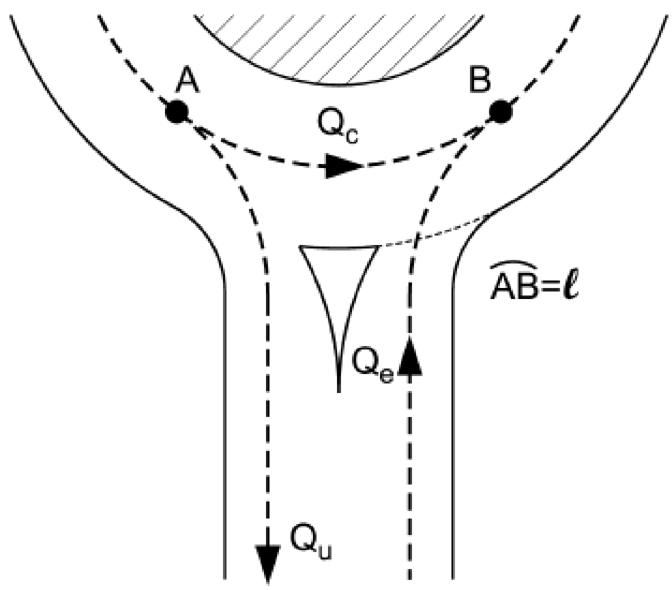

Figure 7 Distance ℓ between the Exiting and Entering Conflict Points

Using results from simulation, Bovy et al (44) establish that α decreases with ℓ until ℓ >28 m and the exiting vehicles do not disturb the entering vehicles (α=0). Figure 8 shows the behavior of the value α as a function of the distance ℓ using circulatory flow speed of 20-25 km/h. The broken lines show the boundaries for speeds below or above the specified range.

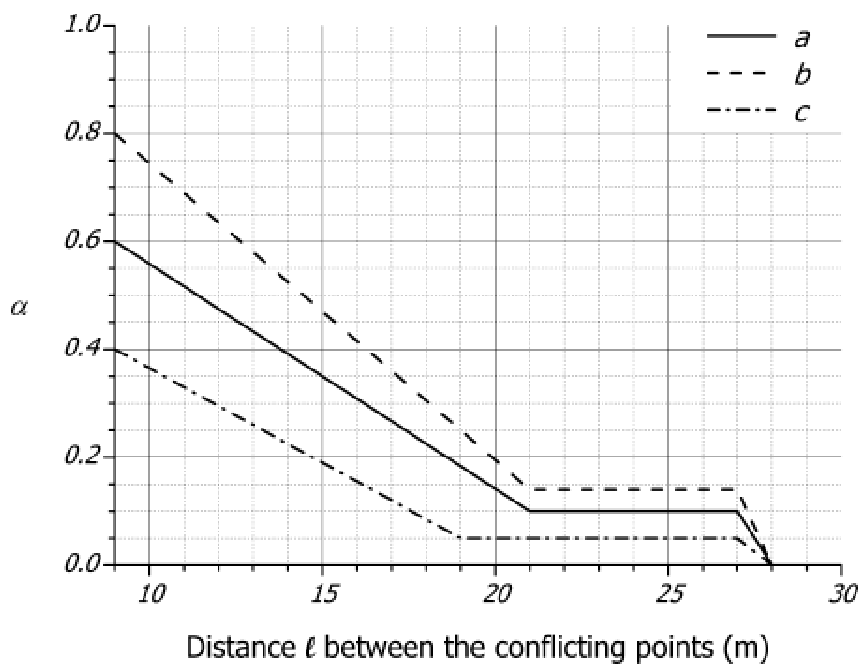

Figure 8 Values of α versus the distance ℓ

2.1.6 HCM Capacity and Delay Models

The HCM model uses a combination of simple, lane-based, regression and gap acceptance (analytical) models for both single-lane and double lane roundabouts. The generalized form of the capacity equation of a roundabout is expressed as

$$c_{pce} = Ae^{(-Bv_c)}$$

(17)

$$A = \frac{3600}{t_f}$$

(18)

$$B = \frac{t_c - (t_f/2)}{3600}$$

(19)

Where,

c_{pce} = lane capacity, adjusted for heavy vehicles, pc/h,

v_c = conflicting flow, pc/h,

t_c = critical headway, s, and

t_f = follow-up headway, s.

The HCM goes further to give equations for estimating capacity of different roundabout scenarios with the basic ones presented below:

Capacity of a single entry lane roundabout conflicted by a single circulating lane is given as:

$$C_{pce} = 1130e^{(-1.0\times10^{-3})v_{c,pce}}$$

(20)

Where,

c_{pce} = lane capacity, adjusted for heavy vehicles, pc/h, and

$v_{c,\,pce}$ = conflicting flow, pc/h.

Capacities of the right and left lanes of a two-lane roundabout conflicted by two circulating lanes are:

$$C_{e,R,pce} = 1130e^{(-0.7\times 10^{-3})v_{c,pce}} \tag{21}$$

$$C_{e.L.pce} = 1130e^{(-0.75\times 10^{-3})v_{c,pce}} \tag{22}$$

where,

$c_{e,R,pce}$ = capacity of the right entry lane, adjusted for heavy vehicles, pc/h,

$c_{e,L,pce}$ = capacity of the left entry lane, adjusted for heavy vehicles, pc/h, and

$v_{c,pce}$ = conflicting flow (total of both lanes), pc/h.

The HCM model for estimating average control delay for each lane of a roundabout approach is expressed as:

$$d = \frac{3600}{c} + 900T\left[x - 1 + \sqrt{(x-1)^2 + \frac{\left(\frac{3600}{c}\right)x}{450T}}\right] + 5 \times min[x, 1] \tag{23}$$

Where,

d = average control delay, s/veh,

x = volume-to-capacity ratio of the subject lane,

c = capacity of subject lane, veh/h; and

T = time period, h (*T* = 1 for a 1-hour analysis, *T* = 0.25 for a 15-minute analysis).

Beyond double-lane roundabouts, the 2010 HCM recommends the use of other analysis software since there is insufficient data available from the U.S.

2.2 INTERACTION OF FLOWS AT UNSIGNALIZED INTERSECTIONS

Generally at unsignalized intersections certain categories of drivers have priority over others and drivers must respect the order of priority (*45*). An important requirement at unsignalized intersections is the need for recognition and adherence to the interaction between the hierarchies of traffic flows. Some flows have absolute priority while others are required to yield to other flow directions which may also have to yield to others. Roundabouts however have two levels of hierarchy:

Rank 1 flow: Vehicles in the circulatory lane (s) have absolutely priority and are not required to yield right of way.

Rank 2 flow(s): Vehicles in the approach lane (s) must yield to rank 1 flow (s) i.e. vehicles in the circulatory lane (s).

Drivers entering the circulatory flow must evaluate the headway between potentially conflicting vehicles and decide whether to merge or not. The times between the arrivals of successive vehicles at the merging point is the time gap and is an important factor for drivers when they attempt to merge. This behavior is described in a technique known as gap acceptance which forms the basis for analysis procedures for unsignalized intersections (*46*).

2.2.1 Gap Acceptance Theory

The operations of unsignalized intersections are based on theories that are fundamental to general traffic flow theories. Gap acceptance theory is one such example. At unsignalized intersections, drivers do not have clear positive indication as to when to leave the intersection. Drivers have to look for a safe headway (gap) in the opposing traffic in order to enter. The headways are measured in time and this technique is referred to as gap acceptance. At unsignalized intersections, the distribution of the headways between the vehicles in the opposing traffic flows has a significant effect on the performance. The two basic elements of gap acceptance are: 1) The extent to which drivers find the gaps or opportunities of a particular size useful when attempting to enter the intersection and 2) the manner in which gaps of a particular size are made available to the driver and the pattern of the inter-arrival times. One of the difficulties in conducting observational studies of gap acceptance is the lack of control over the distribution of gaps presented to drivers waiting to cross (*47*).

Daganzo (*48*) states that gap acceptance functions are used in traffic models to show in probabilistic terms how drivers or pedestrians decide when to cross a roadway whose traffic has the priority. Gap acceptance functions, $\alpha(t)$, relate the duration of a headway, t seconds, to its probability of acceptance. They are non-decreasing functions with all the properties of cumulative distribution functions. He described the shifted negative exponential gap acceptance function as:

$$\alpha(t) = 0 \;\; t \leq T$$

(24)

$$\alpha(t) = 1 - e^{-\beta(t-T)} \;\; t \geq T$$

(25)

Where, β and T are parameters for a given individual, and the heavy side unit step function:

$$\alpha(t) = 0 \;\; t < T$$

(26)

$$\alpha(t) = 1 \;\; t \geq T$$

(27)

Gap acceptance plays a critical role in safety at roundabouts (*49*). This is because safe merging is a complex perceptual task that requires accurate judgment of the gap size in a dynamic traffic flow in order to time the onset of movement. One of the main uses of gap acceptance functions is in developing expressions for delay and capacity in crossing and merging situations. Kettelson and Vandehey (*50*) as well as Adebisi and Sama (*51*) showed that the delay experienced by drivers affects the headway sizes they are willing to accept. It has also been reported that road geometry, age, gender and speed affects the headways presented by the priority flow vehicles and also the headways accepted by the minor flow drivers (*52*,*53*). Other factors that may affect gap acceptance though not very conclusive are the type of vehicles and the weather (*54*).

2.2.2 Usefulness of Headways (Gaps)

An important concept of gap acceptance used in the analysis of unsignalized intersections is the extent to which drivers utilize gaps of a particular size (**Error! Bookmark not defined.**). Based on the size of the gaps presented, one or more vehicles will be able to leave the lower ranked approach. The minimum headway, t_c, that all drivers in the minor flow are assumed to accept at all similar locations is referred to as the critical gap (headway = t_c). Driver behavior models usually assume that no driver on the lower priority will enter the higher priority lanes unless the headway between successive vehicles in the higher priority flow is equal to or greater than their critical headway, t_c (48,*55*). Gap acceptance theory further assumes that a driver will accept that same headway (gap) at any similar intersection. In the case of a roundabout, it is assumed that the drivers in the entry lane seeking to merge onto the circulatory lane will always accept similar gaps depending on which lane they approach from. If the gap presented is relatively long, the theory further assumes that a number of drivers will be able to enter the intersection. If a number of lower priority vehicles enter the intersection using one long gap, the headways between the successive vehicles (lower priority flow) is referred to as follow-up headway t_f. Troutbeck (*56*) found that the number of useful headways in the circulatory traffic flow is influenced by the degree of bunching in the flow.

Another fundamental assumption with the gap acceptance theory for unsignalized intersections is that drivers are both consistent and homogeneous (*57*). Consistent drivers are expected to behave in the same manner every time at similar intersections and homogeneous population expects that all drivers behave exactly the same way. This assumption for all practical purposes is unreasonable and found to be an over simplification of the reality (*58*). Troutbeck (*59*) and Wegmann (*60*) in their analysis showed that if drivers were heterogeneous, the entry capacity will be reduced. However if drivers were inconsistent, then the capacity will increase. The more realistic behavior of drivers is inconsistent and heterogeneous but the difference from assuming drivers to be consistent and homogeneous is negligible. For simplicity, drivers are assumed to be consistent and homogeneous. Harder (*61*) and Troutbeck (59) found that the gap acceptance parameters t_c and t_f are affected by the speed of the major traffic flow i.e. priority flow. Drivers are also expected to be influenced by the difficulty of the maneuver, i.e., the more difficult the maneuver, the longer the critical headway and follow-up headway (**Error! Bookmark not defined.**).

Brilon and Wu (*62*) introduced a new concept for the computation of capacity and delay at unsignalized intersections using the conflict technique. However, their technique requires the computational abilities of a computer to arrive at a solution because of the equations developed. The method also makes it easy to account for the effects of limited-priority effects.

2.2.3 Critical Acceptance Headway

From the discussion above the critical accepted headway for a driver is assumed to be such that all headways greater than this critical headway are acceptable and all headways smaller are unacceptable. The critical acceptance headway for an intersection is the mean of drivers' critical headways. The mean critical headway and the average follow-up headway are required by most roundabout analytic models for computing the capacity and delay of an entry lane.

Several gaps of varying sizes are observed at unsignalized intersections but only the larger gaps are important; these are likely to be accepted. Techniques for estimation of the critical headway and follow up headways are categorized into two groups. The first group is based on regression analysis of the number of drivers that accept a gap against a gap size. The second group estimates the distribution of follow-up headways and the critical headway distributions separately (**Error! Bookmark not defined.**). It is clear from the discussion so far that the critical headway for drivers will vary widely for any particular intersection and must be modeled as a random variable (*63*). The critical headway cannot be estimated directly from the field results therefore researchers use mathematical approaches which depend mostly on probability distributions such as the normal distribution; log-normal distribution, gamma distribution, and exponential distribution to estimate the drivers' mean critical headway. The log-normal distribution is one of the most widely used distributions for critical headway estimation (63,*64*,*65*). The accepted methodology for estimating the mean critical gap in the U.S is the maximum likelihood technique. This technique also uses the log-normal distribution function and was adopted from the Australian studies on unsignalized intersections (*66*). The technique assumes that a driver's critical headway lies somewhere between his accepted gap and his largest rejected gap (66).

2.2.4 Methods for Estimating Critical Headway

Several different techniques have been suggested for estimating critical gap (*67*). The difficulty in finding a common acceptable procedure is due to the nature of observed traffic flow pattern. It is obvious that the critical headway and follow-up headway differ from driver to driver, time to time and between intersections, type of movement and traffic situations. Due the variability of critical headway, the nature is described as one of stochastic rather than dynamic. Brilon et al (17) reviewed eight of the popular methods for critical gap estimation in order to assess their accuracy and validity of estimations. They considered techniques applicable to saturated and unsaturated conditions. A summary of their study findings are presented below:

2.2.5 Estimation Technique for Critical Headway: Saturated Condition

2.2.5.1 Siegloch's Method

Siegloch (*68*) proposed a consistent framework for the theory of capacities at unsignalized intersections. Let $g(t)$ be the number of minor street vehicles that can enter the conflict area during one minor stream headway of size t. The expected number of gaps of size t within the major traffic flow is $q_p h(t)$ where $h(t)$ is the statistical density function of all headways in the major flow. Thus, the amount of capacity that is provided by headways of size t during an hour is $q_p h(t) g(t)$. The total capacity c is obtained by integrating over the whole range of possible major flow headways t. Thus

$$c = q_p \int_{t=0}^{\infty} h(t) g(t) dt$$

(28)

This equation for the capacity of unsignalized intersections forms the foundation of the whole gap acceptance theory. Almost all of the different analytical capacity estimation formulae found in the international literature are based on this concept, even in cases where the original others were not aware of this fact.

The consequence of this equation is that, for capacity calculations, we need to know the major traffic flow headway distribution *h(t)* and the function *g(t)*.

$$g(t) = \begin{cases} 0 & for\ t < t_0 \\ \dfrac{t - t_0}{t_f} & for\ t \geq t_0 \end{cases}$$

(29)

Where,

$$t_0 = t_c - \frac{t_f}{2}$$

Therefore, t_c and t_f can be evaluated from the regression technique directly. This technique fully considers the stochastic nature of gap acceptance. The combination of Equations (29) and (30) together with the assumption that *h(t)* can be described by the exponential distribution leads to the well known Siegloch formula for the capacity of an unsignalized intersection:

$$c = \frac{3600}{t_f} e^{-p t_0}$$

(30)

The advantage of Siegloch's procedure for the estimation of t_c and t_f is its close relation to the subsequent capacity theory. The drawback for practical application is the fact that this method is applicable for saturated conditions only, which is difficult to find in many practical cases.

2.2.6 Estimation Technique for Critical Headway: Unsaturated Condition

2.2.6.1 The Lag Method

This simple method is based on lags. A lag is the time from the arrival of the minor vehicle until the arrival of the next major vehicle. The following conditions were assumed:

- consistent drivers, and
- independence of the minor street vehicle arrival time and the traffic situation on the major street.

Then the proportion $p_{a,lag}(t)$ of drivers who accept a lag of size t is identical to the probability that a driver has a t_c value smaller than t. Thus we can state

$$P_{a,lag} = F_c(t)$$

(31)

From this consideration we could derive the first method of critical gap estimation for under saturated conditions. The mean critical headway is given after a series of analysis as

$$t_c = \sum_{i=1}^{W} t_i[F_c(t_i) - F_c(t_i)]$$

(32)

Where,

W=number of intervals of size Δt, and

Δt = size of time scale

For the method the drawback is that for each interval, i, a sufficiently large sample should be available. This demands very long observation periods because with low major street traffic flow it takes a while to observe enough smaller lags, and with large major street volumes most minor street vehicles have to queue before they can enter the conflict zone. Consequently, although a large number of drivers' decisions have been observed, there will be very few lags that can be used for this estimation procedure.

2.2.6.2 Raff's Method

Raff and Hart's (*69*) method seems to be the earliest method for estimating critical gaps. The definition translated into current terminology means that t_c is that value of *t* at which the intercept of the two functions

$$1 - F_r(t) \text{ and } F_a(t)$$

Miller (67) gave some additional mathematical interpretations for this method. He also points out that the results of this t_c estimation are sensitive to the traffic volumes under which they have been evaluated. Raff's method was used previously in many countries.

2.2.6.3 Ashworth's Method

Ashworth (*70*) used the assumptions of

- exponentially distributed major stream headways with statistical independence between consecutive headways, and
- normal distributions for t_a and t_c,

and estimated the mean critical headway t_c from μ_a (the mean of the accepted headways t_a) and σ_a (the standard deviation of accepted headways) by

$$t_c = \mu_a - p{\mu_a}^2 \tag{33}$$

Where,

P = major stream traffic volume (vehicles per second).

If t_a is not normally distributed, the solution might become more complicated. However, for a gamma distribution or a log-normal distribution of t_a and t_c, Siegloch's equation is a close approximation. Miller (67) provided another correction method for the special case that the t_c are gamma distributed.

2.2.6.4 Harders' Method

Harders (*71*) developed a method for t_c estimation and was popular in Germany. The method only makes use of headways and is similar to the lag method discussed. However, for Harders' procedure, lags should not be used in the sample. The time scale is divided into intervals of constant duration, e.g. Δt=0.5 s. The center of each interval *i* is denoted by t_i. For each vehicle queuing on the minor street, all major stream headways that are presented to the driver have to observe and, in addition, the accepted gap. From these observations we have to calculate the following frequencies and relative values:

- N_i = number of all gaps of size i; that are provided to minor vehicles
- A_i = number of accepted gaps of size i
- a_i = Ai/Ni

Now these a_i values can be plotted over the t_i. The curve generated by doing this has the form of a cumulative distribution function. It is treated as the function $F_c(t)$. With a series of limits the estimation of t_c is given by the expectation of the $F_c(t)$ distribution function. This method appears to be a more pragmatic solution without a strong mathematical background.

2.2.6.5 Logit Procedures

A couple of methods have been proposed that can be summarized as logit models, as they provide similarities to the classical logit models of transportation planning. In each case the models lead to a function of the logit type. In a formulation for these models each minor street driver waiting for a sufficient headway has to judge between the two alternatives:

- i = accept the gap for the crossing or merging maneuver,
- j = reject the gap.

A driver, in his decision situation, *d*, will expect a specific utility from his decision. This utility can be regarded as a combination of safety on one side and low delays on the other side. We regard the total utility U_{id} as an additive combination of a deterministic term V_{id} and a random term ε_{id}

$$U_{id} = V_{id} + \epsilon_{id}$$

$$U_{jd} = V_{jd} + \epsilon_{jd}$$

(34)

This is solved using a series of long processes into a log-likelihood function L(α,β) and solving by maximization. The mean of the critical headway t_c and variance are thus:

$$t_c = \frac{\alpha}{\beta}$$

(35)

$${\sigma_{t_c}}^2 = \frac{\alpha^2}{3\beta^2}$$

(36)

This family of models allows the evaluation of other external effects on the critical gap.

2.2.6.6 Probit Procedure

Probit techniques for the estimation of critical gaps have been used since the 1960s. (67). The formulation for this type of models is quite similar to the logit concept. In their original form, however, these models do not use the utility term, instead, the size of the critical gap, t_c, is directly randomized by an additive term, ε. Thus we formulate for a consistent driver *d*:

$$t_{c,d} = \bar{t}_c + \varepsilon_d$$

(37)

Where,

$t_{c,d}$ = critical headway for driver d (seconds),

$\bar{t}_c$ = average critical headway for the whole population of drivers (seconds),

ε_d = deviations of the critical headway for driver d from $\bar{t}_c$ (seconds)

This is solved by use of a probability function. One problem with all probit approaches is that the normal distribution may not be adequate to be applied for critical gaps since a significant skewness of the t_c distribution must be expected.

2.2.6.7 Hewitt's Method

In this approach, the time scale is divided into intervals of constant duration, e.g. $\Delta t=1s$. The center of each interval i is denoted as t_i. The method uses an iterative procedure. As a first approach for the gap acceptance function $F_c(t)$, the lag method is used. However, for the purpose of analytical tractability, $F_c(t)$ in the first step is estimated according to the probit method. This leads to values for the probability that t_c is inside the interval i, which is denoted as $c_{i,0}$, where the index 0 stands for the 0^{th} step of iteration. The iteration is repeated until the subsequent t_c values become nearly unchanged by the next iteration.

The information to be extracted from observations for each time interval i of duration Δt are the total number of gaps, number of rejected gaps, total number of lags, and number of rejected lags. For practical application, some additional aspects have to be observed if some of the time intervals are not filled up with sufficient empirical values.

2.2.6.8 Maximum Likelihood Technique

This method uses the Log-normal distribution for estimating the mean critical headway. Using the log-normal probabilistic distribution allows a shift to the right skew and has non-negative values as would be the case for traffic situations. Applying the principle to roundabouts, we start with the basis that the maximum likelihood of a sample of n drivers having accepted and largest rejected gaps of (y_i, x_i) is given by the Equation (66):

$$\prod_{i=1}^{n}[F(y_i) - F(x_i)]$$

(38)

Where,

y_i = the logarithm of the gap accepted by the i^{th} driver = ∞ if no gap was accepted,

x_i = the logarithm of the largest gap rejected by the i^{th} driver = 0 if no gap was rejected, and

F() = cumulative distribution function for the normal distribution

The logarithm, L, of the likelihood is then

$$L = \sum_{i=1}^{n} \ln[F(y_i) - F(x_i)]$$

(39)

If μ and σ² are the mean and variance respectively of the distribution of the logarithms of the individual drivers' critical gaps, the maximum likelihood estimators, μ' and σ²' that maximize L are the solution to the Equations (40) and (41):

$$\frac{\partial L}{\partial \mu} = 0$$

(40)

$$\frac{\partial L}{\partial \sigma^2} = 0$$

(41)

Substituting for Equations (40) and (41) gives Equations (42) and (43):

$$\frac{\partial L}{\partial \mu} = \sum_{i=1}^{n} \frac{\frac{\partial F(y_i)}{\partial \mu} - \frac{\partial F(x_i)}{\partial \mu}}{F(y_i) - F(x_i)} = 0$$

(42)

$$\frac{\partial L}{\partial \sigma^2} = \sum_{i=1}^{n} \frac{\frac{\partial F(y_i)}{\partial \sigma^2} - \frac{\partial F(x_i)}{\partial \sigma^2}}{F(y_i) - F(x_i)} = 0$$

(43)

Using algebra, it can be shown that

$$\frac{\partial F(x)}{\partial \mu} = f(x)$$

(44)

$$\frac{\partial F(x)}{\partial \sigma^2} = -\frac{x-\mu}{2\sigma^2} f(x)$$

(45)

Where,

f() = is the probability density function for the normal distribution

And leads to Equations (46) and (47) that can be solved iteratively using numerical methods

$$\sum_{i=1}^{n} \frac{f(y_i) - f(x_i)}{F(y_i) - F(x_i)} = 0$$

(46)

$$\sum_{i=1}^{n} \frac{(x_i - \mu')f(x_i) - (y_i - \mu')f(y_i)}{F(y_i) - F(x_i)} = 0$$

(47)

Where,

$F(x_i)$, $F(y_i)$, $f(x_i)$ and $f(y_i)$ are functions of μ' and $\sigma^{2'}$

Using the iterative tool and optimization in any computer spreadsheet program such as Microsoft Excel, the solution can be arrived at very quickly.

2.2.6.9 Factors affecting Critical Headway

All the factors that affect the gap accepted by drivers also affect the critical headway. Troutbeck in a research (43) reported that the follow-up headway for all lanes in a roundabout decrease with increasing diameter of inscribed circle. The same research

(43) using data in Australia developed a chart which related the volume of flow, inscribed diameter and follow-up time for the main lanes at a roundabout and is shown in Figure 9. Critical gap was also found to be influenced by the average entry width (56).

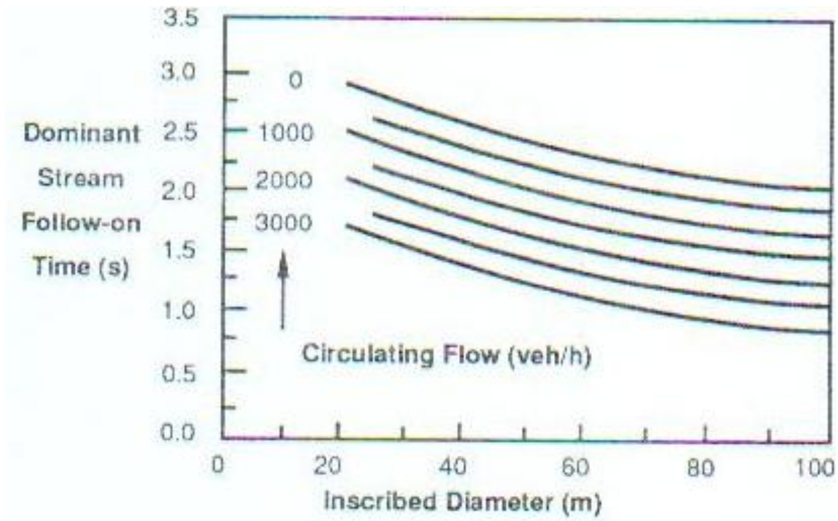

Figure 9 Effect of Circulation flow and diameter on the follow-up headway

Another observation was that both the critical headway and the follow-up headway decrease with increasing circulatory flow. A possible explanation to the observation was that at roundabouts with low circulatory flow, drivers were willing to reject smaller gaps in anticipation that a larger gap will be presented to them shortly. Figure 10 shows the relation between the headway and circulatory flow given the entry lane width in meters (43).

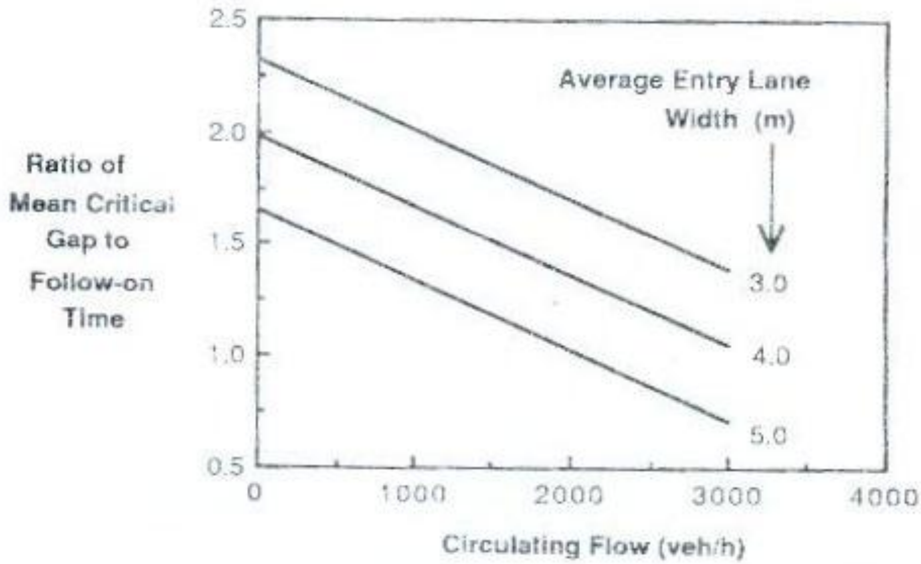

Figure 10 Entry width and flow effect on the ratio of critical headway to follow-up headway (single circulatory lane)

Kimber (15) related the critical headway of a roundabout to the follow-up headway and determined it to be in the order of 0.9-1.1 as the number of entry lanes changes from 1 – 3.

At high circulating flows however, entering drivers cannot always yield the right of way without experiencing excessively long delays. This causes the entering drivers to resort to sharing priority with the circulating drivers thus creating a temporal phenomenon described as "priority reversal". The phenomenon is similar to another which is described as limited priority (14). Limited priority is the particular case of shared priority where the major traffic flow vehicles are assumed to be slightly delayed to accommodate merging vehicles as described by Kimber (21) and Troutbeck and Kako (13). The minor traffic flow vehicles are thus assumed to have limited priority under the circumstances. Bunker and Troutbeck (*72*) applied the principle of limited priority to freeway merge and found the phenomenon was more of the reality and it reduced the delay incurred by merging vehicles. Cowan (*73*) derived solutions for the shared priority case where two traffic flows merge into one. He described the operating rule as one where drivers merge as soon as possible, subject to the restraints that they must leave a safety headway of about 2 seconds between themselves and the most recently merged vehicle. He further described the situation where queues exist on both lanes as one of a tacit operating agreement which allows vehicles to merge alternately from each queue. So the conflict zone gradually becomes a merging zone instead.

Typically, these situations are associated with entering drivers willing to accept smaller gaps in the circulating flow and circulating drivers also willing to slow down to allow a merge. Sometimes, circulating drivers just slow down a little and entering drivers accept the gap. There are also situations where, entering drivers actually edge themselves into the circulatory lanes and force the drivers to slow down. Usually, there is a form of mutual arrangement that occurs when the circulatory speed is slow enough to allow safe merging conditions. A research (14) reported a significant correlation (at a 5 percent level) for the critical headway with the expected follow-up headway, the circulating flow, entry width and the number of entry lanes.

A study in the U.K. (*74*) found that the number of saturated legs at a roundabout appeared to have little influence on the capacity of the entry lane. Instead, the level of saturation on the circulating lane (s) directly in front of the approach lane (merge point) appeared to have a greater effect. The level of saturation at the merge point also influences the motorists in the entry lane waiting for gaps. When drivers wait longer than their expectation, they try to force gaps and by so doing affect the circulatory motorists. Akcelik, (*75*) in his assessment of the 2010 HCM roundabout capacity model suggested that small changes in the driver response times could result in significant capacity changes.

Polus et al (*76*) also found that the critical gaps are dependent on the average waiting times prior to the vehicle's entry into a heavily trafficked roundabout. They found that an increase in waiting time resulted in a significant decrease in critical gaps.

2.2.7 Priority Reversal

Gap acceptance computations have traditionally been based on the assumption that, the drivers in main traffic flow have absolute priority and the minor traffic flow drivers do not affect the drivers in the main flows (16). However, researchers have found that traditional gap acceptance theory does not fully explain the observed driver behavior at roundabouts and other unsignalized intersections (21). Troutbeck (45) showed that for high traffic flows with lower relative speeds traditional gap acceptance approach was unable to adequately explain the observations. This is because observation at roundabouts for example showed that drivers in the circulatory lane (s) tended to yield to entering drivers when the flows were high. Some drivers in the entering lane also forced themselves into the circulatory lanes forcing the circulatory drivers to yield. These behaviors, referred to as limited-priority gap acceptance processes where temporal reversal of priority occurs are in variance with the absolute priority assumptions used in the ideal gap acceptance theory. Vehicles in the major stream may be slightly delayed when they slow down to accommodate entering vehicles while the capacity of entering lanes may be increased more than expected (21). Troutbeck (45) in his analytical study showed that under limited priority situations lower critical headways will be recorded which should result in an increased capacity at the merge. For limited-priority merges Troutbeck (*77*) presented an equation for the capacity at the merge based on Cowan's M3-type distribution as shown in Equation (38);

$$Capacity = \frac{\alpha C q e^{-\lambda(t_a - \tau)}}{1 - e^{-\lambda t_f}}$$

(38)

Where,

$$C = \frac{1 - e^{-\lambda t_f}}{\left[1 - e^{-\lambda(t_a - \tau)} - \lambda\left(t_a - t_f - \tau\right)e^{-\lambda(t_a - \tau)}\right]}$$

$$\lambda = {}^{\alpha q}\big/\left(1 - \tau_q\right)$$

t_a = Critical acceptance headway (gap),

t_f = follow-up headway, and

τ = minimum headway to the vehicle in front after the merge on the major stream.

2.3 PERFORMANCE MEASURES FOR ROUNDABOUTS

Traffic performances are measured using parameters that determine the outputs of a facility based on delay, capacity, queue length etc. They are typically compared with standard values to determine the degree of acceptability. Robinson and Rodegerdts (*78*) in a study recommended the degree of saturation, total delay and average queue length be used to estimate the operational performance of roundabouts. Based on several research findings, they explained the need to estimate capacity for a roundabout entry before computing specific performance measures. Flannery and Data (*79*) found that roundabouts have great potential for capacity improvement at locations where traffic volumes vary substantially hence the performance measure need be measured over a longer period of time. "Roundabouts are known to reduces delays and eliminate the need to stop by replacing the interrupted spatial and temporal discharge of vehicles on conflicting paths with slow-speed merges and diverges for vehicles moving in the same direction" (*80*). Using before and after studies for several intersections, Eisenman et al (*81*) found that delay could be reduced by over 50 percent after installing roundabouts. Akcelik (*82*) and Fisk (*83*) identified a number of ways of computing roundabout delay.

The roundabout models developed by countries such as U.K., Germany, Australia and France are specifically adapted for their environment. These models predict the capacity of a given approach for given conditions using geometric and/or behavioral relationships (*84*). Brilon (40) recommended the generation of empirical data from a recipient country if capacity formulae were to be transferred from one country to another.

The 2010 HCM (12) also recognized that the capacity of a roundabout is directly influenced by several factors including the flow patterns, entering, circulating and exiting vehicles. For roundabouts, the capacity and performance measure are better evaluated for each approach lane rather than the intersection as a whole (75). The HCM capacity estimation models are presented in equations (20-22). The equations predict a capacity reduction as the volume of traffic flow increases. Circulating traffic is the primary conflicting traffic stream, though the exiting traffic does affect driver perception during decision making (22,*85*). Capacity for a roundabout is not a single value, but a set of values, one for each approach in a time period, and are computed using specific models. The 2010 HCM recommended equation for estimating average control delay for each approach lane of a roundabout is given in Equation (23).

Data collected in the U.S. suggested that the control delays for roundabouts can be predicted in a manner similar to stop-controlled and signalized intersections (79). The 2010 HCM (12) LOS criteria for vehicles at roundabouts are given in Table 3. As shown in the table, an LOS of “F” is assigned when the volume-to-capacity (v/c) ratio of a lane exceeds 1.0, regardless of the control delay.

Table 3 LOS Criteria for Vehicles

Control Delay (s/veh)	**LOS by Volume-to-Capacity Ratio** $v/c \le 1.0$	$v/c \ge 1.0$
0-10	A	F
>10-15	B	F
>15-25	C	F
>25-35	D	F
>35-50	E	F
>50	F	F

Source: FHWA Guidelines

The 95th percentile queue for a given approach lane is estimated using Equation (39):

$$Q_{95} = 900T\left[x - 1 + \sqrt{(1-x)^2 + \frac{\left(\frac{3600}{c}\right)x}{150T}}\right]\frac{c}{3600}$$

(39)

Where,

Q_{95} = 95th Percentile queue, veh,

x = volume-to-capacity ratio of the subject lane,

c = capacity of subject lane (veh/h), and

T = time period (h: T=1 for 1-h analysis, T=0.25 for 15-min analysis).

For a good roundabout evaluation, it has been established that an exit flow rate greater than 1400 veh/h is unlikely even under good operating conditions. Therefore for practical purposes, when the exit flows exceeds 1200 veh/hr it is recommended to have a double-lane exit (78). When unbalanced traffic flows are experienced at approaches, metering helps to reduce long delays and queues (*86*) on the minor approach. Metering is often installed on selected roundabout approaches and only operated during periods of heavy demand within the peak hour.

2.3.1 Roundabout Analysis and Design Software

In the analysis of roundabouts, there are two main approaches: empirical and analytical. While empirical models use observations at many intersections to develop regression equations that relate intersection characteristics to intersection capacity and delay, analytical models estimate capacity based on traffic flow theory. The 2010 HCM (12) however adopted a combination of a simple lane based regression model and the gap acceptance theory to determine the approach capacity for roundabouts. Computer software for roundabout evaluations has been successfully developed using both empirical and analytical models (*87*).

Simulations generally come in three styles: live, virtual and constructive. A simulation also may be a combination of two or more styles. Most of the popular simulation software in use is grouped under macroscopic or microscopic models and discussed below. These software analyses are typically focused on either macroscopic or microscopic simulation methods. Whereas models are mathematical, logical, or other structured representations of reality, simulations are the specific application of models to arrive at some required outcomes. Traditional macro-simulation models provide a simplified aggregated representation of traffic, typically expressed in terms of total flows per hour. In such models, all vehicles of a particular group obey the same rules or behavior. This simplistic approach does not allow the accurate modeling of some complex transport planning / traffic engineering applications. Traffic micro-simulation computer models however capture the interactions of real world road traffic through a series of complex algorithms describing car following, lane changing, gap acceptance, and spatial collision detection. In addition, free form pedestrian movement is replicated using agent based spatially aware models allowing road traffic to interact with pedestrians as they do in the real world. This involves treating each vehicle, bus, train, tram, cyclist, pedestrian etc. in the model as a unique entity with its own goals and behavioral characteristics; each possessing the ability to interact with other entities in the model (*88*).

2.3.2 Macro-Simulation Models

Macroscopic models tend to employ flow rate variables and other general descriptors of the traffic movement. The flow rate within one segment of the roadway is related to upstream and downstream flow rates through conservation-of-flow equations and other equations that ensure the boundary conditions are met at the interface between system segments (*89*,*90*). The macro-simulation software models commonly used for roundabout analysis include ARCADY, RODEL, HCS and SIDRA Solutions. Popular models are discussed below.

2.3.2.1 RODEL

RODEL (ROundabout DELay) and ARCADY (Assessment of Roundabout Capacity and DelaY) are empirical macroscopic analysis models for roundabouts that are based on many observations in the United Kingdom. These two programs are often used to estimate the capacities, queues and delays. RODEL (*91*,*92*) is an interactive program intended for evaluation and design of roundabouts. The program was developed in the Highway Department of Staffordshire County Council in England. RODEL is based on an empirical model developed by Kimber (*93*) at the Transport and Road Research Lab

(TRRL) in UK. The empirical model was chosen over the gap acceptance model because it directly related capacity to detailed geometric parameters. Required inputs for parameters include geometric features such as entry width, approach width, entry radius, and inscribed circle diameter (**Error! Bookmark not defined.**). There are two main modes of operation. In mode 1, the user specifies target parameters for average delay, maximum delay, maximum queue, and maximum volume-to-capacity (v/c) ratio. RODEL then generates several sets of entry geometrics for each approach based on the given input e.g. width of lane. Depending on site specifics and constraints, the generated geometrics can be used for design purposes. Mode 2 focuses more on performance evaluation using specified values of the geometry and traffic characteristics. RODEL simultaneously displays both input and output data on a single screen which appeals to some users.

2.3.2.2 ARCADY

ARCADY (*94*) is also a British analysis program with the same empirical theoretical background as RODEL which incorporates Kimber's capacity model (93). Kimber used the idea of entry geometry affecting the capacity and related the equation to several site specific parameters. The model assumes a linear relationship between the circulating flow and the maximum entry flow. In ARCADY, input data requirements are similar to RODEL since both programs follow the same methodology and include entry width, inscribed circle diameter, flare length, approach road width, entry radius, and entry angle. Like RODEL, ARCADY deals in the concept of confidence level. The main difference is that the confidence level may be specified for RODEL, but is embedded in the ARCADY model at 50 percent.

2.3.2.3 SIDRA

SIDRA (Signalized and Unsignalized Intersection Design and Research Aid) is an analytical based computer software program developed in Australia for predicting the performance of roundabouts. This analytical model uses an approach based on the gap acceptance theory (also adopted in the HCM) for analyzing non-signalized intersections. The SIDRA Solutions package was developed in Australia as an aid for design and evaluation of signalized intersections, roundabouts, two-way stop control, all-way stop control and yield sign control (*95,96,97*). The capacity formula calculates the capacity of each approach as a function of the circulating flow, critical gap and follow-up time (**Error! Bookmark not defined.**). For roundabouts SIDRA computes the capacity of each approach lane separately. This method allows for capacity losses due to lane under-utilization and allocates the largest degree of saturation in any lane movement. In SIDRA, the gap acceptance parameters are calculated in the following order: The follow up headway in the major traffic flow is estimated as a function of the circulating flow and the inscribed circle diameter; the follow up headway in the minor traffic flow is calculated as a function of the ratio of flows between the lanes considered and the dominant-traffic flow follow-up time. The critical headway is calculated as a function of the follow up headway, the major traffic flow, the number of effective circulating lanes and the entry lane width.

SIDRA requires site-specific data including traffic volumes by movement, number of entry, exiting and circulating lanes, central island diameter, and circulating roadway width. It uses several parameters for which reasonable default values are offered. One parameter of particular importance is the practical capacity of roundabouts. A default value of 85 percent of the possible capacity (i.e. v/c = 0.85) is used as the maximum operational capacity. The SIDRA documentation points out that roundabout operation at maximum capacity levels is less predictable than signal operation, because signal control is less dependent on drivers' behavior. Therefore, more caution is urged in dealing with roundabouts that operate above the practical capacity. SIDRA offers the option to include or exclude geometric delay from computations.

2.3.2.4 Highway Capacity Software (HCS)

The HCM software for analysis of roundabout is the Highway Capacity Software (HCS). This is based on the equations developed as part of the NCHRP 3-65 project research on roundabouts and incorporated into the 2010 HCM. The HCS model is based on the gap acceptance theory with the 2010 HCS (*98*) being updated to incorporate the new models introduced into the 2010 HCM. The program allows users to assess the operational performance of single-lane or double-lane roundabouts using traffic demand flow. HCS can implement the procedures for signalized intersections, roundabouts, basic freeway segments, freeway weaving segments, freeway merge and diverge segments, two-lane highways, and multilane highways. It can also evaluate multimodal (pedestrian, bicycle and transit) levels of service; modeling the effects of access points on travel speed and platoon integrity. It also has a visual mode for a graphic input option with background maps and tabular data screens. While the database on which these procedures are based is the most comprehensive developed for U.S. conditions, there are limitations. Some of the limitations are listed below:

- Upstream/downstream signals influence on the performance of the facility
- Entry priority reversal occurrences, such as unusual forced entry conditions under extremely high traffic flows

• A high level of pedestrian or bicycle traffic exists

• Two roundabouts in close proximity

• More than two entry lanes present on one or more approaches.

2.3.3 Micro-Simulation Software

The microscopic approach is generally implemented in a simulation model that processes individual vehicles and accumulates performance measures based on their progress through the system. VISSIM, CORSIM and Paramics are popular micro-simulation software packages that are used for roundabout evaluation. Unlike macroscopic models, the user has to write codes to specify details of operations such as entering, circulation, and exiting maneuvers at the roundabout. Three of the models are described below.

2.3.3.1 VISSIM

VISSIM gives a flexible platform that allows users to realistically model a roundabout or any other traffic situation using a psycho-physical car following model and a rule-based algorithm for lateral movements (*99*). It is based on a link-connector instead of a link-node structure which is able to build a complete network or a single intersection. It allows users to import CAD layout (dxf or jpg) and set it as a background on which links can be drawn. An appropriate scale is assigned so that all the measurements are in the same units and all geometric elements are precisely drawn. There are three principal features needed for accurate simulations: 1) approach speed, reduced speed zones and circulatory speed; 2) priority rules; and finally, 3) traffic assignment. Driver behavior is user defined.

2.3.3.2 CORSIM

CORSIM is a microscopic simulation model designed for the analysis of freeways, urban streets, and corridors or networks (*100*). CORSIM uses the link-node network model approach. CORSIM was developed and maintained by FHWA and includes both NETSIM (for surface street simulation) and FRESIM (for freeway simulation). CORSIM can also be used to simulate different intersection controls including roundabouts. It can handle almost any surface geometry that includes numbers of lanes and turn pockets, and a wide range of traffic flow conditions. The links represent the roadway segments, whereas the nodes mark a change in the roadway, an intersection, or entry points. It is run within a software environment called the Traffic Software Integrated System (TSIS), which provides an integrated, Windows-based interface and environment for execution of the model. The TRAFVU Viewer provides animation and static graphics of traffic networks, using the CORSIM input and output files created by a licensed user of TSIS.

2.3.3.3 PARAMICS

Paramics (*101*) simulates driver behavior based on a model of the street network and also uses gap acceptance theory to determine roundabout operations. This software uses a link - node structure to define the roadway network and an origin-destination matrix to define vehicle paths through the study area. The output includes both technical data for measurement of effectiveness (e.g. delay) and vehicle animation for visual inspection. It is useful in modeling closely spaced roundabouts since it can account for the interaction between them. Paramics is also good for public involvement because the movement of individual vehicles through a proposed roundabout is clearly illustrated.

2.4 ROUNDABOUT INSTALLATION CONSIDERATIONS

Roundabout installation requires consideration of multiple factors. Generally most state agencies in the U.S. rely on the FHWA's Roundabout Guide (11) for guidance in the design of roundabouts. Therefore considerable similarity exists in the rationale for selecting a roundabout control as one travels across the U.S. Burley (*102*) suggested that the factors usually vary in relative importance from site to site but can be grouped broadly into general and site specific factors. General factors are safety, cost, economic evaluation, and community view. Site specific factors are physical controls, road environments, road user costs, and traffic management considerations. Geometric considerations are typically addressed after the site selection has been concluded.

Roundabouts have been successfully constructed and operated at a wide variety of locations and different traffic conditions. Generally any intersection that meets the criteria for a four-way stop control or traffic signal, also qualifies for consideration as a roundabout. A basic prohibitive circumstance that must be improved if a roundabout is to be considered at any intersection is a site where there is insufficient sight distance prior to the entrance (*103*). From literature, the following locations are suggested as best suited or unsuitable for roundabout location (*104*). These only serve as a guide to preselecting the sites but further preliminary investigations are required before final selection is made.

2.4.1 General Locations Where Roundabouts are often Advantageous

The list identifies conditions where roundabouts can provide advantages over other traffic controls and includes:

1. Intersections where there are a high number of left turn or U-turn movements
2. Intersections with safety problems
3. "Y" or "T" intersection configuration
4. Intersections with large peak period traffic volumes but relatively low traffic volumes during off-peak periods
5. Intersections where traffic growth is expected to be high and future traffic patterns are uncertain
6. More than four legs or unusual geometry or configuration
7. Existing two-way stop-controlled intersections with large side-street delays
8. At a gateway or entry point to a campus, neighborhood, or commercial development
9. Intersections where widening one or more approaches might be difficult or cost-prohibitive, such as at bridge terminals
10. Locations where the speed environment of the road has to be reduced
11. Locations with a need to provide a transition between land use types
12. Roads with a problem of excessive speeds
13. Location with constrained queue storage
14. Large traffic signal delays when volumes are not very high
15. Freeway interchange ramp terminals

2.4.2 Locations with Limited Roundabout Opportunities

There are a number of locations and site conditions that often present complications for installing roundabouts. Some of these locations can also be problematic for other intersection control alternatives as well. Therefore, these site conditions should not necessarily lead to elimination of a roundabout from consideration. However, extra care should be exercised when considering roundabouts at these locations:

1. Intersections in close proximity to a signalized intersection where queues may spill back into the roundabout.
2. Intersections located within a coordinated arterial signal system.
3. Intersections with a heavy flow of through traffic on the major street opposed by relatively light traffic on the minor street.
4. Locations with steep grades or unfavorable topography that might limit visibility and complicate construction.
5. Intersections with heavy bicycle or pedestrian volumes. Some international studies have shown bicyclists may be more at risk at roundabouts than at other intersection types.

2.4.3 Locations Where Roundabouts Might be Inappropriate

Certain locations tend to be disadvantageous for roundabouts. In such situations, other controls should be considered (*105*). These locations include:

- Places where the cost of right-of-way is very high that a project becomes uneconomical.

- Where pedestrians regularly comprise the predominant traffic movement through the intersection under present or future conditions (e.g. downtown areas)
- Locations with traffic volumes in excess of 50,000 ADT

2.4.4 Roundabout Geometric Design Considerations

Several factors are considered for a good geometric design of roundabouts. Some critical factors involved in geometric design include capacity, safety, right-of-way, cost, percentage of trucks and sight distance. Some factors are at variance with each other during design. Example, while safety requires a geometry that encourages drivers to travel at safe speed, optimum capacity requires a geometry that might encourage drivers to travel above safe speeds. Minor changes in roundabout geometry can create significant changes in capacity, safety, or other operational performances. To achieve optimum design, there usually is a tradeoff between the safety and capacity needs. A good design therefore requires a process of determining the optimal balance between all these provisions. Three fundamental elements are required for preliminary roundabout design: 1) optimal roundabout size, 2) optimal position and 3) optimal alignment and arrangement of approach legs *(11)*. The FHWA Roundabout guideline provides primary information source for geometric design. Some states have additional supplements to the FHWA guidelines. These states include Arizona, California, Florida, Maryland, Oregon, Kansas, Washington, Wisconsin, Utah, Kentucky, Oregon, New York, Pennsylvania, Iowa and Idaho. The general considerations necessary for effective and efficient geometric design of roundabouts are listed below. For the construction phase, further specific design considerations will be needed for categories such as double-lane, rural and mini roundabouts which include:

1. Lane number and configuration
2. Design vehicle
3. Design speed
4. Speed consistency
5. Inscribed circle diameter
6. Angle between legs
7. Roundabout sight distance
8. Stopping sight distance
9. Pedestrian and bicyclist considerations
10. Rural roundabouts

2.5 MULTI-CRITERIA DECISION ANALYSIS

Multi-criteria decision analysis (MCDA) has been recognized as an important tool in decision making for several areas of society. Generally when the decision making involves several competing objectives, multi-criteria approach is useful for generating a preference order among a number of available options. MCDA can generally be described as a collection of formal approaches which seek to take explicit account of multiple criteria in helping explore decisions that matter. MCDA therefore is an aid to decision making and a process which seeks to integrate objective measurement with value judgment and make explicit decisions while managing subjectivity.

Subjectivity is inherent in all decision making, particularly in the choice of criteria on which to base the decision and the relative weight given to those criteria. MCDA methods do not dispel that subjectivity; they simply seek to make the need for subjective judgments explicit and the process by which they are taken into account transparent during review. Additionally, some conflicts or trade-off are usually evident amongst the objectives. Computer programs also exist to assist the technical aspects of MCDA.

The first comprehensive work on MCDA was done by Keeney and Raiffa in 1976 (*106*). They expanded decision theory which was associated with decision tree, modeling of uncertainty and the expected utility rule. They incorporated multi-attributed consequence into decision theory and provided a theoretically sound integration of the uncertainty associated with future consequence and the multiple objectives those consequences realize. MCDA process involves problem identification, problem structuring, model building and using the model to inform and challenge thinking before ultimately determining the action plan. Broadly speaking, MCDA may be applied to resolve the following categories of problems (*107*).

- The choice problem: to make a simple choice from a set of alternatives
- The sorting problem: to sort actions into classes or categories
- The ranking problem: to place actions in some form of preference ordering which might not necessarily be complete

- The description problem: to describe actions and their consequences in a formalized and systematic manner
- The design problem: to search for, identify or create new decision alternatives to meet the goals and aspirations revealed through the MCDA process
- The portfolio problem: to choose a subset of alternatives from a larger set of possibilities taking account not only of the characteristics of the individual alternatives, but of the manner in which they interact and of positive and negative synergies

The main role of the MCDA techniques are therefore to deal with the difficulties that human decision makers have exhibited in dealing with large amounts of complex information in a consistent way (106). A standard feature of multi-criteria analysis is a performance matrix in which the rows describe the options and the columns describe the performance of the options against each criterion. The individual options are often assessed with a numerical parameter. In order to assess the options effectively, two critical requirements are scoring and weighting of the options. Scoring involves assigning a numerical score based on the strength of preference scale for each option with regards to a criterion. More preferred options score higher. Scales of between 0-10 and 0-100 are commonly used. Weightings are assigned to each criterion as a definition of the relative valuation of a shift between the upper and lower chosen scale value.

2.5.1 Types of Multi-Criteria Analysis

There are many types of multi-criteria analysis methods in use. Multi-criteria analysis procedures are primarily distinguished from each other in terms of how they process the basic information in the performance matrix. A key consideration for selecting a technique is the number of alternatives to be appraised. For problems with a finite number of alternatives, the techniques are fairly easy and straight forward. For problems with infinite number of variables, the techniques require special skills (*108*). Most MCDA techniques apply numerical analysis to the performance matrix in two stages: scoring and weighting. Scoring is the process where the expected outputs of the options are assigned numerical scores on a preference scale for each option of all criteria. Weighting is the process where numerical weights are assigned to define the relative valuations of shift between the top and bottom scale for each criteria. An overall assessment of each option being appraised can be obtained by computer coding using mathematical routines to combine these two processes (23, 24).

The MCDA process has several advantages including:

1) Transparent and definite,

2) The objectives and criteria are open to analysis and change,

3) Score and weight used are explicit and developed according to established techniques and can be adjusted and

4) There is an audit trail that can be verified for each decision weight and score.

There are different types of MCDA procedures which can be distinguished from each other in terms of how the performance matrix information is processed. A few of the most popular methods are briefly described here (*109*,*110*):

2.5.1.1 Direct analysis of the performance matrix

From a direct observation of the performance matrix, a limited amount of information about the options' relative advantages can be obtained. Dominance occurs when an option performs as well as another on all the criteria and better than the other on at least one other criterion. Once dominance has been achieved, the next stage is for the decision making team to determine whether trade-offs between different criteria are acceptable, so that good performance on one criterion can compensate for weaker performance on another.

2.5.1.2 Multi-attribute utility theory

Multi-attribute utility theory is the procedure that comes closest to universal acceptance. Though it provides strong theoretical basis, it does not directly help in undertaking complex decisions. There are three building blocks for this procedure: First is the performance matrix, second is the procedure to determine whether or not criteria are independent of each other, and third is the ways of estimating the parameters in a mathematical function that allows the estimation of a single performance index.

2.5.1.3 Linear additive models

For problems in which the criteria are assumed to be preferentially independent of each other and uncertainty not formally built into the model, then the simple linear additive evaluation model is applicable. The linear model shows how an option's values on the criteria can be combined into one overall value. This is achieved by multiplying the value score on each criterion by the weight of that criterion and adding all the weighted scores together. This approach is used by most multi-criteria models. Models of this type have a reputation of providing robust and effective support if working on a range of problems.

2.5.1.4 The Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) also develops a linear additive model but uses procedures for deriving the weights and the scores achieved by alternatives which are based respectively on pair-wise comparisons between criteria and between options. In determining weights, users have to compare the importance of each criterion relative to all the others. The pair-wise comparison is easy and convenient. Although some serious doubts have been raised about the theoretical foundations of the AHP and some of its properties, such as the rank reversal phenomenon, it is still one of the most widely used multi-criteria analysis methods.

2.5.1.5 Outranking methods

These methods depend upon the concept of outranking and seek to eliminate alternatives that are dominated using a set of comparisons. Dominance within the outranking frame of reference uses weights to give more influence to some criteria than others. An option is said to outrank another if it performs better than the other on enough criteria of sufficient importance and is not outperformed by the other where it is significantly inferior. All options are assessed by the extent to which they sufficiently outrank others options for all the criteria. With outranking method it is possible to classify two options that are incomparable because of difficulty. A major concern is that it is dependent on rather arbitrary definitions of what outranking really constitutes and how threshold parameters are set.

2.5.1.6 Procedures that use qualitative data inputs

These procedures depend on the use of numerical weights and scores on a cardinal scale. If the input data is not accurate, the less precise and reliable will be the outputs. In order to rectify problems of less reliable data, decision makers usually approximate to the linear additive model or amend outranking models to allow them to process imprecise qualitative data.

2.5.1.7 Multi-criteria analysis methods based on fuzzy sets

Fuzzy sets provide an alternative basis for decision making models to address imprecision that surrounds much of the data. Fuzzy sets attempt to synthesize the idea that humans naturally do not discuss issues on a precise basis hence it is easier to relate to range i.e. a 0-10 scale. Fuzzy multi-criteria models develop procedures for aggregating fuzzy performance levels using weights that are sometimes also represented as fuzzy quantities. These methods generally tend to be difficult for non specialists to understand and use.

2.5.1.8 Other multi-criteria

There are many other multi-criteria analysis approaches. Some have records of applicability and many others have not advanced beyond the conceptual stages. These include those based on “Rough Sets” or “Ideal Points” and methods heavily dependent on interactive developments using constructed computer packages. Generally, for decision problems it is more practical to try undertaking sensitivity testing of the options rankings to changes in critical performance assessment rather than modeling the uncertainties explicitly.

2.5.2 Steps in Applying MCDA

MCDA can be used either to appraise products or ideas that are newly proposed or in retrospect to evaluate things to which resources have already been committed. In both uses, the stages listed and discussed below apply:

1. Establish the decision context
2. Identify the options to be appraised
3. Identify criteria and sub-criteria
4. Scoring
5. Weighting
6. Combine the weights and scores for each option to derive an overall value
7. Examine the results
8. Sensitivity Analysis

Step 1: Establish the decision context

The first step is to establish a shared understanding of the decision context. Central to it are the objectives of the decision making agency, people to be affected and identification of all stake holders in the decision process. Since the decision is about multiple conflicting objectives, there are trade-offs to be made; however, the single highest objective and sub-objectives will have to be defined clearly. A clarity of the aims helps to define the tasks and keep the analysis on track.

Step 2: Identify the options to be appraised

The second step is to identify and list the options to be considered. Sometimes, there are endless possibilities and there is the need to provide a structured system of alternatives selection before making a shortlist using basic information and quick procedures. The options are important only for the value they create by achieving objectives hence it is very critical to explicitly define the objectives. It is typical for decision makers to be open to the possibility of modifying or adding to the options as the analysis progresses.

Step 3: Identify criteria and sub-criteria

The performance of the decision process is evaluated by the criteria and sub-criteria. By establishing a sound base set of criteria, the process is enhanced. The criteria need to be operational since they serve as performance measures. The process of identifying the criteria should involve all the stakeholders and usually begins with a clear understanding of the needs from steps 1 and 2. The number of criteria should be kept as low as is consistent with making a well-founded decision. The number of criteria typically ranges from six to twenty. A more useful approach is to group the criteria into a series of sets that relate to help separate and distinguish components of the overall objective for the decision. Sometimes it is necessary to structure the criteria. An acceptable structure is one that shows a clear, logical and shared viewpoint of how the many criteria are brought together into coherent groups. The final choice of criteria can be assessed against the following range of measures:

i. Completeness: Have all the required criteria been included?
ii. Redundancy: Is it possible to do away with unnecessary criteria?
iii. Operational: Are the criteria able to judge the options adequately?
iv. Mutual independence of preferences
v. Double counting
vi. Size
vii. Impacts occurring over time

It is necessary to organize the criteria into higher-level and lower-level objectives in a hierarchy cluster. This helps to highlight the conflicts amongst the objectives and lead to a better definition, after which a simple qualitative description for each option taking into account each criterion is carried out. This will usually be in the form of a matrix for simpler problems or value tree for complex problems.

Step 4: Scoring

The concept of scoring under MCDA is to allow the various criteria to be compared. This is achieved by constructing a scale representing preferences for the consequences. Scoring is followed by weighting the scales for relative importance and then calculating the weighted averages across the preference scales. There are many ways of doing this. A common example is relative preference scale which has two boundaries of the scale. Each represents the most and least preferred options on a criterion. For a scale of 1-10, the most preferred option will have a score of 10 and the least preferred a score of 1. The difference-scaling method results in numbers that represent relative strength of preference. Relative scaling is very useful when comparing several options presented at the same time. A major requirement is the need to check for consistency in the scores during assessment. Sometimes, several iterations may be necessary to achieve consistency in the preferences.

Step 5: Weighting

Since the scales used are sometimes different and do not allow the preferences to be combined automatically, weighting becomes necessary. Weighting helps address this problem by judging the relative importance of the scales so that a meaning can be derived out of different scales. There is a special difference between measured performance and the value of that performance in a specific context. Thus the weight on a criterion reflects both the difference of the options and how significant that difference is. The process of arriving at an acceptable weight is fundamental to the MCDA process. Often weights are derived from the views of a group of people and the meaning is reasonably clear and unambiguous despite the difficulties in arriving at them.

Step 6: Combine the weights and scores for each option to derive an overall value

This step begins with calculating the overall weighted preference score at each level of the hierarchy. This score is simply the weighted average of the scores on all the criteria. In practice, multiply an option's score on a criterion by the importance weight of the criterion for all the criteria and sum the products to give the overall preference score. If the score for an option i on criterion j be represented by S_{ij} and the weight for each criterion by w_j, then n criteria the overall score for each option, S_i, is expressed as:

$$S_i = w_1 s_{i1} + w_2 s_{i2} + \cdots \ldots \ldots \ldots w_n s_{in} = \sum_{j=1}^{n} w_i s_{ij}$$

(22)

With MCDA the simple weighted average is justified if all of the criteria are mutually preference independent. Usually failure of mutually preference independence is discovered during scoring even if missed earlier on.

Step 7: Examine the results

The weighted average of all the preference scores gives the level of ordering of the options. The scores also give an indication of how much an option is preferred over another. The overall results could also be displayed in a two-dimensional plot using the value tree, which also shows the main trade-offs. Sometimes an MCDA yields results that require understanding before decisions are taken. In some instances, a temporary decision system is necessary to deal with unexpected results and to consider the implications of new perspectives revealed.

Step 8: Sensitivity Analysis

Sensitivity analysis provides a means to examine the extent to which vagueness about the inputs or difference in people's opinions make an impact on the overall final results. This is because the choice of weights may be contentious and experience shows that MCDA can help reach a more satisfactory solution for such instances. To ensure that the MCDA includes all the necessary criteria to satisfy a broad section of the community, interest groups can be consulted for their views. Since the different stakeholders might disagree on the weights and scores, the model may help to check the ranking of options using different scoring and weighting systems. If the model comes up with the same 2 or 3 options as the best overall outcomes irrespective of the scores and weights used, then it is robust enough. Sensitivity analysis is thus useful for helping resolve disagreements between interest groups. The advantages and disadvantages of a selected option will have to be examined. In this case, an advantage is a high score on heavily weighted criterion and a disadvantage is a low score on important criterion. At the end of the analysis, a requisite model (one that is just good enough to resolve issues at hand) is obtained.

2.6 SUMMARY

This chapter was a review of previous studies that relate to the research objectives. Based on the literature review the following are worth mentioning.

- Many countries have developed models for evaluating roundabout capacity, delay and queue. These models are either analytical, empirical or a combination of the two methods. An important caution however was the discouragement from exporting these models to other environments without having base data for comparison and calibration.
- Reversed priority occurrence has been identified as having an effect on the estimation of roundabout capacity and delay and needs to be considered in the evaluation of roundabouts.
- Simulation was also found to have multiple uses in traffic engineering studies with well advanced tools available for research purposes.

- Multi-Criteria Decision Analysis was a proven method for ranking and selecting an option in the presence of several options and many factors devoid of bias

3 CHAPTER THREE - METHODOLOGY

The methodology for this research consisted of two components: field data collection and micro simulation modeling. The field data collection involved video recording of driver behavior and traffic characteristics followed by laboratory data extraction. The micro simulation component involved the coding and calibration of a VISSIM model by using data extracted from the field. This chapter describes the two components in detail.

3.1 FIELD DATA COLLECTION

The field data collection was carried out using three tripod-mounted wide angle video cameras. A single-lane roundabout on the U.S 50 Highway and Farmers District Road intersection in Fernley was selected for this study. The roundabout was selected because it has high PM peak traffic volumes on the southbound (SB) and eastbound (EB) approaches with the northbound (NB) approach having a medium volume. The westbound (WB) approach has high right turning volume with low through and left turn volumes. Figure 11 shows the camera positions, labeled Cam1, Cam2, and Cam3 and the directions of recording indicated by the arrow head. The PM peak traffic demand volume and turning movement used are shown in Figure 12.

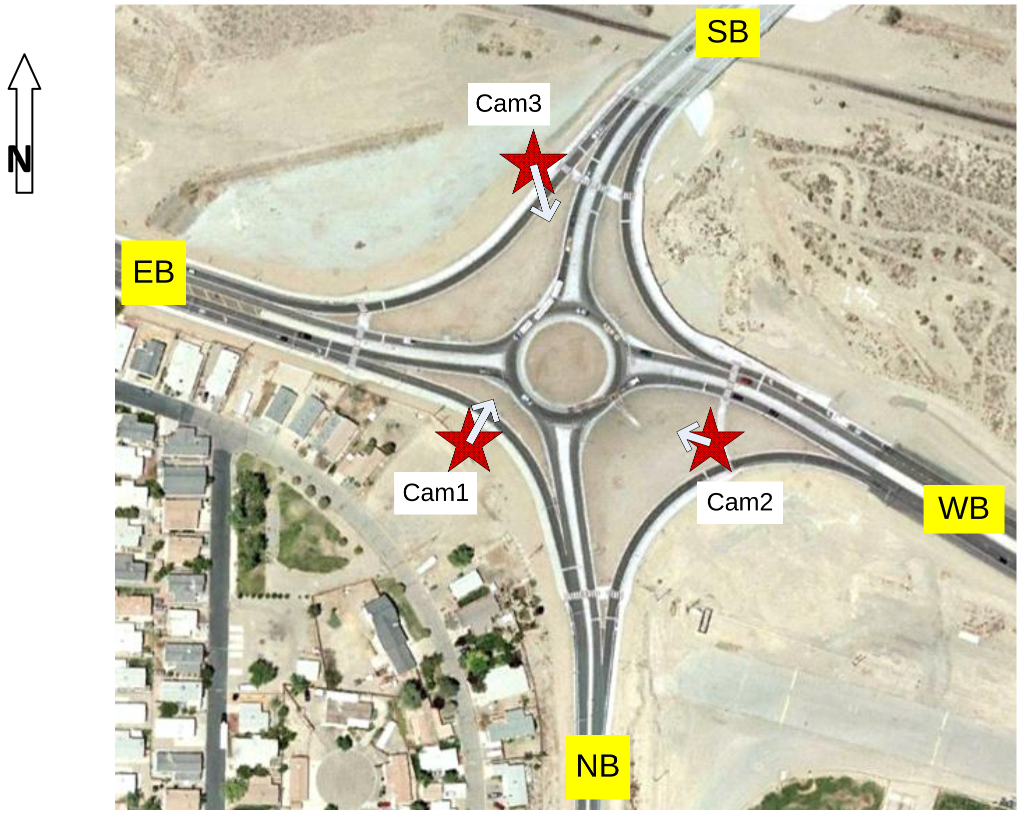

Figure 11 Aerial Photograph of the Site Showing the Camera Positions

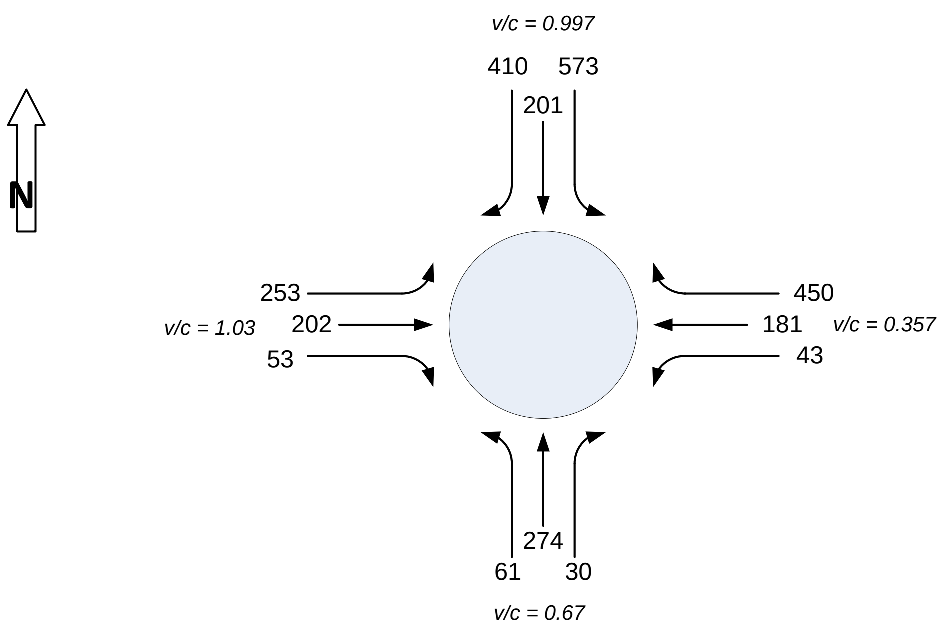

Figure 12 PM Peak Demand Volumes and Direction

Camera 1 was positioned to collect driver behavior information at the merge point between the main subject entry lane (EB) and the circulatory lane directly in front of it. This enabled the extraction of headways required for the computation of critical headway, queue and delay required for calibrating the VISSIM models. The periods of priority reversal and associated headways were also extracted from this video. Camera 1 also gave a good view of the queue formed on the SB approach. Camera 2 enabled the observation of the queue lengths on the main subject approach lane, EB and the NB approach. Camera 3 enabled the observation of queue lengths on the NB and WB approaches. This was possible because the topography of the site had the SB lane on the highest elevation. Cameras 2 and 3 combined enabled the observation of the vehicles using the by-pass lanes, hourly traffic volume counts and the directional turning movements from each approach.

3.1.1 Data Extraction

A total of 16 hours of video recording was done over a one week period. From the video recordings four “time events” necessary for the computation of critical headway, follow-up headway, queue and delay for the subject approach lane (EB) were extracted. The time events captured are described as:

i. *“Enter queue time”:* the time a vehicle joined the queue or a marked point about 10 feet from the yield line when there is no queue.

ii. *“First in queue”:* the time a vehicle became the first in the queue or when the front bumper of a vehicle in motion arrived just behind the yield line.

iii. *“Exit queue time”:* the time a vehicle joined the circulatory lane at the conflict zone on the circulatory lane

iv. *“Passage time”:* the time circulatory lane vehicles passed the conflict zone.

Figure 13 illustrates the conflict zone on one approach of a single-lane roundabout.

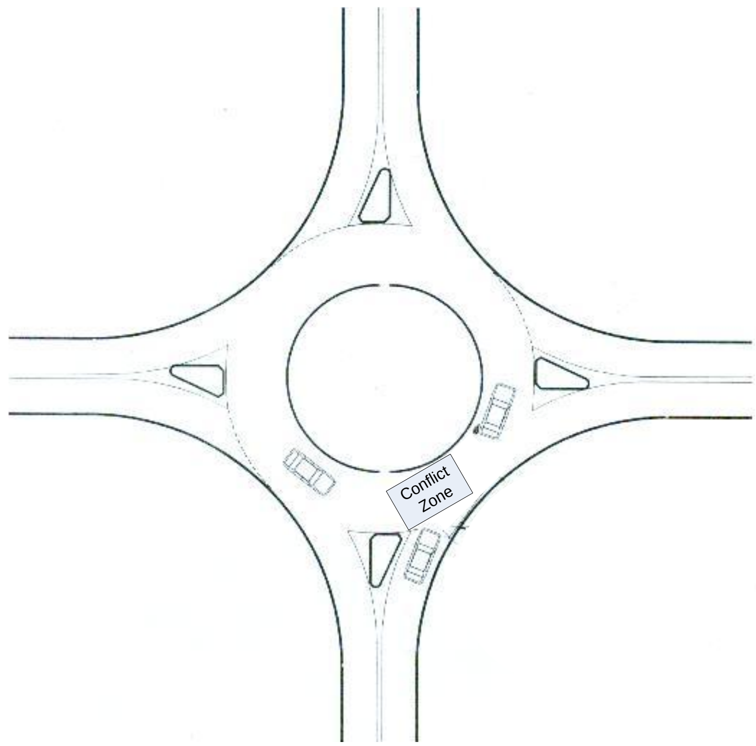

Figure 13 Illustrated Diagram of a Roundabout Showing the Conflict Zone

The data extraction was completed with the aid of computer software similar to the one used for NCHRP 3-65 (*111*) report but was modified from the two stage system into a one stage system by reprogramming in C-Sharp. Eight seconds was used as the default upper threshold for the driver acceptable headways. Meaning any accepted headway larger than 8 seconds was reduced to 8 seconds which was consistent with earlier research such as reported in the NCHRP report 572. The “passage times” were used to compute headways between successive circulating vehicles. Using the computed headways together with the "first in queue" and "exit queue" times, the "accepted", "maximum rejected" and "follow-up" headways were computed. The mean critical headway was computed using Troutbeck's (*112*) maximum likelihood methodology approach. The percentage of vehicles forcing priority reversal was also determined by repeated observations of the driver behavior and measuring the headways accepted by drivers of entering vehicles observed to force circulatory vehicle to momentarily stop or slow down. Typically the measured headways were much lower than the critical headway obtained. The data acquired was useful for calibration of the VISSIM model.

3.2 SIMULATION AND DATA COLLECTION

The micro-simulation software package VISSIM version 5.40 was used for coding the roundabout. Accuracy of the traffic simulation depended on the quality of the model and the calibration effort. Three parameters that required careful calibration were vehicle parameters, driver behavior parameters, and network parameters.

The network parameter adjustments involved the road length and width, lanes for various sections etc. Route decisions assigned the traffic on each approach to its destination according to the proportions of turning movement. It was important to guide vehicles around the roundabout carefully to prevent stoppages within the circulating lane. VISSIM characterizes vehicles with similar specifications into vehicle types and for each of the types, physical dimensions, acceleration/deceleration and other kinetic properties were specified and coded to follow a chosen distribution. The vehicles selected for this model were cars, buses, trucks (WB-67) and motorcycles. For this research, a special group of vehicles was introduced and labeled "Car1". Car1 group of vehicles were responsible for causing priority reversal. The average headway accepted by Car1 vehicles was determined to be lower than the mean critical headway calculated for the approach from the field data. Car1 vehicles were thus assigned the lower critical headway and also coded to accept smaller gaps within the circulatory flows similar to the field observation. The purpose was to enable the occurrence of the priority reversal for the study. Car following behavior, lane changing and lateral behavior were adjusted as part of the driver behavior. The driver behavior parameters were important for modeling the behavior since the vehicles were required to maintain a constant speed within the circulatory lane and were only permitted to accelerate at the exit points.

The priority assignment in VISSIM was set up using the priority tool. This tool consisted of one stop line placed at the entering point and one or more conflict markers placed on the circulating lanes associated with the stop line. Two parameters were specified for this tool to work effectively: minimum headway and minimum gap time. Minimum headway defined the length of the conflict area required to prevent the entering vehicles from crashing into the vehicles downstream of the circulating lane. Minimum gap time is the critical headway (gap) parameter required for each vehicle type in the vehicle group to merge into the circulatory flow. Field observations showed heavy goods vehicle (HGV) required larger gaps than cars so these had to be set accordingly. The minimum gap was adjusted to the critical headway value measured in the field so that the simulations were comparable to field observations. After adjustment the entering vehicles waited for suitable gaps upstream of the circulating flow while ensuring the downstream distance was sufficient for a safe merge into circulating traffic. Approaching vehicles did not stop at the yield line if the gap upstream was larger than the critical headway and the distance downstream was larger than the minimum headway specified. Since Car1 vehicles were responsible for causing priority reversal, they required separate coding. The gap set-up for Car1 required a stop line on the circulatory lane and a gap within the conflict zone which required circulatory vehicles to slow or stop when a Car1 vehicle was partially within the circulatory lane. Car1 vehicles were enabled to accept gaps within the circulatory lane that were smaller than required for other vehicles in the group.

3.2.1 Model Calibration

Model calibration was critical for obtaining reliable data. It involved adjustment of parameters to enable the model to closely reproduce the field observations. A critical requirement for this research was for vehicles within the circulating lane to decelerate or stop for forced entry by Car1 type vehicles. The calibration process involved running the simulations several times and adjusting components like the speed range, speed curves etc. until delays and queue lengths observed from the model were comparable to the field values. For Car1, a critical headway value of 2.2 seconds was used, (which was the average critical headway obtained from the video recordings for such vehicles). A critical headway of 3.6 seconds was used for all other vehicles in the group, except for trucks/ HGV (WB-67) where a value of 3.9 second was used. Car1 vehicles were coded to accept minimum headways of 13 feet when a car conflicted with them, but accept a gap of 15 ft when a truck or bus conflicted with them. Other vehicles accepted a minimum headway of 20 feet. The average percentage of Car1 vehicles was estimated to be 10 percent of the total vehicle percentage at the peak hour. Truck percentage was 2.5 percent, cars 87 percent, buses 0.4 percent, and bikes 0.1 percent.

3.2.2 Measurement of Effectiveness

For intersection analysis, the most common parameters used for measurement of effectiveness (MOE) are average control delay and 95th percentile queue. Delay is typically used as an indication for the measure of level of service (LOS) and the 95 percent queue length gives an indication of the storage requirement and spill over if other intersections are close by. In addition to the above, travel times were also obtained for this research. The travel time data was measured because it gave an indication of the level of intolerance experienced by drivers which could trigger a higher likeliness to accept smaller gaps and therefore force priority reversal.

There were six data collection points in all. Four on the yield lines of the approach lanes and two on the circulatory lane shown as Pt1 and Pt2 respectively. Figure 15 is a schematic diagram copied from VISSIM showing the data collection points.

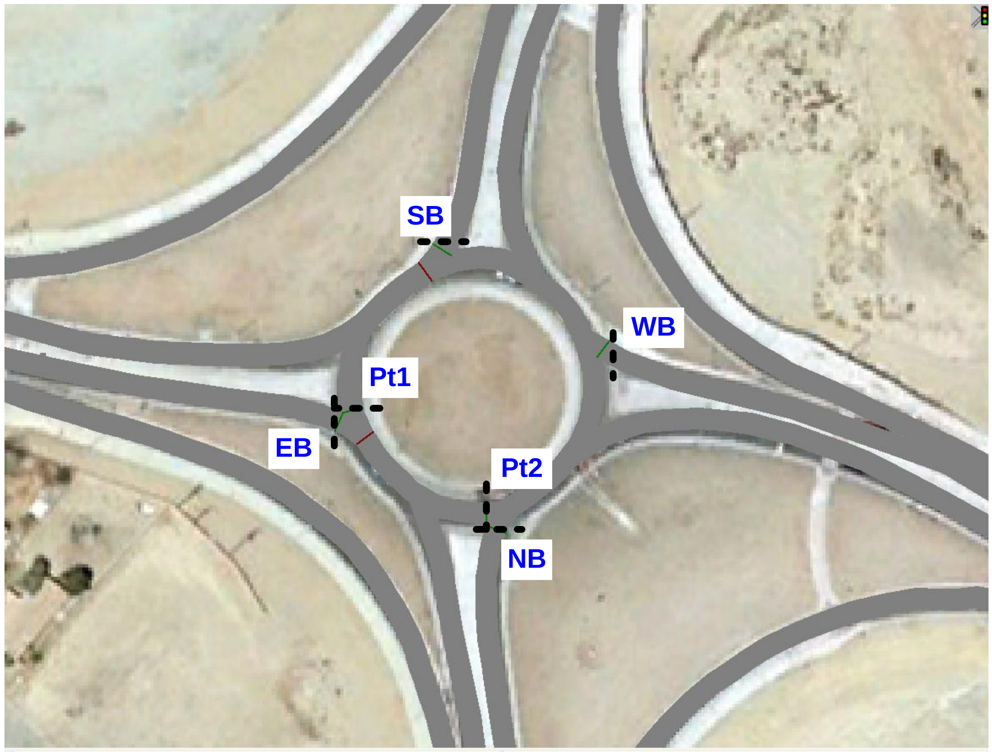

Figure 14 A VISSIM Output Showing the Data Collection Points

3.2.3 Model Scenarios

The base case of the model used 10 percent as the average Car1 proportion as determined from the field. The studied involved changing the Car1 proportion and total traffic volumes as specified by the simulation scenarios. Four scenarios model were created and simulated for this study. The scenarios are labeled S1, S2, S3, and S4 with the details explained:

3.2.3.1 S1 Model

The S1 group of simulations investigated the effects of increased Car1 proportion on the performance of the approaches. Car1 percentages used were 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 25, 30, 35, 40, 50, 60, 75, 80, 90 and 100 percent of the total vehicle composition. Ten simulation runs were performed for each percentage of Car1 and the average of delays, 95th percentile queues and travel times were computed for each approach. To investigate the effect of speed of Car1 vehicles on the S1 group of simulation, a second variant of S1 simulations were carried out and labeled S1i. For S1i Car1 speed was set at 10 mph higher than the vehicle group and the simulations repeated. The results obtained from the two simulations were compared.

3.2.3.2 S2 Model

Troutbeck (*113*) showed that the bigger the inscribed circle diameter the lower the delay and the higher the capacity, however the effects of different proportions priority reversal causing vehicles was not investigated. The S2 simulations therefore investigated the effect of varied Car1 proportion and diameter of inscribed circle on the performance of a roundabout. The inscribed circle diameters investigated are 80, 100, 120, 140, 160, 180 and 200 ft and Car1 percentages investigated are 0, 10, 20, 30, 40 and 50 percent.

3.2.3.3 S3 Model

The S3 group of simulations investigated the effect of varied Car1 proportion and increased intersection traffic volume on the performance of roundabouts. For each Car1 proportion, the traffic volumes were increased from 0 - 50 percent in 5 percent increments. Car1 percentages investigated were 0, 10, 20, 30, 40, and 50 percent. The average travel time, delay and queue length were computed from 10 simulation runs.

3.2.3.4 S4 Model

The S4 group of simulations tested the sensitivity of the model to a sudden increase in the traffic volume from one approach lane of the roundabout and its effect on the performance of the other approaches. For these simulations, the approach with the least volume (WB) was chosen for volume increases. The volume increments were in 5 percent and ranged from 0 - 50 percent. The Car1 percentage was kept at 10 percent for all the simulations. Two variants, based on traffic volume distributions were investigated:

TYPE 1 (S4-1): These simulations used equal percentage increment for the right-turn (RT) (33.33 percent), through (33.33 percent) and left-turn (LT) (33.33 percent) traffic for all vehicles types.

TYPE 2 (S4-2): These simulations used a higher left turn traffic volume. The LT increase was (40 percent), RT (30 percent) and thru traffic (30 percent) for all vehicle types.

3.3 SUMMARY

This chapter discussed the methodology used for the field data collection, extraction and the simulation model build-up. A roundabout in Fernley, Nevada was studied because it operated at high PM peak traffic volumes and long queues formed which fit the conditions for reversed priority occurrence. Sixteen hours of video recordings were carried out using three wide angle video cameras mounted on tripods.

Data extraction was done with the help of computer software in the laboratory. The extracted data was used to calibrate a micro-simulation model coded in VISSIM. Four simulation scenarios were investigated and data was obtained at six points on the simulation model for analyses which is discussed in the next chapter.

4 CHAPTER FOUR - RESULTS AND MODELING

Based on the 2010 HCM models for single-lane roundabouts (equation 5), the capacity of the subject approach lane was computed to be 471 vehicles per hour (vph). The delay and 95th percentile queue length for the subject approach were also computed to be 80 seconds per vehicle (sec/veh) and 288 feet (ft) (15 cars) respectively. From the data extracted from the field videos, the computed average delay per vehicle was 57 sec/veh and average queue length was 170 ft (9 cars) for the EB lane. The results obtained from the HCM model were higher than the delay at the EB approach. When the HCM model was calibrated using the Nevada data, the capacity, delay and queue were computed to be 680 vph, 21 sec/veh and 115 ft (6 cars)

4.1 EFFECT OF INCREASING CAR1 PROPORTION (S1)

From the data obtained after S1 simulation scenario runs, the averages of delay, queue length and travel time were computed at the Car1 proportions used. The data was checked for normality using the MINITAB (Anderson–Darling test) and Microcal Origin (Shapiro–Wilk test) computer software.

Delay Plot and Analyses for S1 Scenario

The delays for all the approaches were computed as an average of 10 simulation runs at each Car1 percentage. The results obtained were plotted against the percentage of Car1 in the vehicle stream and are presented in Figures 15-18.

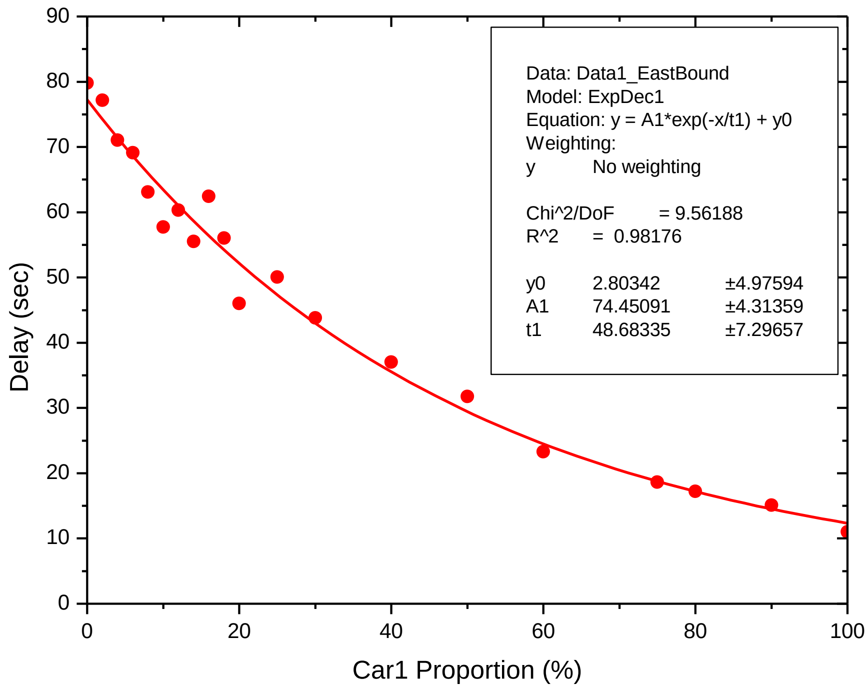

Figure 15 Change of Delay with Car1 proportion – S1 (EB)

The data plotted in Figure 15 showed that the delay on the EB approach decreased with increased percentages of the Car1. The average delay reduction rates obtained were in the range of 8 – 12 percent for every 10 percent increase in Car1.

The fit obtained for the data was an exponential decay with equation and r-square:

$$y = 74.45e^{-\frac{x}{48.683}} + 2.803$$

(23)

R^2 of 0.982

When the delay obtained from the field data was compared to the simulation curve, it fitted the curve for delay in the presence of about 12 percent Car1 in the vehicle composition. When the HCM model delay was compared to the simulation curve, it coincided with approximately 0 percent Car1 in the traffic flow. This indicated that the

HCM model might be overestimating the delays when the roundabout operates at or near saturation.

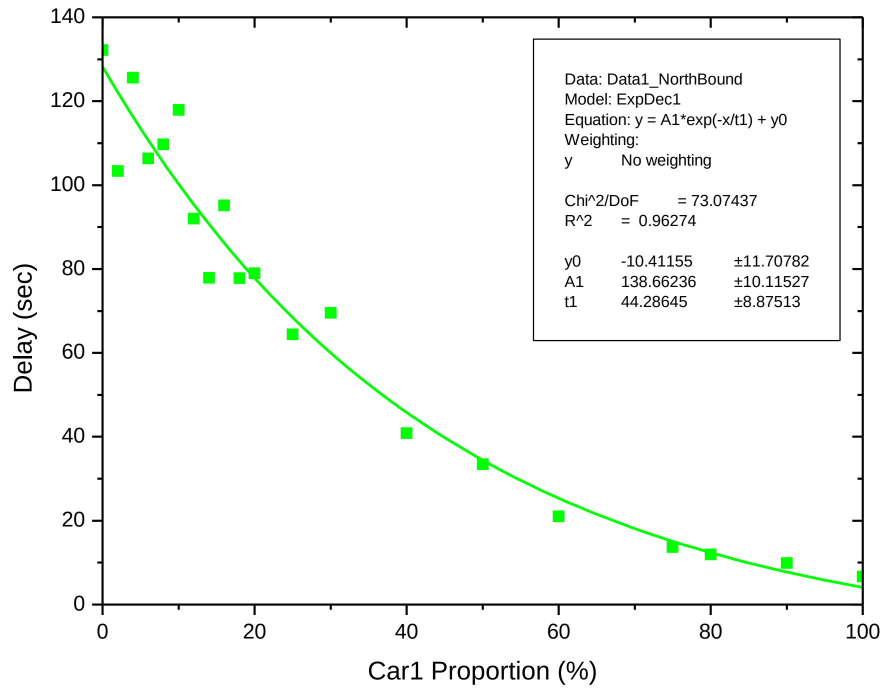

Figure 16 Change of Delay with Car1 proportion – S1 (NB)

The data plotted in Figure 16 showed that the delay on the NB approach decreased with increased Car1percentages. The average delay reduction rates were in the range of 9 – 16 percent for every 10 percent increase in Car1.

The fit obtained for the data was an exponential decay with equation and r-square:

$$y = 138.66e^{-\frac{x}{44.286}} - 10.412 \tag{24}$$

R^2 of 0.963

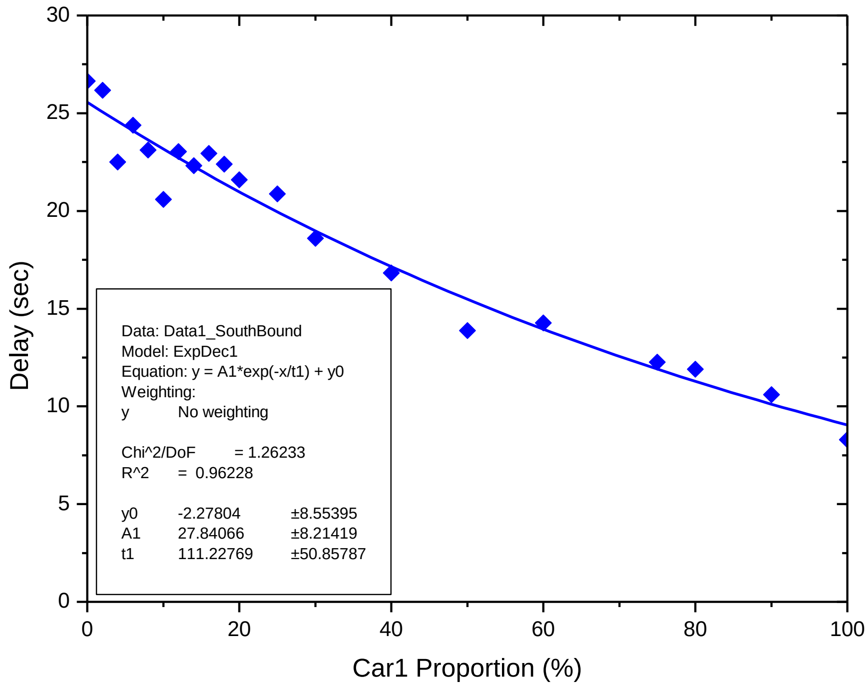

Figure 17 Change of Delay with Car1 proportion – S1 (SB)

From the data plotted in Figure 17 it can be seen that the delay on the SB approach decreased with increased Car1 percentages. The average delay reduction rates were in the range of 7 – 12 percent for every 10 percent increase in Car1.

The fit obtained for the data was an exponential decay with equation and r-square:

$$y = 27.84e^{-\frac{x}{111.23}} - 2.278 \tag{25}$$

R^2 of 0.962

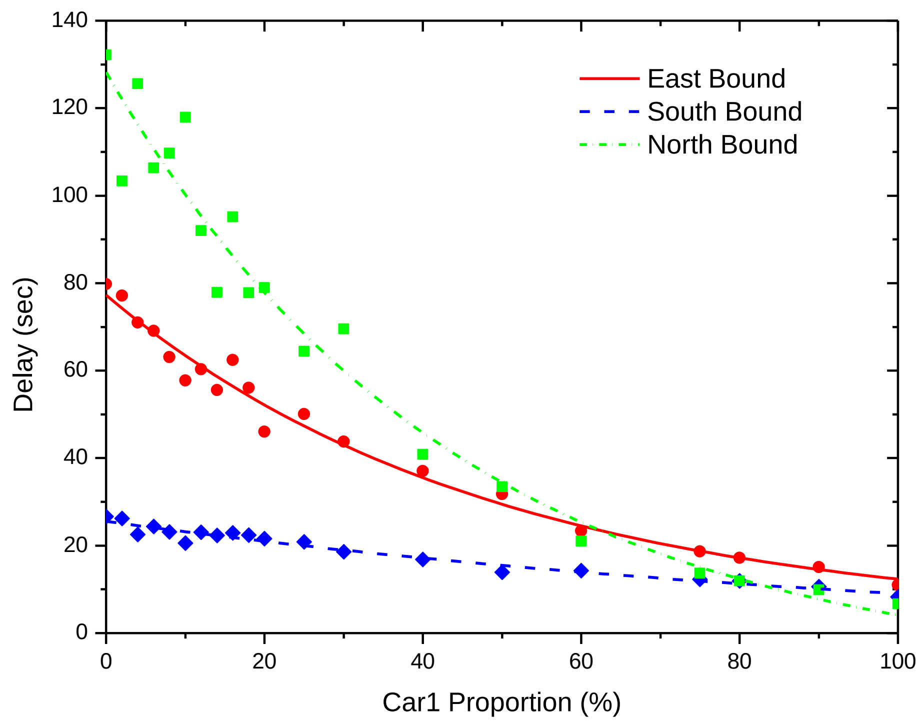

Figure 18 Change of Delay with Car1 proportion – S1 (EB, NB and SB)

Figure 18 showed plots of the average delay obtained for the EB, NB and SB to on the same axes for comparison. From a comparison of the curves, it was observed that the delays were reduced with increased Car1 proportion on all three approaches. From the delay reductions observed on the three approaches, the average delay reduction was estimated to be 8-16 percent for every 10 percent increase in Car1.

The NB approach experienced the highest delays though it had the lowest traffic volume compared to the EB and SB approaches. This observation was due high traffic volumes from the EB and SB approaches that were exiting to either the EB or NB downstream that conflicted with it.

The SB approach experienced the least delays though had the highest traffic volume. This was due to the very low traffic volumes that conflicted with it mainly as a result of the low through and left-turn traffic volumes coming from the WB and NB approaches.

Figure 19 shows plotted data of delay at different Car1 proportions measured at two points (Pt1 and Pt2) on the circulatory lane.

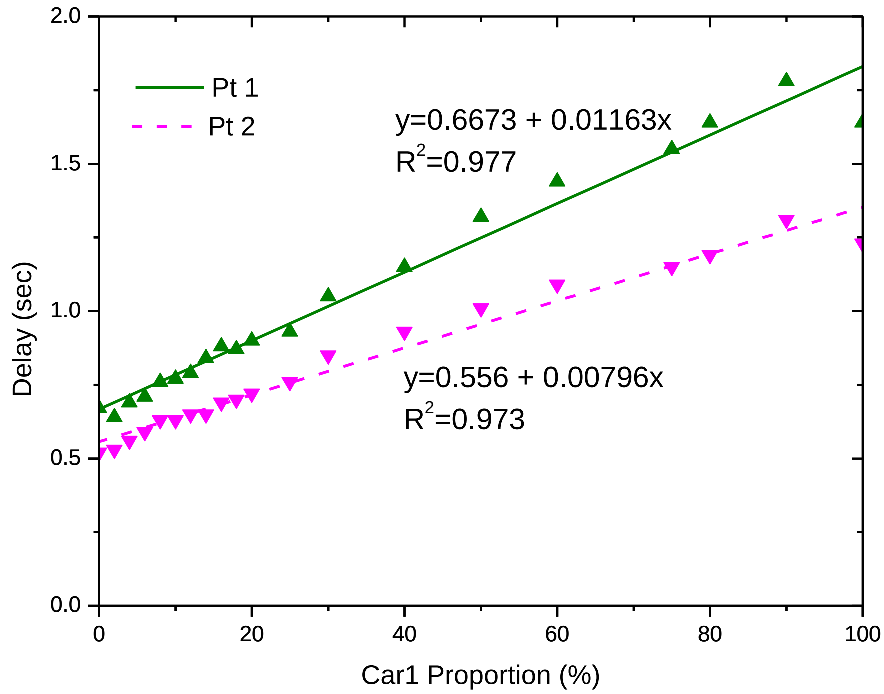

Figure 19 Change of Delay withCar1 proportion – S1 (Pt1 and Pt2)

The plots in Figure 19 showed 13-15 percent delay increase for every 10 percent increase in Car1. The increase in delay was significant when expressed in terms of percentage but in terms of absolute delay measurement there was approximately 1 second delay increase for 100 percent Car1. The effect would hardly be noticeable and the effect would be absorbed by circulatory drivers with the exception of the occasional discomfort when drivers might have to momentarily stop or slow down. This observation of delay increase on the circulatory lane was also observed by Troutbeck and Kako (13) and Troutbeck (14) in the studies of limited priority merges at unsignalized intersections.

Queue Length Plots and Analyses for S1 Scenario

From the approach averages computed in the S1 simulations, the 95th percentile queue lengths were plotted against the proportion of Car1 in the traffic stream and are presented in Figures 20 – 23.

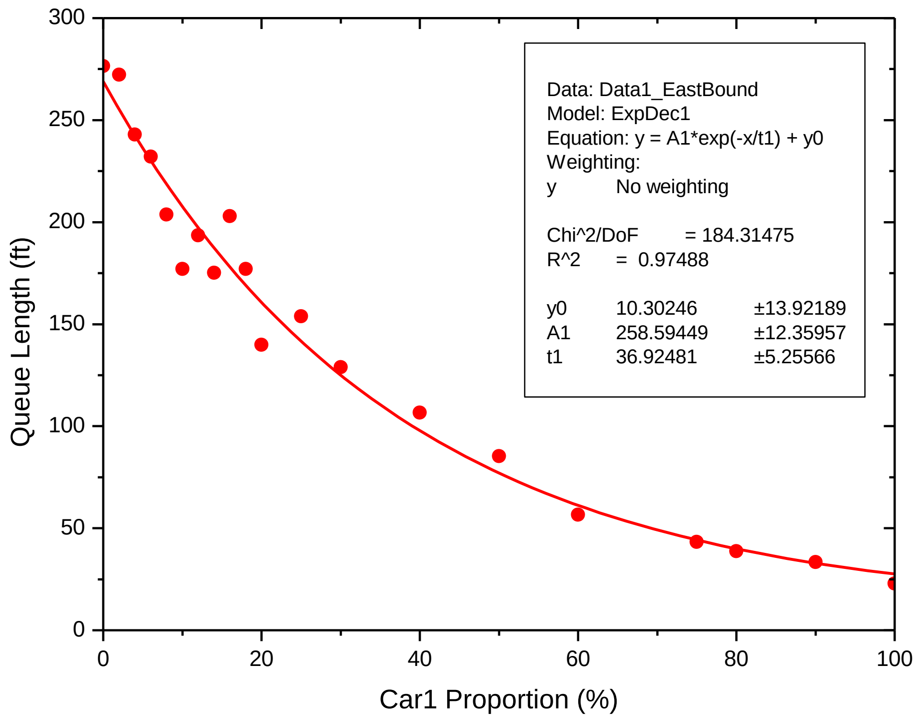

Figure 20 Change of Queue Length with Car1 Proportion – S1 (EB)

The data plotted in Figure 20 showed that the queue length on the EB approach decreased with increased Car1 percentages. The average rates of queue length reduction were in the range of 12 – 20 percent for every 10 percent increase in Car1. When the delay obtained from the field data was compared to the simulation curve, it fitted for 12-13 percent Car1. When the HCM model estimate was compared to the simulation curve, it fitted the queue at about 0 percent Car1. The Nevada calibrated model gave results that were lower and fitted for about 40 percent Car1.

The fit obtained for the data was an exponential decay with equation and r-square:

$$y = 258.59e^{-\frac{x}{36.925}} + 10.302 \tag{26}$$

R^2 of 0.975

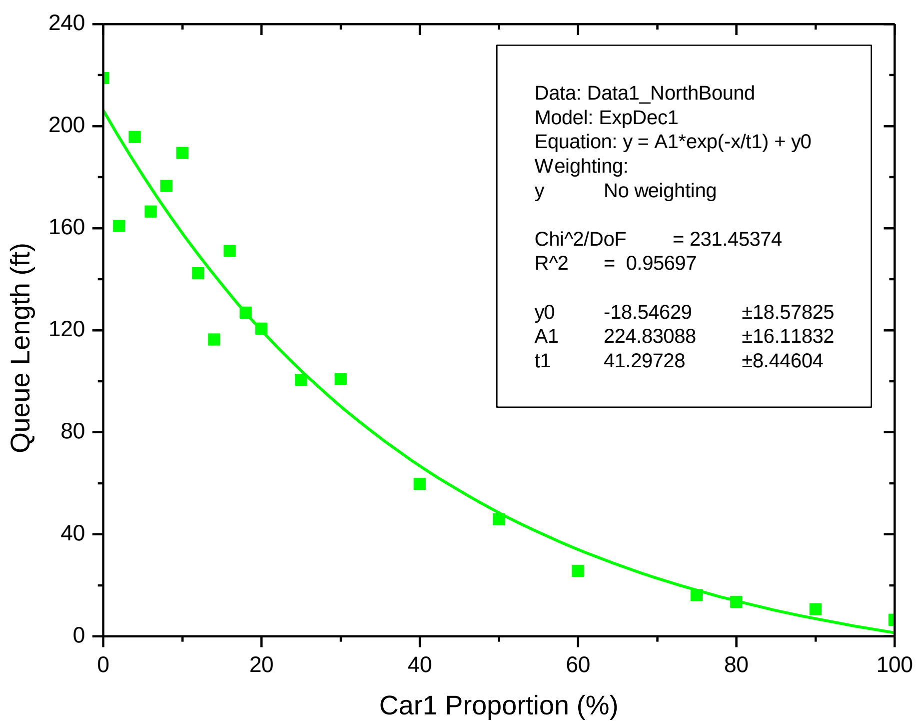

Figure 21 Change of Queue Length with Car1 Proportion – S1 (NB)

From the data plotted in Figure 21 it can be seen that the queue length on the NB approach decreased with increased Car1percentages. The average rates of queue length reduction were in the range 11 – 16 percent for every 10 percent increase in Car1.

The fit obtained for the data was an exponential decay with equation and r-square:

$$y = 224.831e^{-\frac{x}{41.297}} - 18.546 \tag{27}$$

R^2 of 0.957

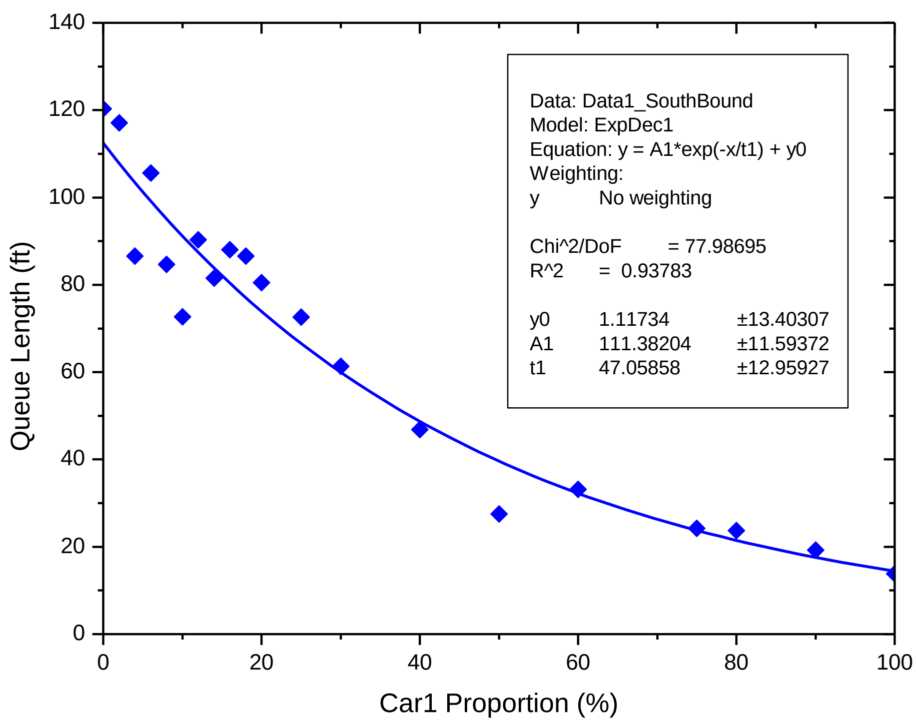

Figure 22 Change of Queue Length with Car1 Proportion – S1 (SB)

From the data plotted in Figure 22 it can be observed that the queue length on the SB approach decreased with increased Car1percentages. The average rates of queue length reduction on the SB approach lane were in the range 9 – 14 percent for every 10 percent increase in Car1.

The fit obtained for the data was an exponential decay with equation and r-square:

$$y = 111.38e^{-\frac{x}{47.059}} + 1.117 \tag{28}$$

R^2 of 0.938

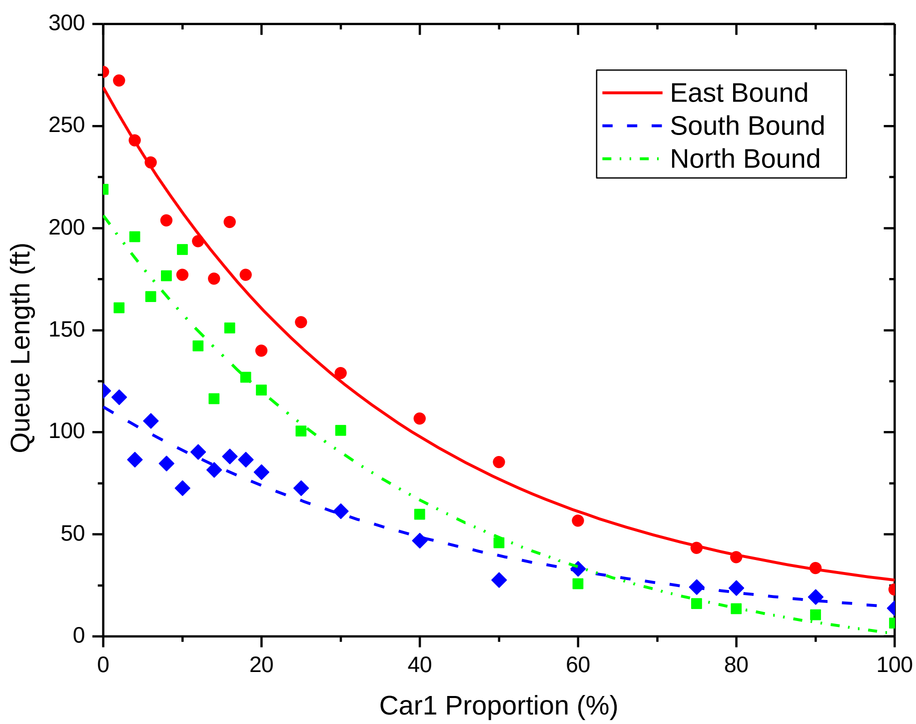

Figure 23 Change of Queue Length with Car1 Proportion – S1 (EB, NB, SB)

Figure 23 shows plots of queue lengths against the Car1 proportion for the EB, NB and SB approaches. A comparison of the curves showed that unlike the delay data for the approaches, the EB had the longest queue followed by the NB and then the SB. Inferring from the traffic volume counts at the approaches, the SB approach was expected to have the longest queue length but this was not the case. An explanation to the observed situation was that the WB approach had very low through and left-turn traffic volumes, which enabled the SB approach near uninterrupted merge onto the circulatory lane. This observation was similar to the field observation.

The traffic flow from the SB and WB approaches conflicted with the EB approach and since the SB had the largest traffic volume it translated into longer queues. Traffic from the SB approach that exited at the EB downstream and traffic from the EB approach that exited at the EB and NB downstream conflicted with the NB approach vehicles. From the above, though the NB approach had the lowest traffic volume compared to the EB and SB approach, the queue length was longer than the queue observed on the SB approach. The traffic interactions therefore resulted in the EB and NB approaches to have longer queue lengths than the SB approach. Averaging the data obtained for EB, NB and SB approaches, the queue length reduction for every 10 percent change in Car1was averaged at 10 – 18 percent.

The data plotted in Figure 24 shows the changes in the queue length as Car1 proportion increased as measured at Pt1 and Pt2 on the circulatory lane.

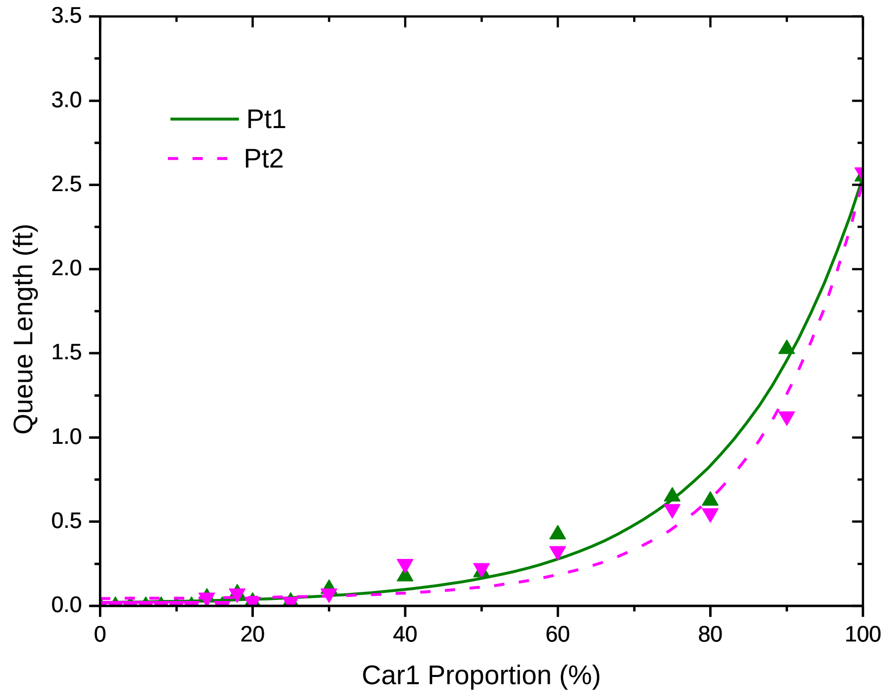

Figure 24 Change of Queue Length with Car1 Proportion – S1 (Pt1 and Pt2)

From 0 – 60 percent Car1 proportion, the two plots in Figure 24 showed small increments in queue length. Beyond 60 percent, the increment was more rapid as indicated by the sharp rise in the gradients of the curves. In terms of actual queue length, a change from zero to 2.5 feet may not be visualized because it is smaller than the average length of a car. However it was significant to present it since it validated the delay observations seen due to the momentary stops or slowdown of vehicles on the circulatory lane caused by entering drivers accepting smaller gaps.

Travel Time Plots and Analyses for S1 Scenario

After computing the average travel times for S1 simulations, they were plotted against the percentage of Car1 in the vehicle stream and the results are presented in Figures 25-28.

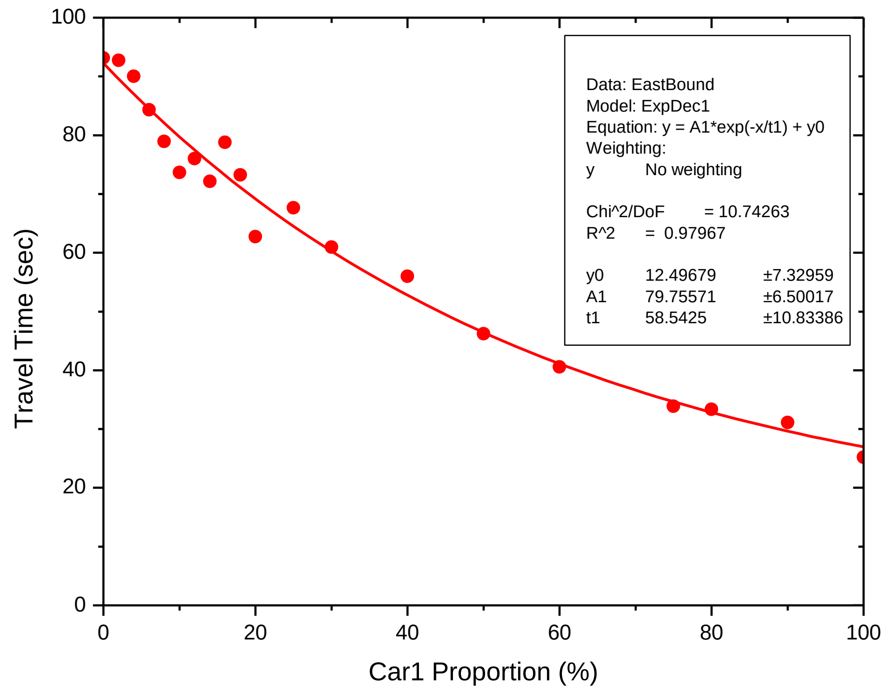

Figure 25 Change of Travel Time with Car1 Proportion – S1 (EB)

From the data plotted in Figure 25 it can be observed that the travel time on the EB approach decreased with increased Car1 percentages. The average rates of travel time reduction were in the range 7 – 10 percent for every 10 percent increase in Car1.

The fit obtained for the data was an exponential decay with equation and r-square:

$$y = 79.76e^{-\frac{x}{58.543}} + 12.497 \tag{29}$$

R^2 of 0.980

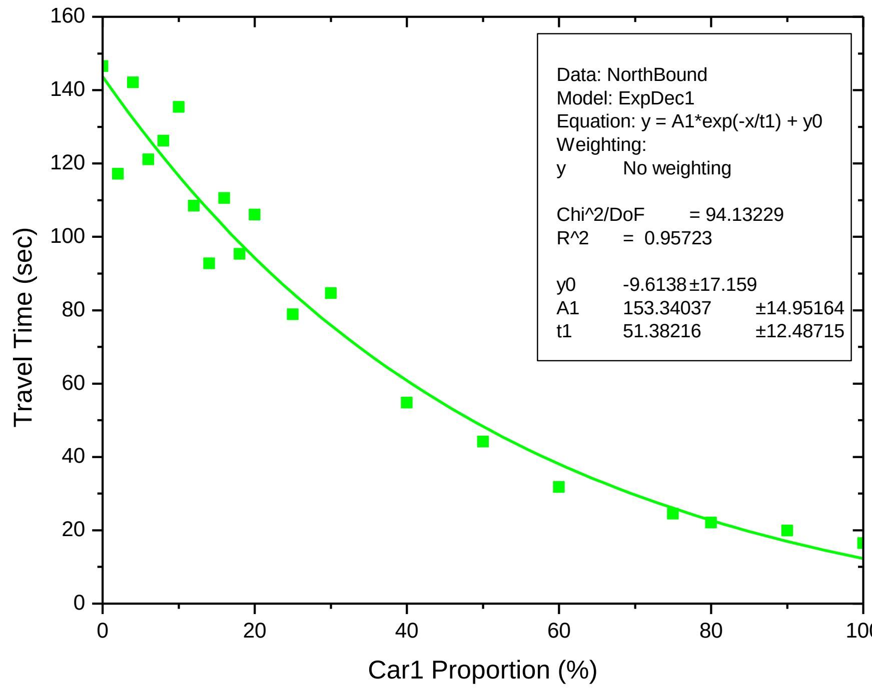

Figure 26 Change of Travel Time with Car1 Proportion – S1 (NB)

The data plotted in Figure 26 showed that the travel time on the NB approach decreased with increased Car1 percentages. The average rates of travel time reduction were in the range of 8 – 12 percent for every 10 percent increase in Car1.

The fit obtained for the data was an exponential decay with equation and r-square:

$$y = 153.340e^{-\frac{x}{51.382}} - 9.614 \tag{30}$$

R^2 of 0.957

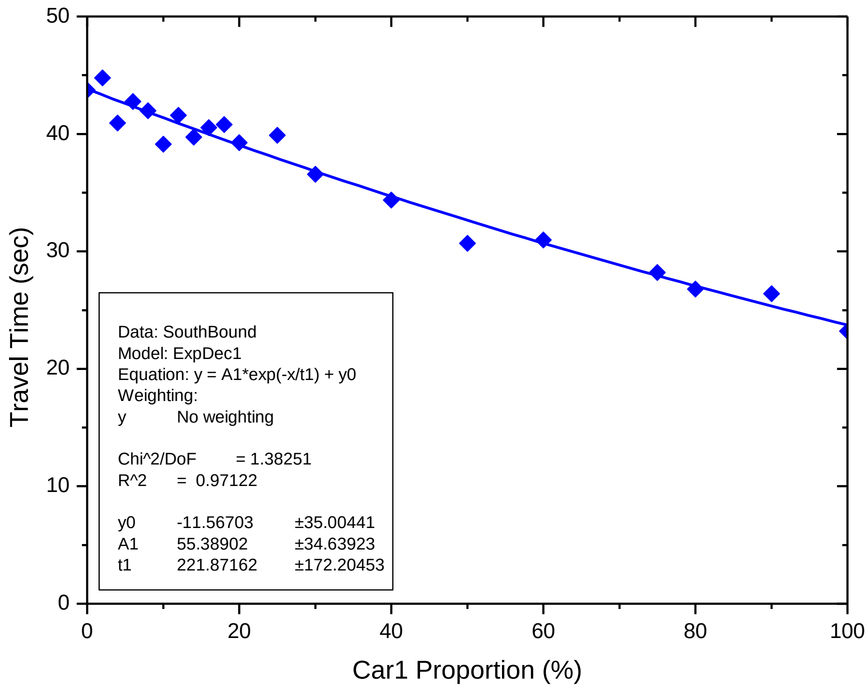

Figure 27 Change of Travel Time with Car1 Proportion – S1 (SB)

From the data plotted in Figure 27 it was observed that the travel time on the SB approach decreased with increased Car1 percentages. The average rates of travel time reduction were in the range of 5 – 9 percent for every 10 percent increase in Car1.

The fit obtained for the data was an exponential decay with equation and r-square:

$$y = 55.389e^{-\frac{x}{221.872}} - 11.567 \tag{31}$$

R^2 of 0.971

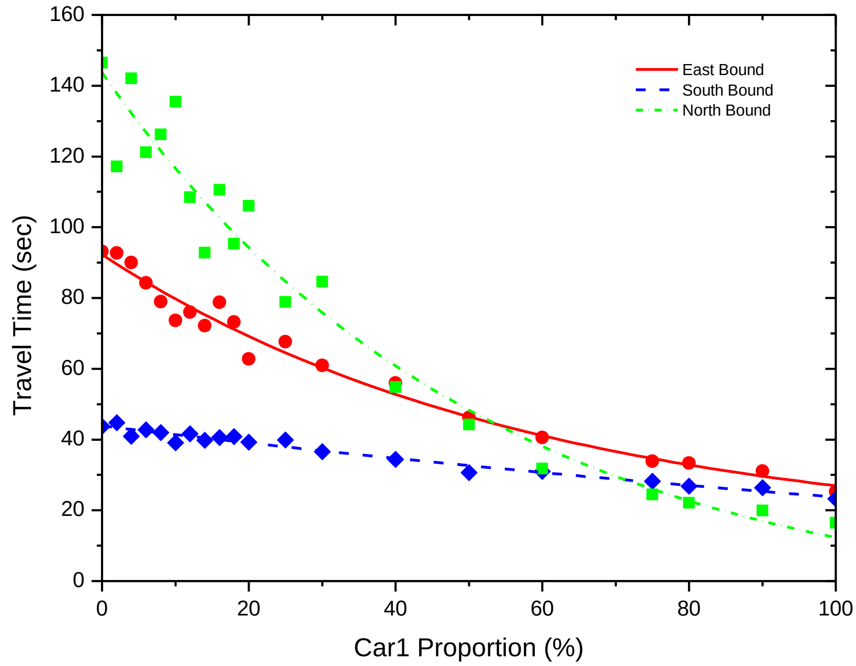

Figure 28 Changes in Travel Time with Car1 Proportion – S1 (EB, NB, SB)

Figure 28 showed travel time plots for the EB, NB and SB approaches. It was observed from the three curves that the travel time was longest on the NB approach followed by the EB and SB approaches respectively, though the traffic volumes were higher on the last two. This was attributed to the traffic from the SB and EB approaches that conflicted with the NB approach traffic. The EB approach also experienced a considerably longer travel time because the traffic from the SB approach conflicted with it. The SB approach experienced the least travel times because the vehicles on that approach had shorter waiting times at the yield line. This was due to the low traffic volume that conflicted with the approach lane as a result of the low left-turn and through traffic volumes from the WB and NB approaches.

Figure 29 showed plots of the travel time data obtained for the Pt1 and Pt2 on the circulatory lane. It can be seen that there was insignificant variation in travel times.

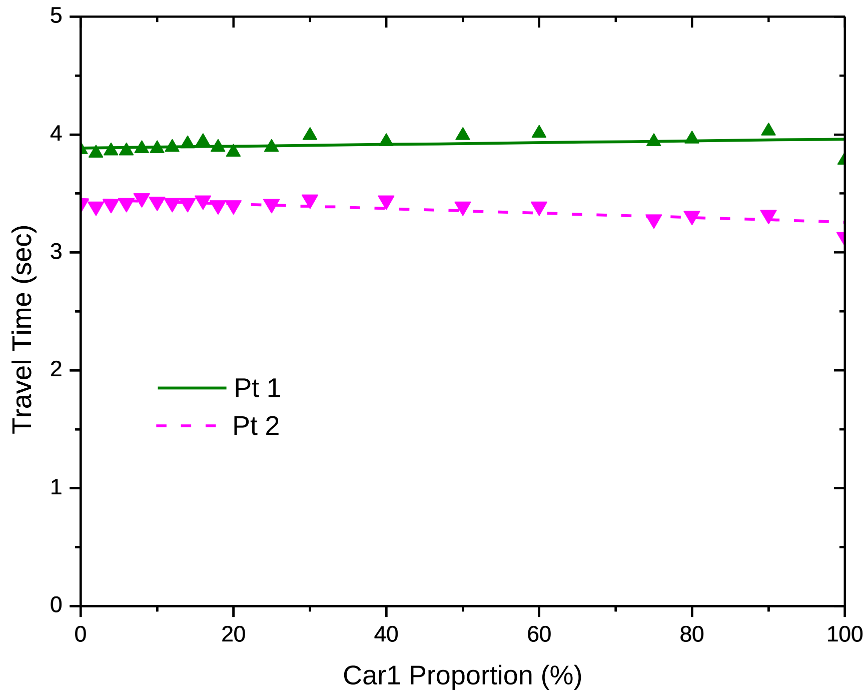

Figure 29 Change of Travel Time with Car1 Proportion – S1 (Pt1 and Pt2)

For S1 Scenario simulations, the averages obtained for WB approach were very small and showed little to no variation because of the low volume of through vehicles. It is thus not presented here

4.2 EFFECT OF SPEED OF CAR 1 ($S1_I$)

To investigate the effect of the speed of Car1 on the performance of the roundabout, the speed of Car1 was altered and the S1 simulations repeated (S1i). The results obtained were plotted together with the S1 data. The delay, queue length and travel time plots are shown in Figures 30 – 32, Figures 33 – 35, and Figures 36 – 38 respectively.

Delay Plots and Discussions for S1 and S1i Scenarios

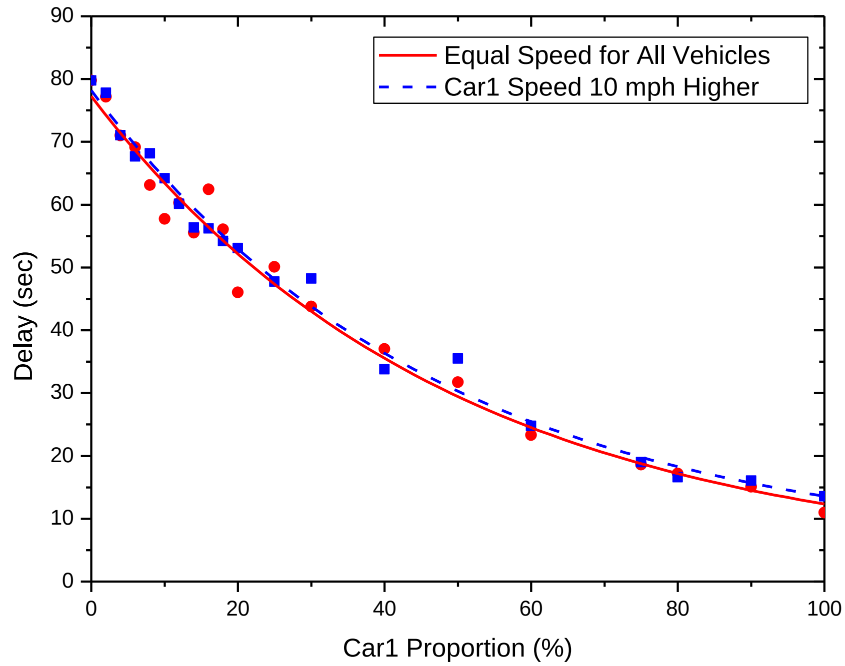

Figure 30 Change of Delay with Car1 Proportion – S1 and S1i (EB)

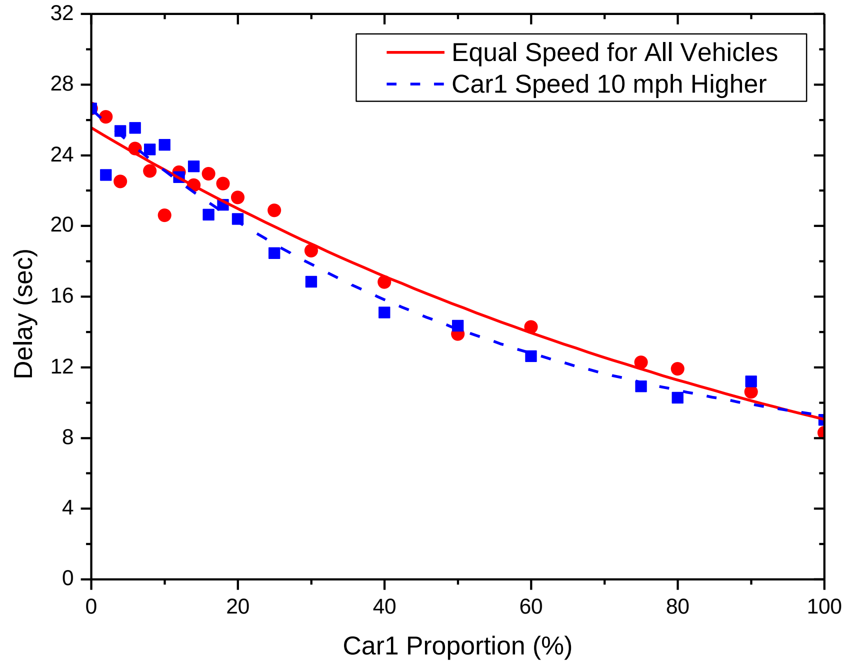

Figure 31 Change of Delay with Car1 Proportion – S1 and S1i (NB)

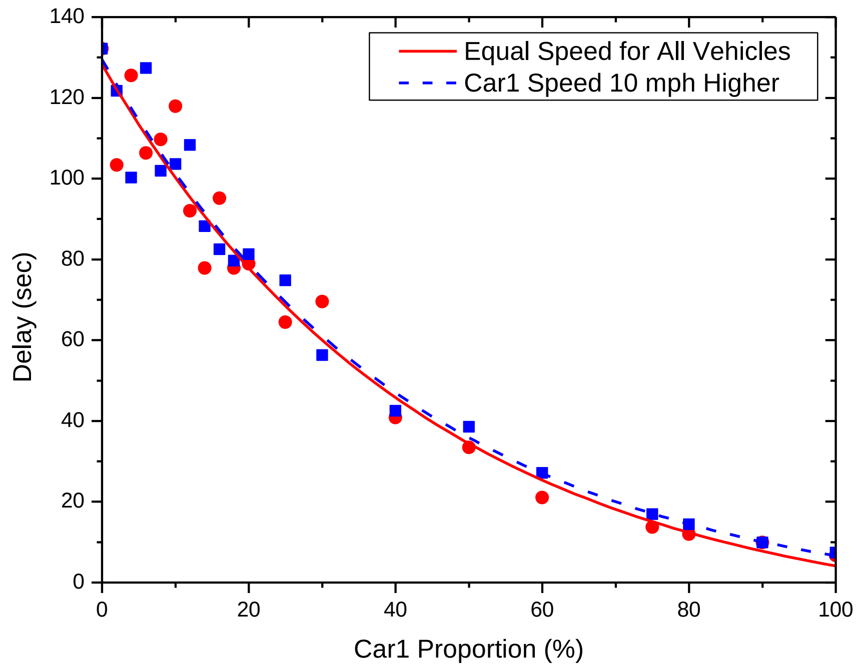

Figure 32 Change of Delay with Car1 Proportion – S1 and S1i (SB)

The delay data obtained from the S1 and S1i simulations are plotted on the same axes in Figures 30 – 32 for the EB, NB, and SB approaches respectively. It can be seen that the two plots were closely matched for all three approaches as shown by the fitted curves. It can therefore be deduced from the simulation results that the speed of Car1 did not appear to have a significant effect on the delay obtained. This observation may be attributed to the features of the roundabout.

Queue Plots and Discussions for S1 and S1i Scenarios

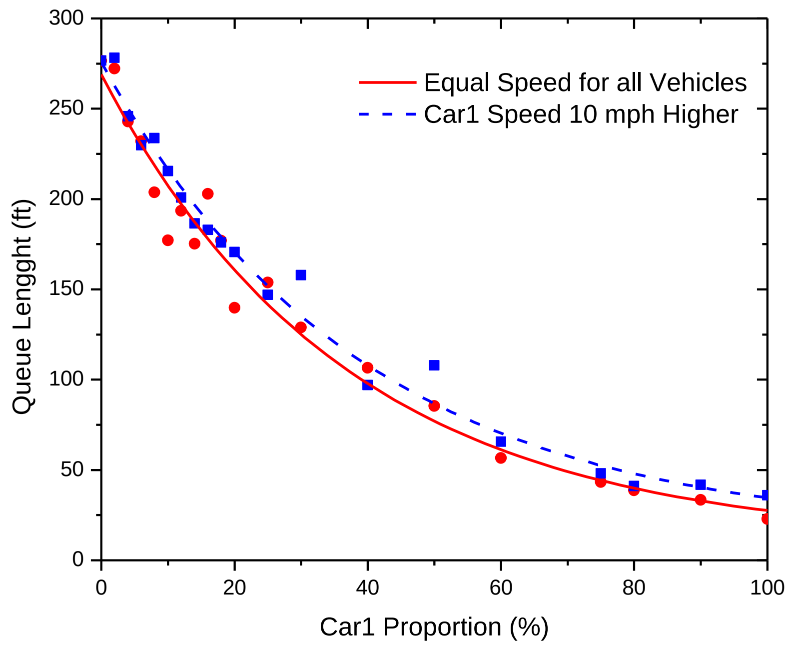

Figure 33 Change of Queue Length with Car1 Proportion – S1 and S1i (EB)

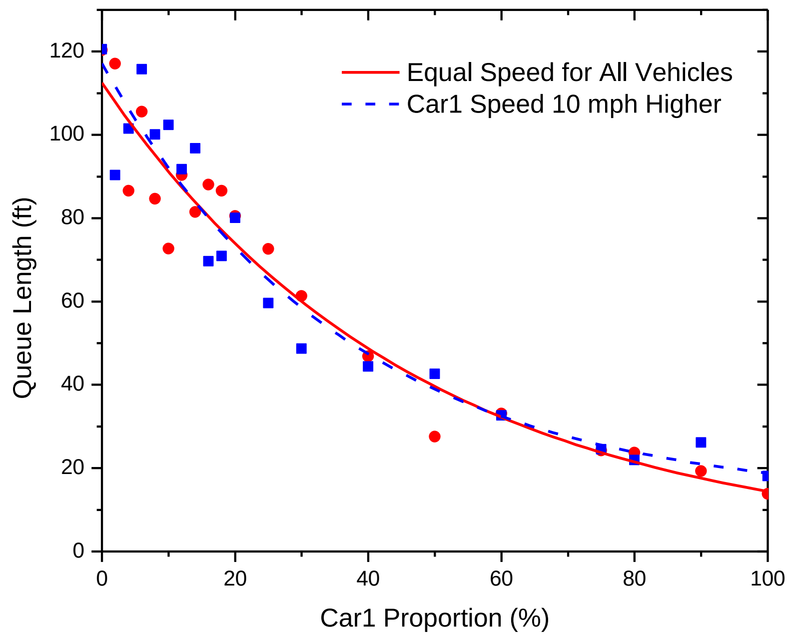

Figure 34 Change of Queue Length with Car1 Proportion – S1 and S1i (NB)

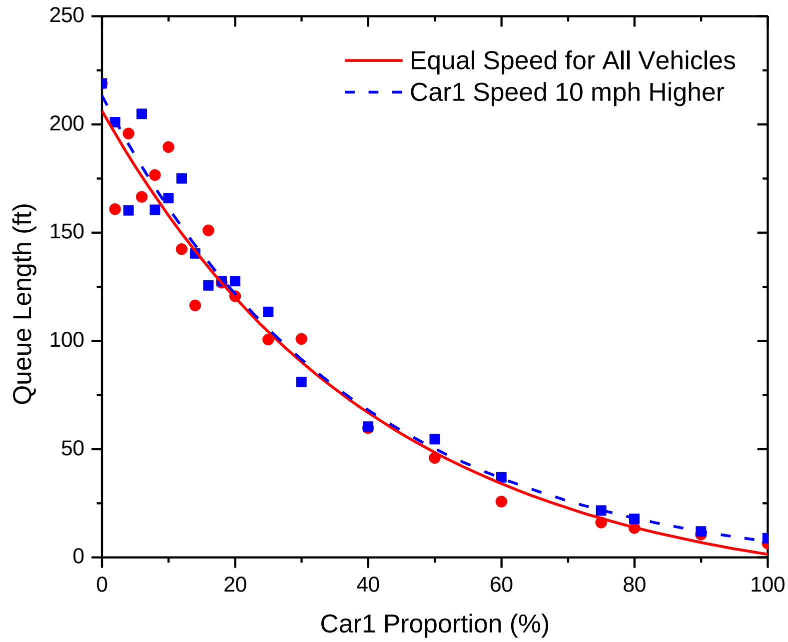

Figure 35 Change of Queue Length with Car1 Proportion (SB)

The S1 and S1i simulation queue length data are plotted and presented in the Figures 33 – 35 for the EB, NB and SB approaches respectively. The plots from the two simulations appeared closely matched for all three approaches. It can be deduced from the fitness of the plots that the speed of Car1 had an insignificant effect on the queue lengths obtained. This might be attributed to the overall speed calming effect from the roundabout design.

Travel Time Plots and Discussions for S1 and S1i Scenarios

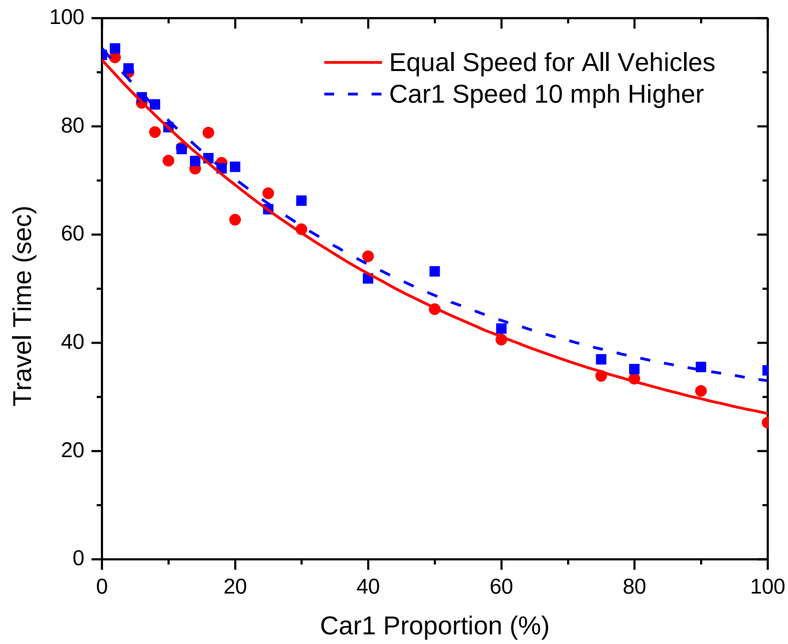

Figure 36 Change of Travel Time with Car1 Proportion – S1 and S1i (EB)

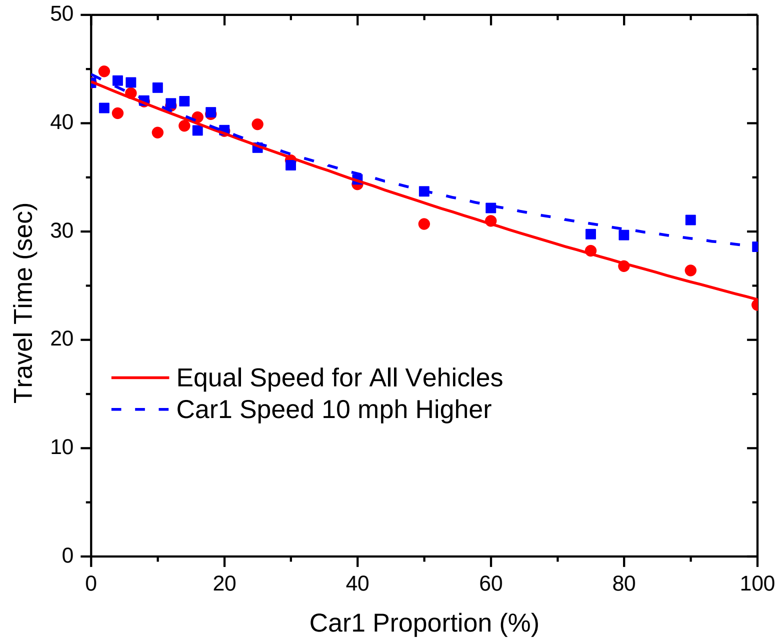

Figure 37 Change of Travel Time with Car1 Proportion – S1 and S1i (NB)

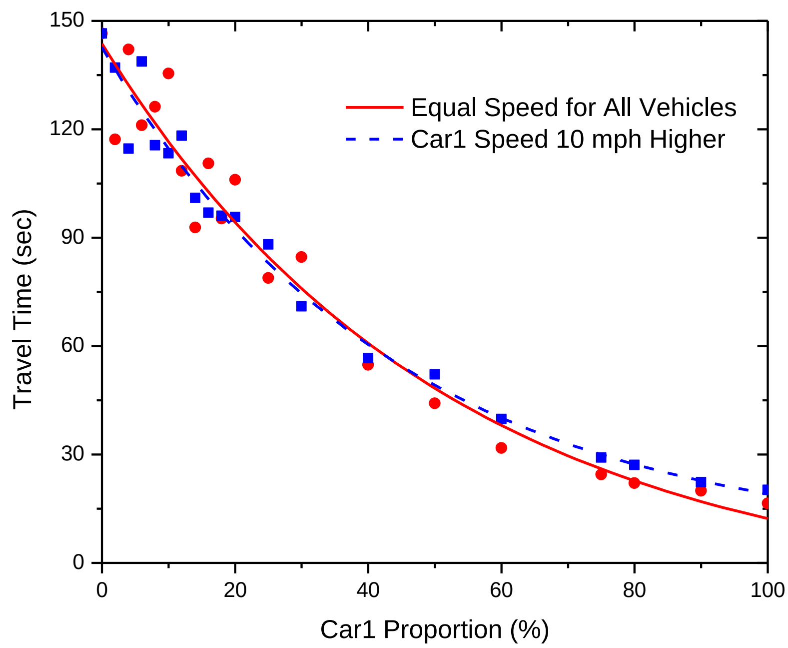

Figure 38 Change of Travel Time with Car1 Proportion – S1 and S1i (SB)

The travel time data obtained from the S1 and S1i simulations are plotted on the same axes in Figures 36 – 38 for EB, NB, and SB respectively. It can be seen that the two travel time plots were closely matched for all three approaches and which is further shown by the fit of the curves. It can therefore be deduced from the simulation results that the speed of Car1 appeared to have a minimal to no significant effect on the travel time. This observation may be attributed to the features of the roundabout which seemed to maintain a constant speed for all vehicles.

4.3 EFFECTS OF INSCRIBED CIRCLE DIAMETER SIZE (S2)

In this group of simulation scenarios (S2) the inscribed circle diameters were varied for different Car1 proportions. The delay, queue length, and travel time plots are shown in Figures 39 – 42, Figures 43 – 46, and Figures 47 – 50 respectively.

Delay Plots and Discussions for S2 Scenario

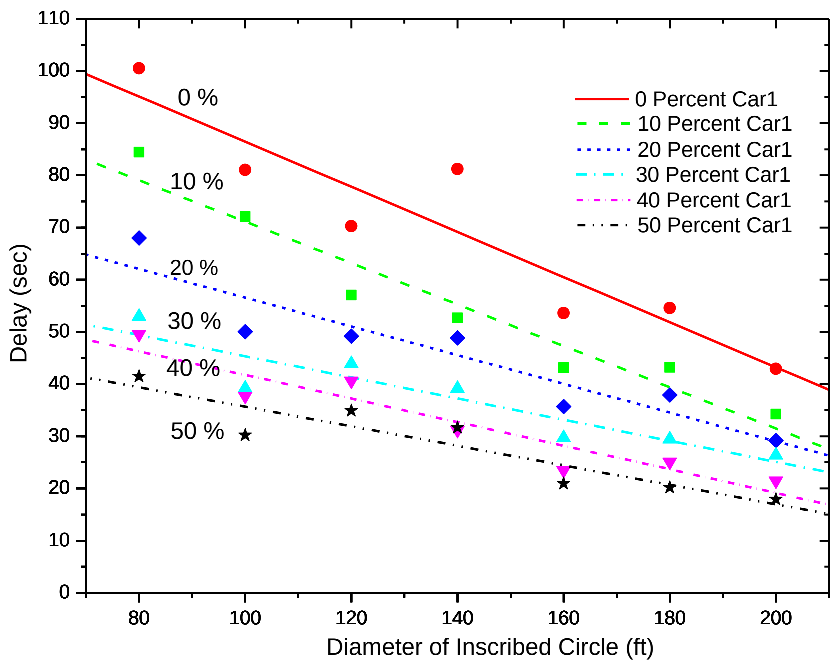

Figure 39 Change of Delay with Roundabout Size – S2 (EB)

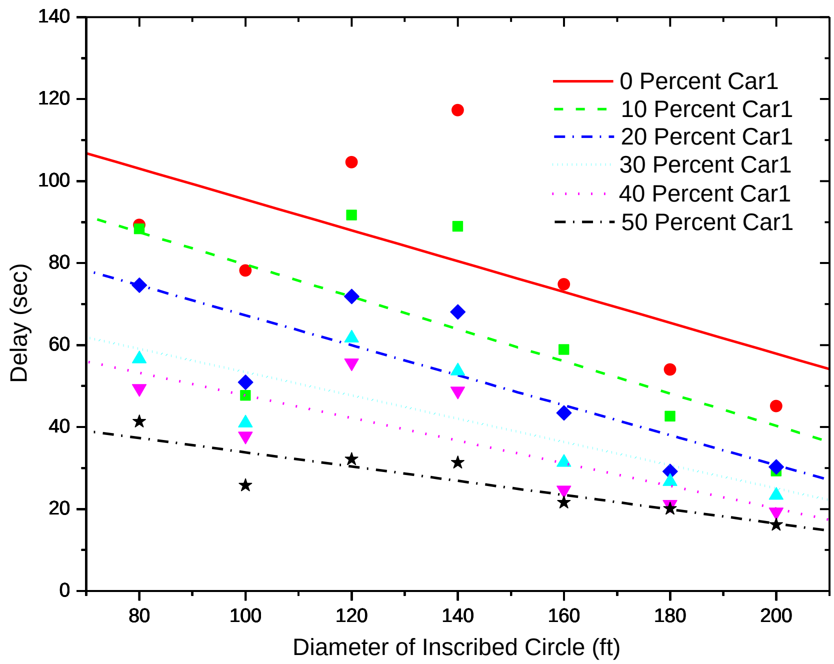

Figure 40 Change of Delay with Roundabout Size – S2 (NB)

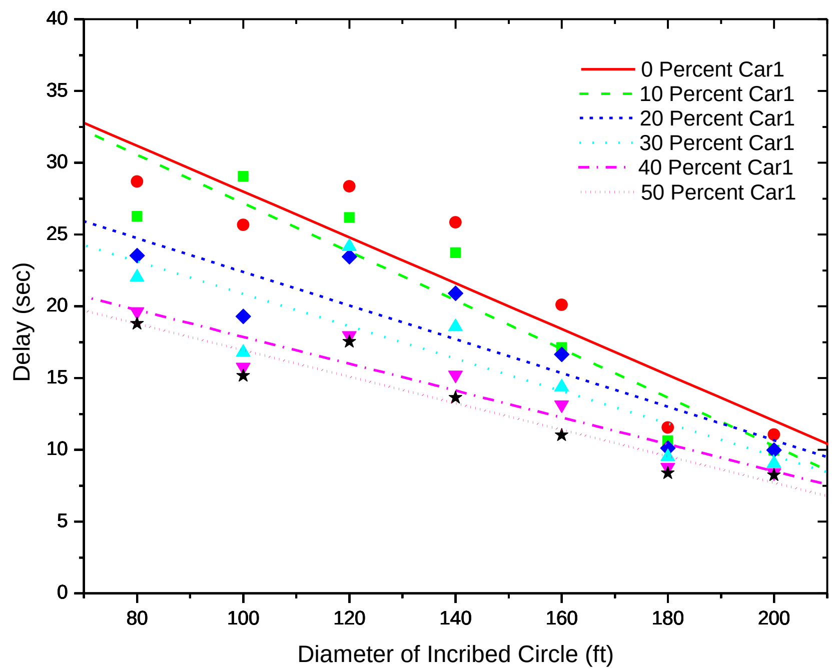

Figure 41 Change of Delay with Roundabout Size – S2 (SB)

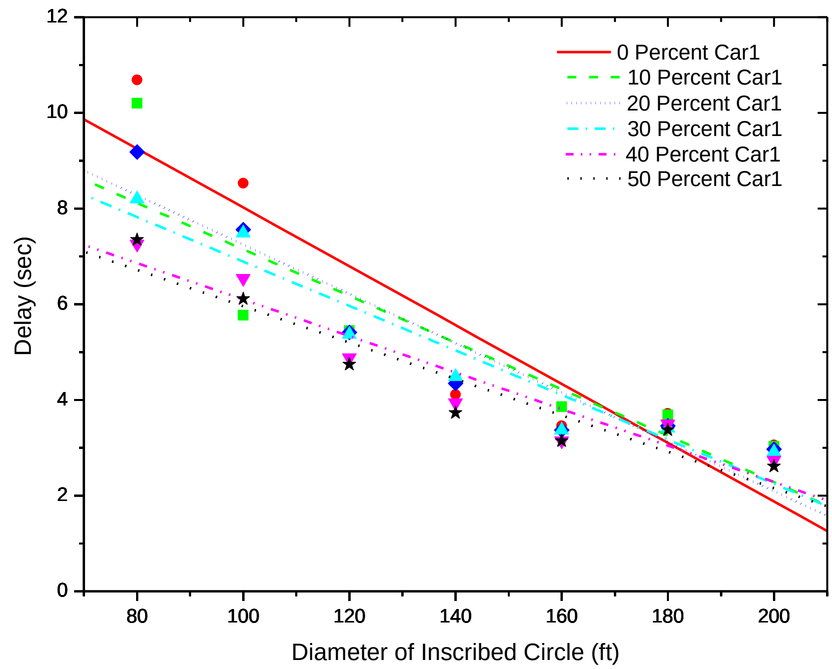

Figure 42 Change of Delay with Roundabout Size – S2 (WB)

Figures 39-42 showed a general decrease in delay as the inscribed circle diameter increased. It was observed that the delay decreased with increased Car1 proportion as shown by the curves. Another observation made was that the rate of delay reduction decreased with an increase in the Car1 proportion for the range of inscribed diameter investigated. In terms of percentage the reductions in delay that occurred at the lower diameter were comparable to the reductions at the larger diameters. Table 4 gave the delay reductions between 0 and 50 percent Car1 at 80 ft and 200 ft inscribed diameter. In terms of absolute value, the largest reductions were observed at the lower diameters. The largest delay reduction was observed on the NB approach, followed by the EB, SB and the WB.

Table 4 Delay Reduction between 0 and 50 Percent of Car1

Direction of Approach	Delay Reduction (%)	
	80 (ft) Diameter	200 (ft) Diameter
EB	59	61
NB	64	71
SB	40	37
WB	3	2

Queue Length Plots and Discussions for S2 Scenario

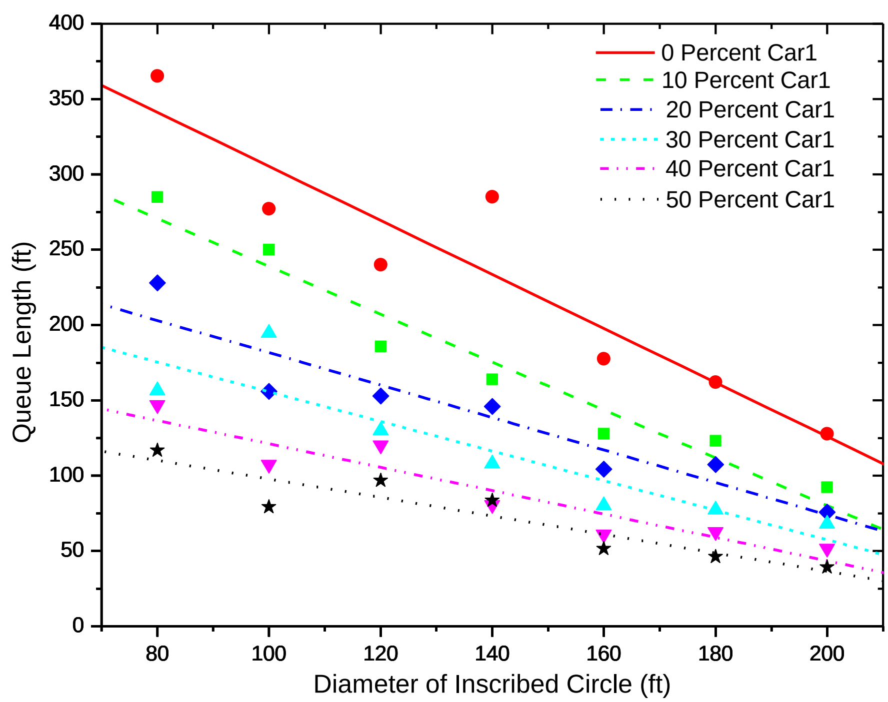

Figure 43 Change of Queue Length with Roundabout Size – S2 (EB)

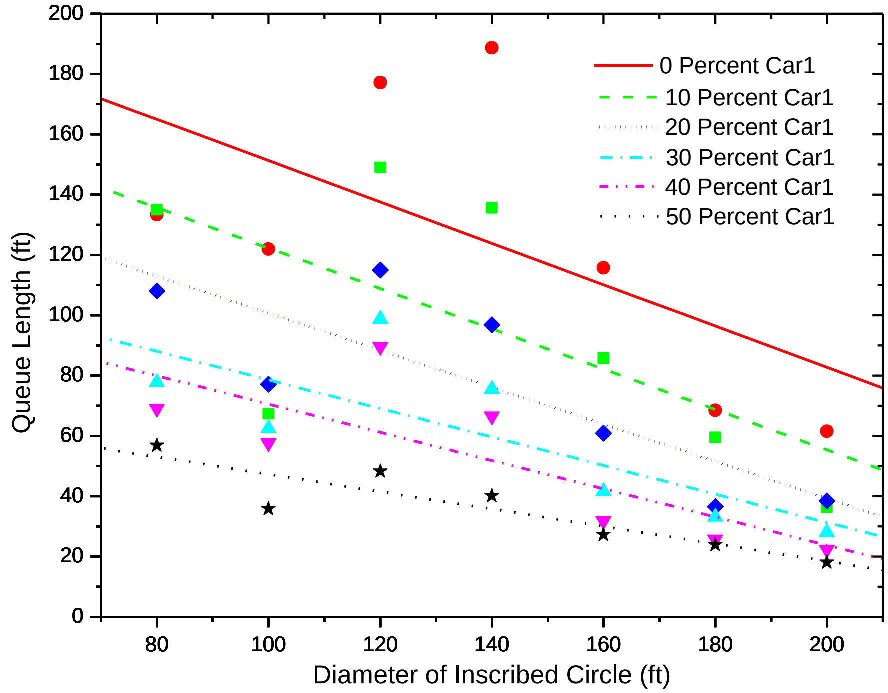

Figure 44 Change of Queue Length with Roundabout Size – S2 (NB)

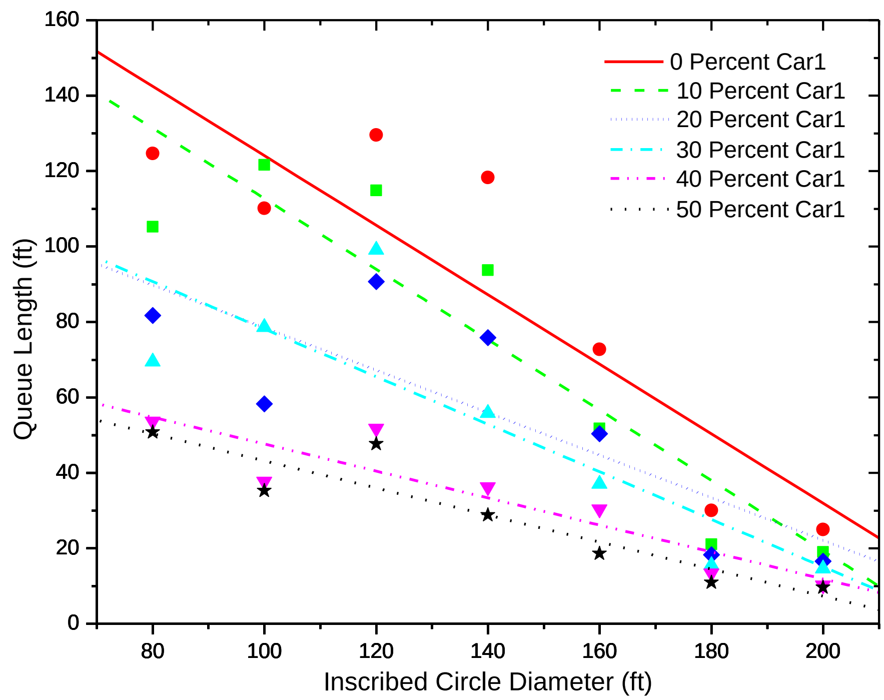

Figure 45 Change of Queue Length with Roundabout Size – S2 (SB)

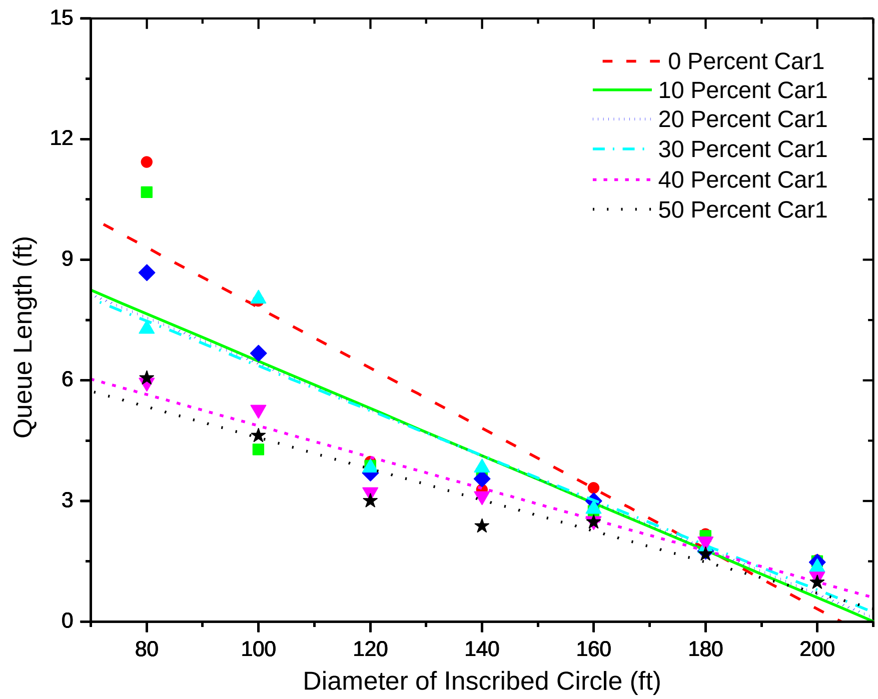

Figure 46 Change of Queue Length with Roundabout Size – S2 (WB)

Figures 43 – 46 showed the changes in queue length plotted against the inscribed circle diameter at different Car1 percentages. It was seen from the plots that there was reduction in queue length when inscribed circle diameter increased. As observed with the delay, the rate of queue length reduction tended to decrease with increasing Car1 proportion. It also showed a decrease in queue length when the Car1 proportion increased.

Table 5 shows the percentage decrease in queue length between 0 and 50 percent Car1 percentage for 80 ft and 200 ft inscribed diameter. In terms of absolute value, the largest reductions were observed at the lower diameters. The largest delay reduction was observed on the NB approach, followed by the EB, SB and the WB. The curves for the

WB approach were not very well defined and, possibly due to the low traffic volumes on that approach.

Table 5 Queue Length Reduction between 0 and 50 Percent of Car1

Direction of Approach	Queue Length Reduction (%)	
	80 (ft) Diameter	200 (ft) Diameter
EB	68	72
NB	68	78
SB	65	78
WB	42	15

Travel Time Plots and Discussions for S2 Scenario

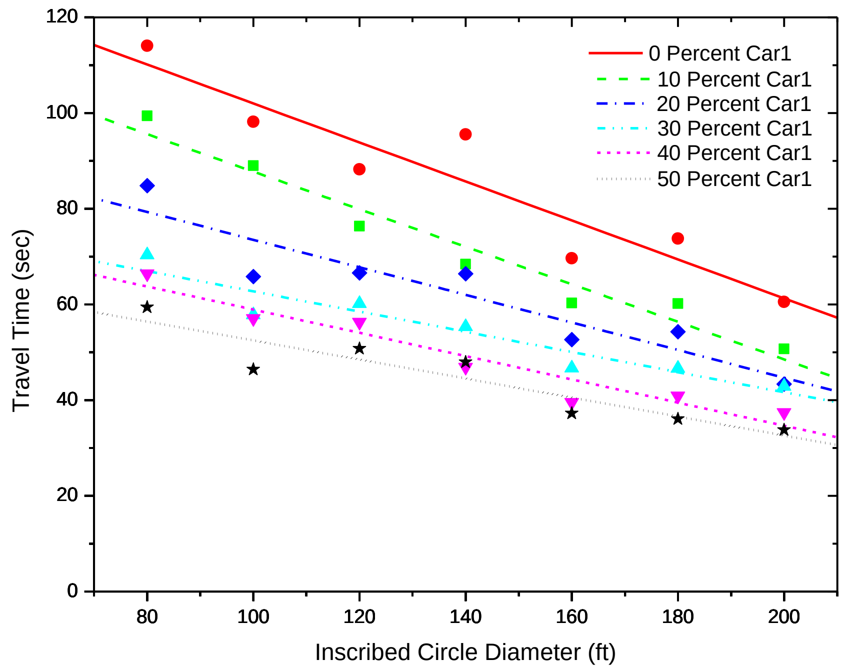

Figure 47 Change of Travel Time with Roundabout Size – S2 (EB)

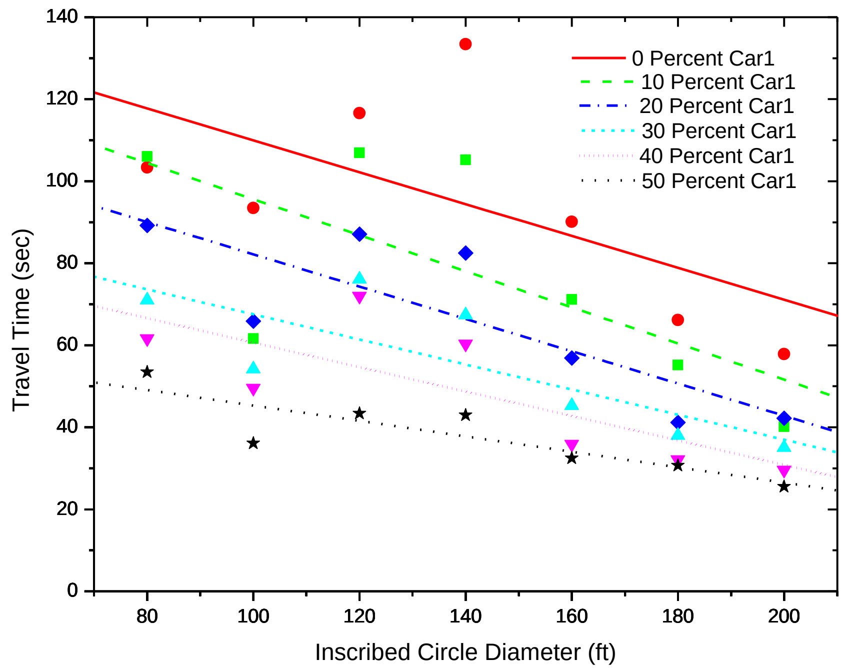

Figure 48 Change of Travel Time with Roundabout Size – S2 (NB)

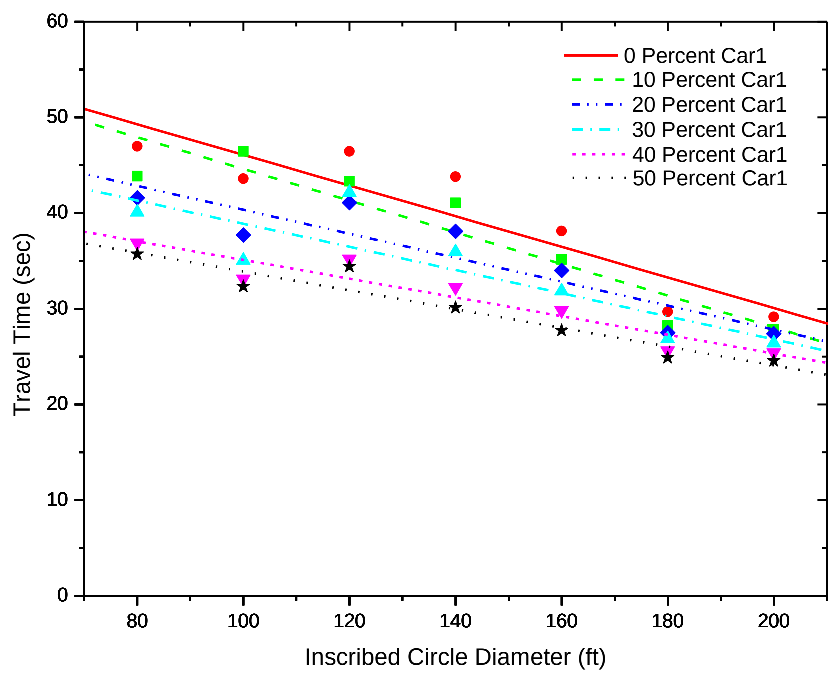

Figure 49 Change of Travel Time with Roundabout Size – S2 (SB)

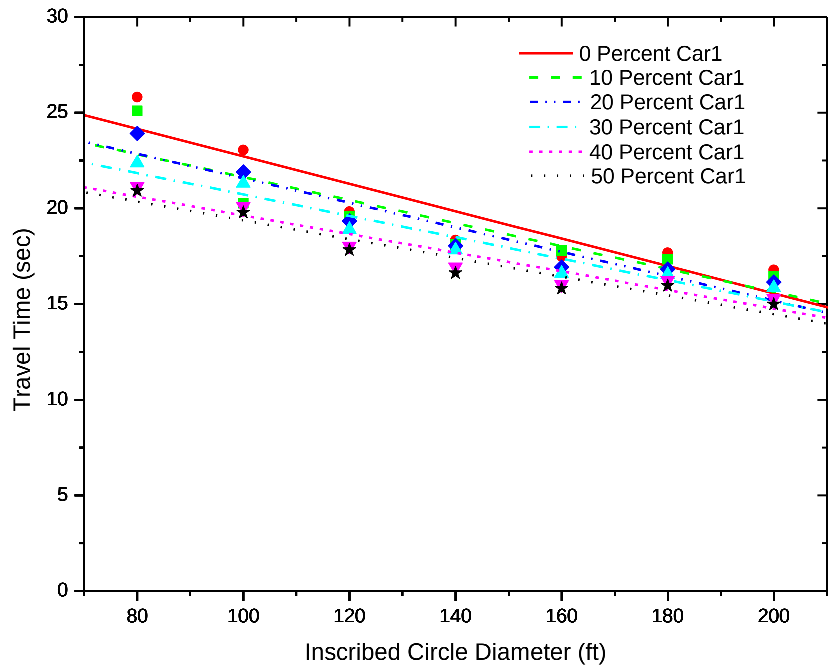

Figure 50 Change of Travel Time with Roundabout Size – S2 (WB)

Figures 47 – 50 showed the travel times plotted against inscribed circle diameter at different Car1 percentages. From the plots, it can be seen that as the inscribed circle diameter increased, the travel time decreased. As observed with the delay and queue length, the rate of travel time reduction tended to decrease with increasing Car1 proportion. The plots also showed a decrease in travel time as Car1 proportion increased. The percentage reduction in travel time between 0 and 50 percent Car1 percentages for 80 ft and 200 ft inscribed diameters are given in Table 6. In terms of percentages, the reductions were fairly uniform, but in terms of the actual value, the reductions were greater at the smaller diameters. The largest travel time reduction was observed on the NB approach, followed by the EB, SB and the WB.

Table 6 Travel Time Reduction between 0 and 50 Percent of Car1

Direction of Approach	Travel Time Reduction (%)	
	80 (ft) Diameter	200 (ft) Diameter
EB	49	47
NB	59	63
SB	27	20
WB	16	8

4.4 EFFECTS OF INCREASED TRAFFIC VOLUME (S3)

This group of simulations (S3) had traffic volumes increased for the total intersection while the Car1 proportion was kept constant for each range. The delay, queue length, and travel time data obtained were plotted against the increased traffic volume percentage and the results are presented in Figures 51 – 54, Figures 55 – 58, and Figures 59 – 62 respectively.

Delay Plots and Discussions for S3 Scenario

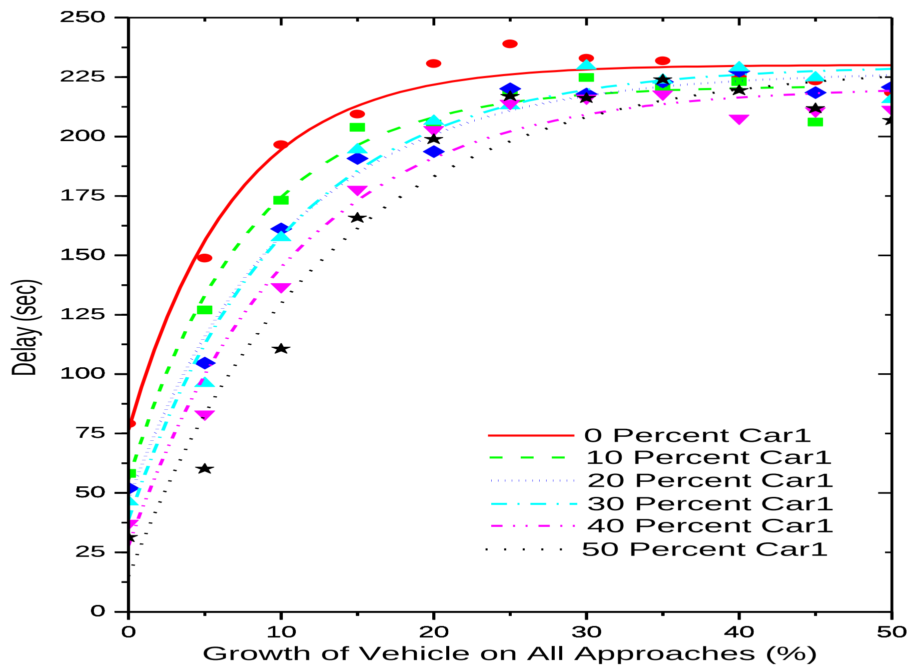

Figure 51 Change of Delay with Traffic Volume Increase – S3 (EB)

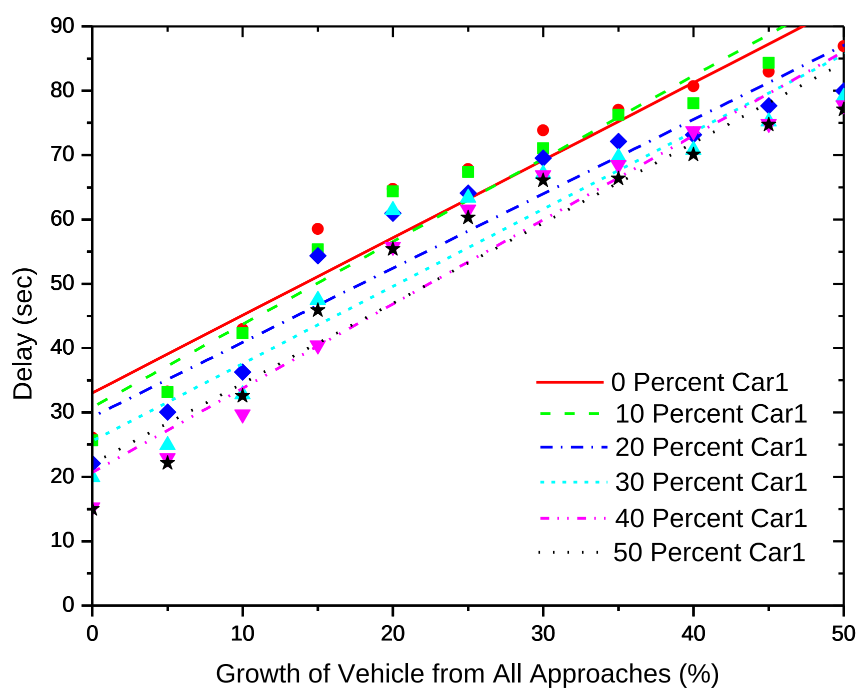

Figure 52 Change of Delay with Traffic Volume Increase – S3 (NB)

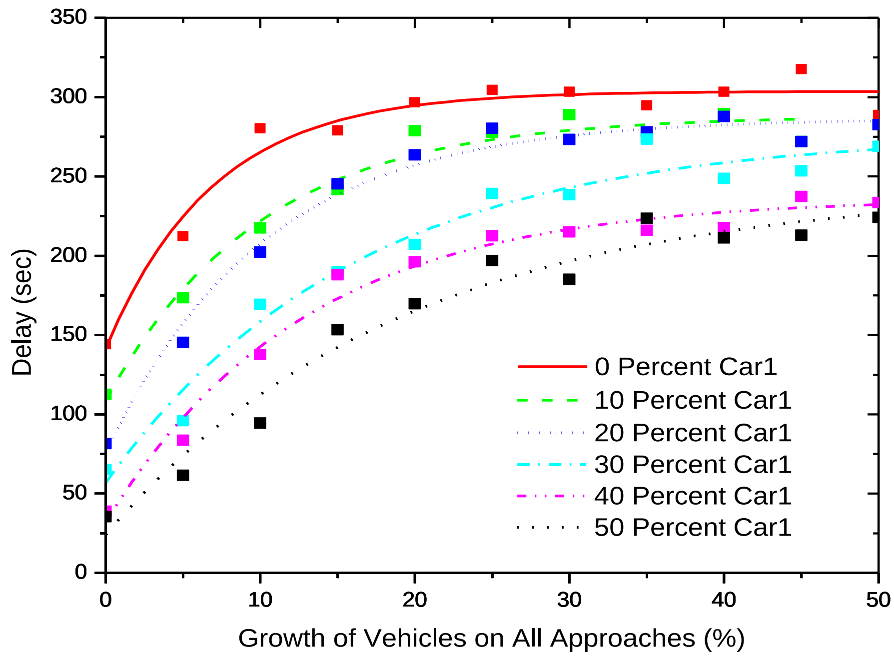

Figure 53 Change of Delay with Traffic Volume Increase – S3 (SB)

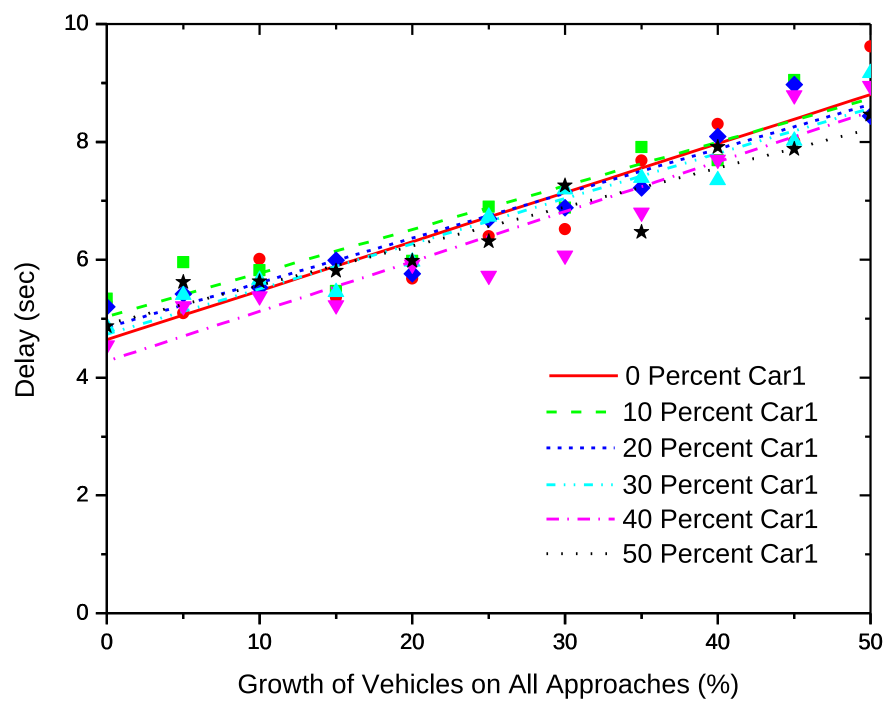

Figure 54 Change of Delay with Traffic Volume Increase – S3 (WB)

Figures 51 – 54 showed delay generally increased with traffic volume increase. The EB and SB approaches showed rapid increase in delay from 0 – 30 percent traffic volume increase but slowed considerably afterwards. The delays appeared to have reached a threshold at about 200 seconds per vehicle. The NB and WB approaches however showed continuous increase in delay for the range tested. The NB and WB approach plots appeared to match the trend observed for the first portion of the EB and SB approaches. Another observation made on all approaches was that delay decreased with increased Car1 proportion. This can be interpreted to mean that at high traffic volumes, the proportion of Car1 had significant reduction effect on the delays observed.

Queue Length Plots and Discussions for S3 Scenario

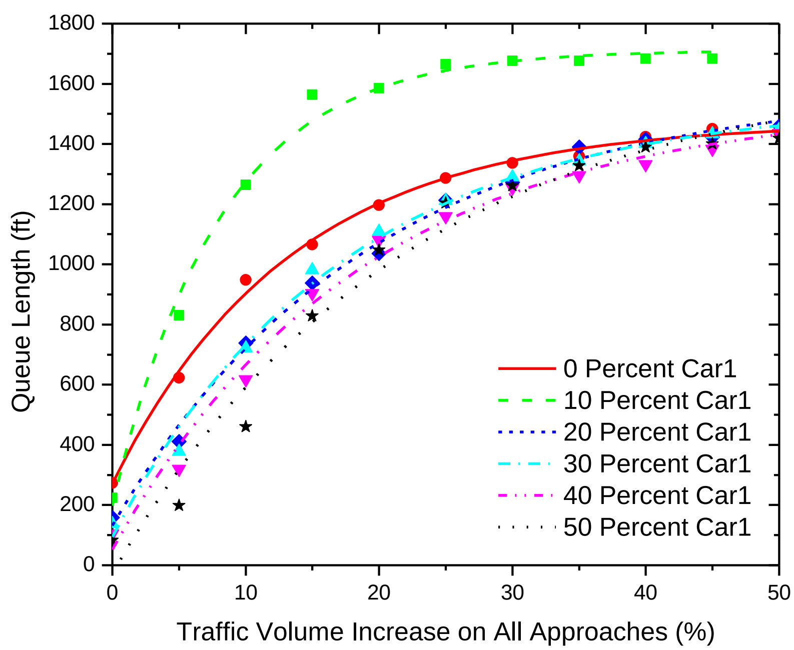

Figure 55 Change of Queue Length with Traffic Volume Increase – S3 (EB)

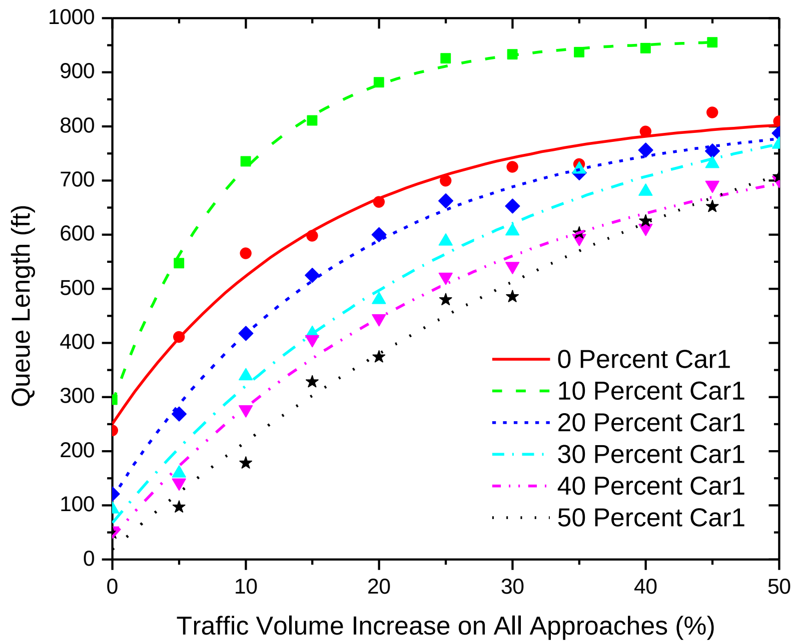

Figure 56 Change of Queue Length with Traffic Volume Increase – S3 (NB)

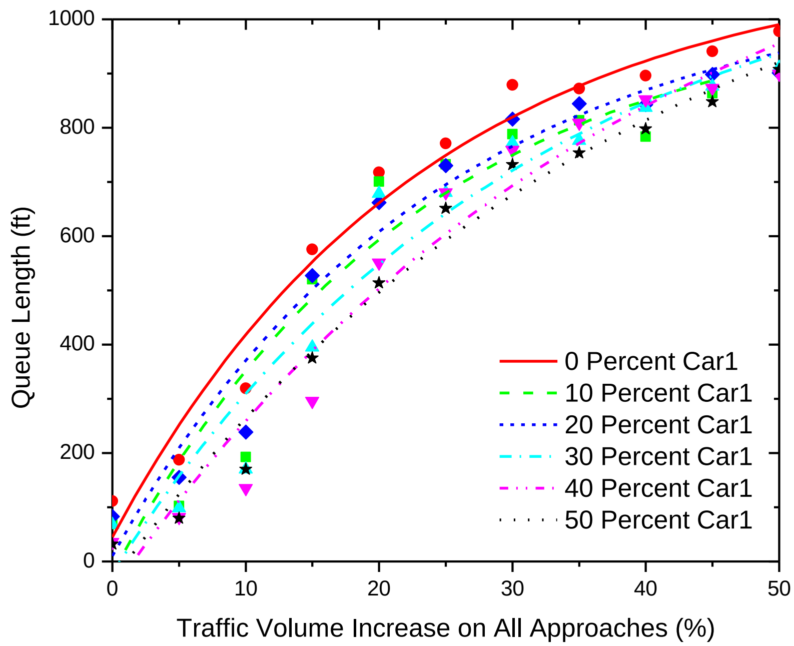

Figure 57 Change of Queue Length with Traffic Volume Increase – S3 (SB)

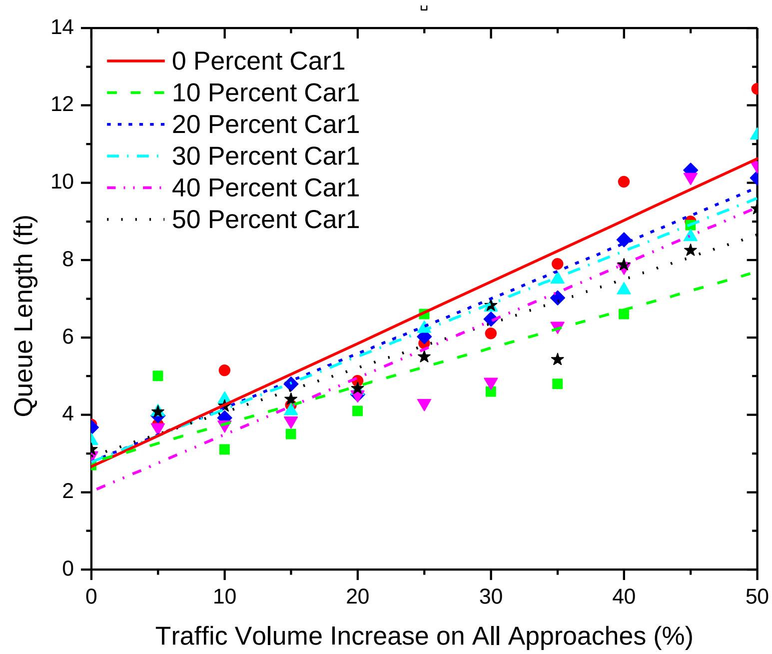

Figure 58 Change of Queue Length with Traffic Volume Increase – S3 (WB)

From Figures 55 – 58 it was observed that the queue lengths increased as the traffic volume increased for all the approaches. It was also observed that the queue lengths reduced as the Car1 proportion increased. The curves for the EB, NB and SB showed queue lengths increased continually (exponential growth curve) as traffic volumes increased. The fitted lines for the WB approach showed a continuous increase in queue length but these were straight lines. The observation on the WB approach was attributed primarily to the low traffic volumes from the WB approach that merged onto the circulatory lane. The plots for the WB approach were comparable to the initial portions of the curves obtained for the other three approaches at low traffic volumes.

Travel Time Plots and Discussion for S3 Scenario

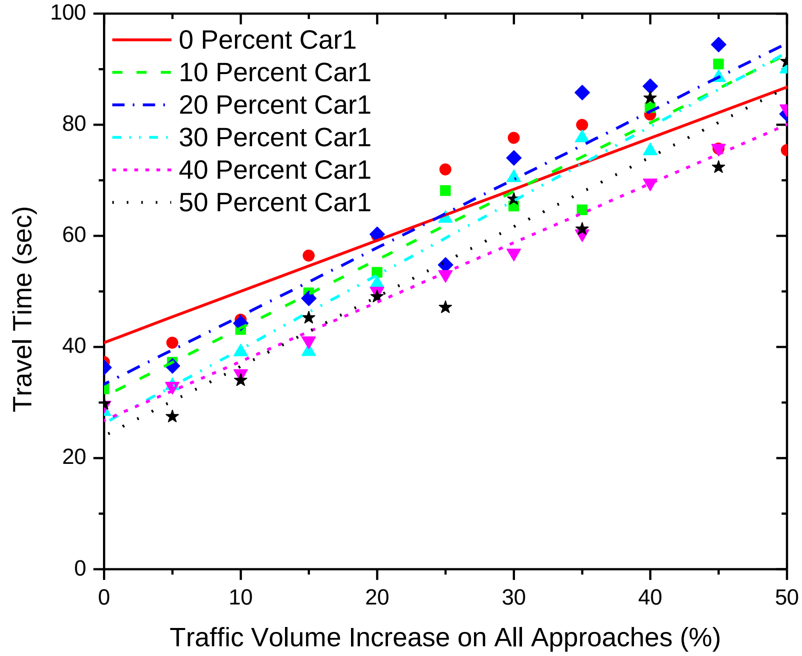

Figure 59 Change of Travel Time with Traffic Volume Increase – S3 (EB)

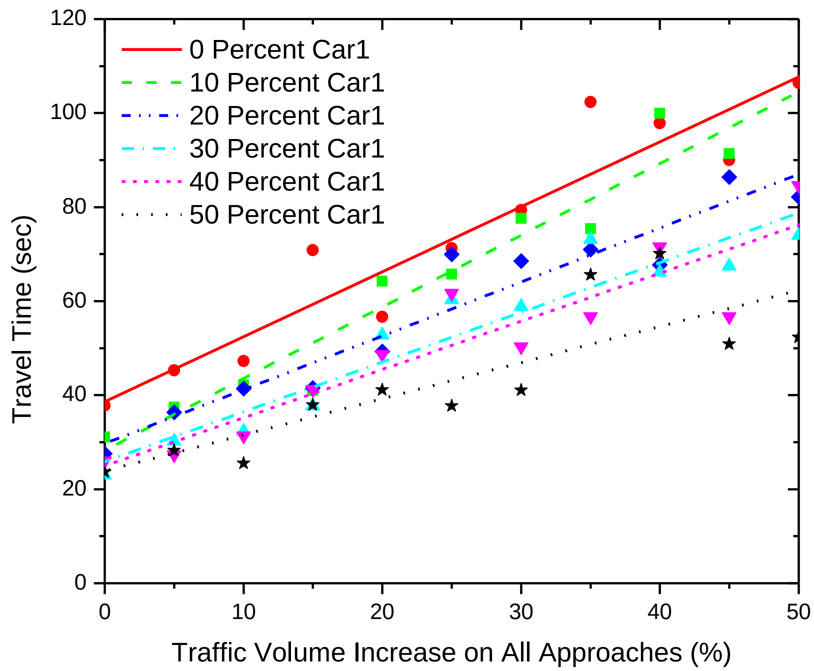

Figure 60 Change of Travel Time with Traffic Volume Increase – S3 (NB)

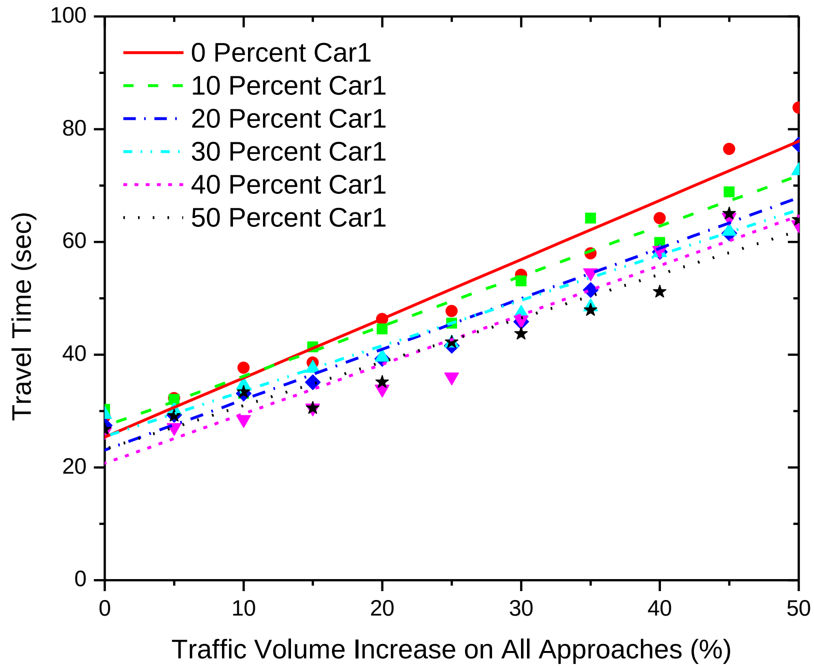

Figure 61 Change of Travel Time with Traffic Volume Increase – S3 (SB)

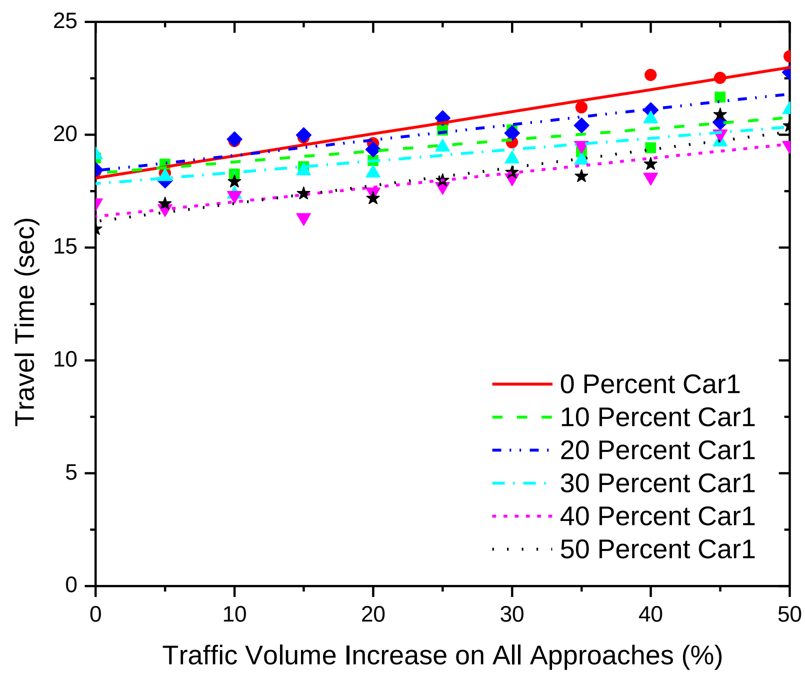

Figure 62 Change of Travel Time with Traffic Volume Increase– S3 (WB)

Figures 59 – 62 showed generally that travel time increased with increased traffic volume. The average rates of travel time increase for a unit increase in traffic volume for the EB, SB, NB, and WB approaches were computed as 1.15, 0.88, 1.15, and 0.063 respectively. The lowest rate of increase was obtained for the WB approach and may be directly attributed to the low rate of traffic volume increase on that approach. It was also observed that for all the approaches queue length reduced as Car1 proportion increased.

4.5 SUMMARY

This chapter presented results obtained from the simulation runs and made analyses from the observations. From the simulation scenarios investigated, the following deductions were made:

- There was a general reduction in delay, queue length and travel time with an increased Car1 proportion in the vehicle composition mix.
- There was about 8-16 percent delay reduction for every 10 percent increase in Car1.
- There was 10-20 percent reduction in queue length for every 10 percent increase in Car1.
- The inscribed circle diameter had a significant effect on the operations of a roundabout. The bigger the inscribed circle diameter, the better the performance of the roundabout (reduction in delay, queue length and travel time.

- At higher percentages of Car1, the rate of delay, queue length and travel time reductions decreased as the inscribed circle diameter increased.
- With traffic volume increase for the total intersection, delay, queue length and travel times also increased according. It was also observed that the performance measures showed significant reductions at higher Car1 proportions.

5 CHAPTER FIVE - SENSITIVITY ANALYSIS AND DISCUSSION

Sensitivity analyses were conducted to check the robustness of the model. Sensitivity analyses are techniques used to determine how different values of an independent variable impact a particular dependent variable under a given set of assumptions. For this research, sensitivity analyses were carried out by investigating the effects of change in traffic volume from one approach on the performance measured from the other approaches. Two traffic directional distribution based simulation scenario (S4-1 and S4-2) were investigated. The results obtained are presented in the two sections below.

5.1 SCENARIO 1: EQUAL DIRECTIONAL DISTRIBUTION OF TRAFFIC VOLUME INCREASE - (S4-1)

In this simulation scenario (S4-1) traffic volume from the WB approach were increased and evenly distributed to the right-turn, through and left-turn directions. Car1 proportion was kept constant for each traffic volume increase. The delays, queue lengths, and travel time data plots are shown in Figures 63 – 68, Figures 69 – 74, Figures 75 – 80 respectively.

Delay Plots and Deductions for S4-1

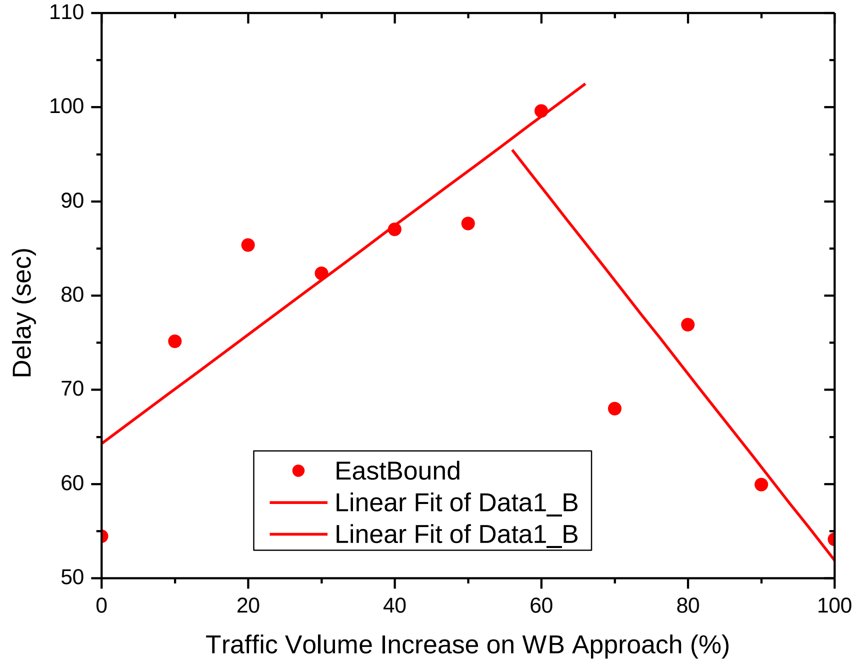

Figure 63 Change of Delay with Traffic Volume Increase on WB Approach – S4-1 (EB)

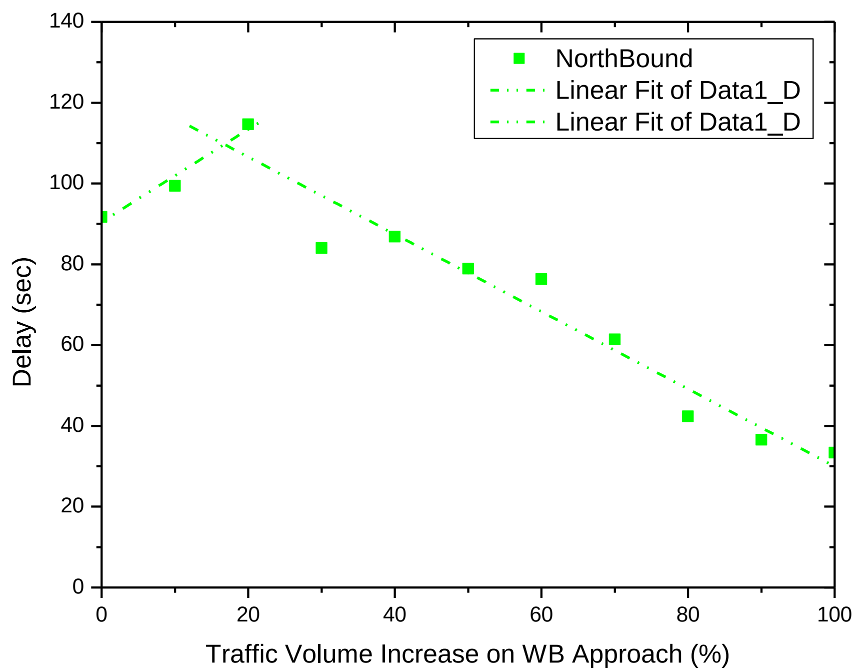

Figure 64 Change of Delay with Traffic Volume Increase on WB Approach – S4-1 (NB)

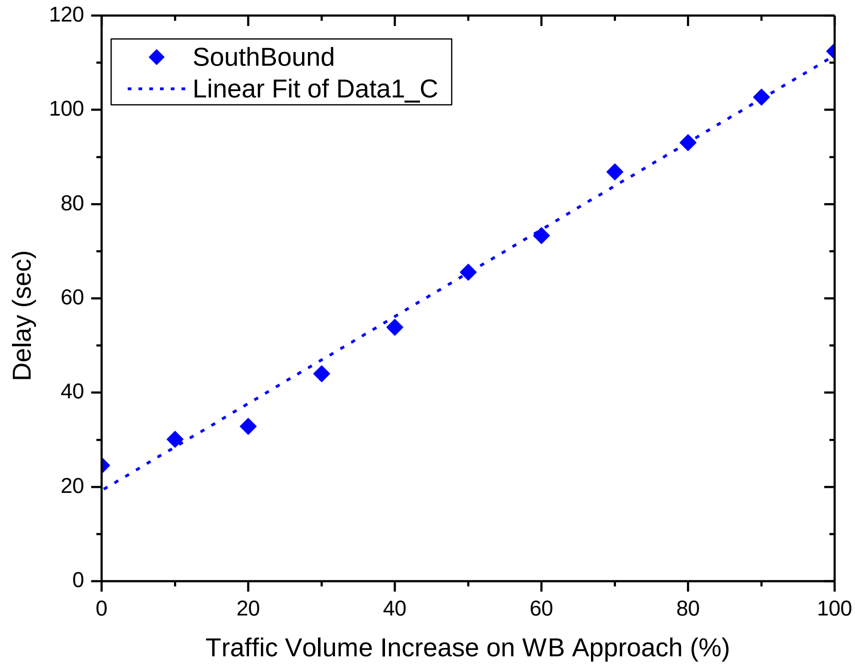

Figure 65 Change of Delay with Traffic Volume Increase on WB Approach – S4-1 (SB)

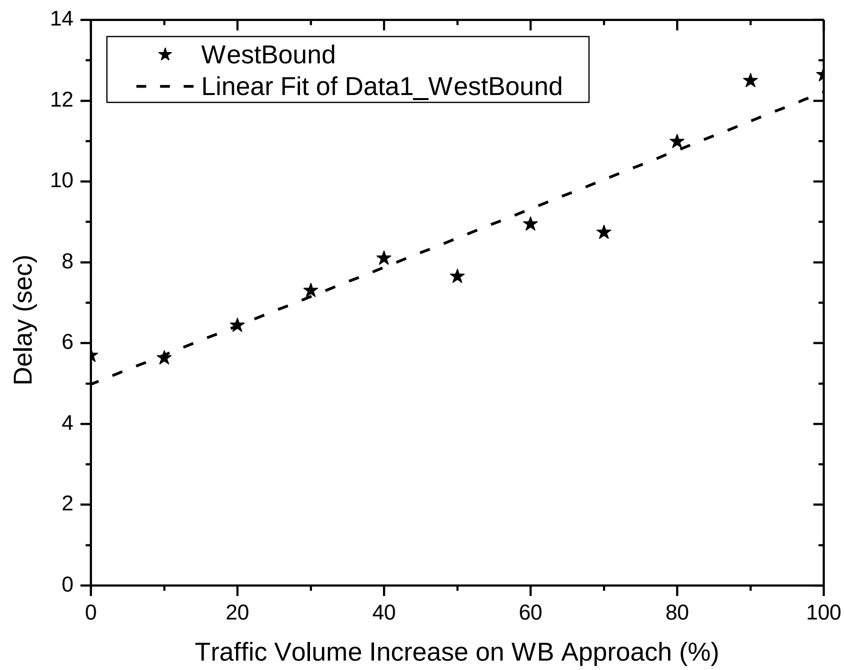

Figure 66 Change of Delay with Traffic Volume Increase on WB Approach – S4-1 (WB)

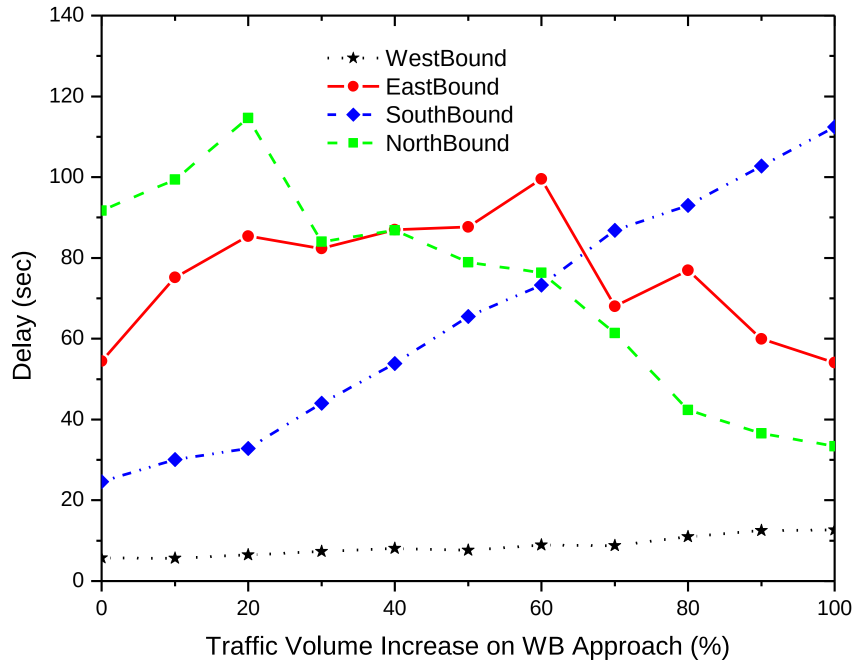

Figure 67 Change of Delay with Traffic Volume Increase on WB Approach – S4-1 (EB, NB, SB and WB)

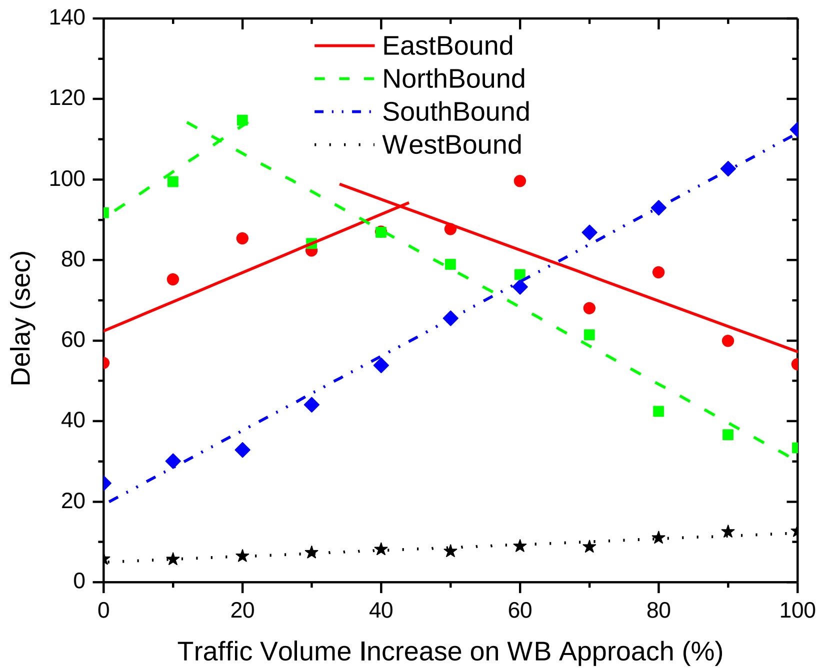

Figure 68 Change of Delay with Traffic Volume Increase on WB Approach – S4-1 (EB, NB, SB and WB)

As the LT and through traffic volume from the WB approach increased, the EB (Figure 63) and NB (Figure 64) approaches exhibited initial increases in delay followed by reductions. The initial increase was due to the fact that with increased traffic volume on the WB approach, the volume of vehicle that conflicted with the other three approaches (SB, EB, NB) also increased. With further increase in traffic from the WB approach, the circulatory lane traffic increased and the SB approach experienced more conflicts therefore resulting in more merging opportunities available to the EB and NB approaches. The more gaps presented, the higher the merging opportunities available, which translated into reduced delay.

The NB approach experienced delay reductions after about 20 percent increase in WB approach traffic. This was attributed to the observation that the LT traffic from the WB approach conflicted with the EB approach. The NB approach did not experience an increase in conflicts from the WB traffic increase hence was presented with merging opportunities. The EB approach experienced reductions in delay after 60 percent increase in WB approach traffic. This was attributed to the increased traffic volume on the circulatory lane that caused more conflicts with the SB approach which therefore resulted in the EB approach traffic having more merging opportunities.

However, the delay on the SB and the WB approaches increased continuously as shown by the Figures 65 and 66. The observation was expected since the SB approach had lower conflicts compared to the EB and NB due to the low traffic volume from the WB. Figures 67 and 68 showed plots of the delays measured on all four approaches as a result of increased WB approach traffic volume. It can be seen that at about 60 percent WB traffic increase the delays on EB, SB and NB were about the same due to the balance.

Queue Length Plots and Discussion for S4-1

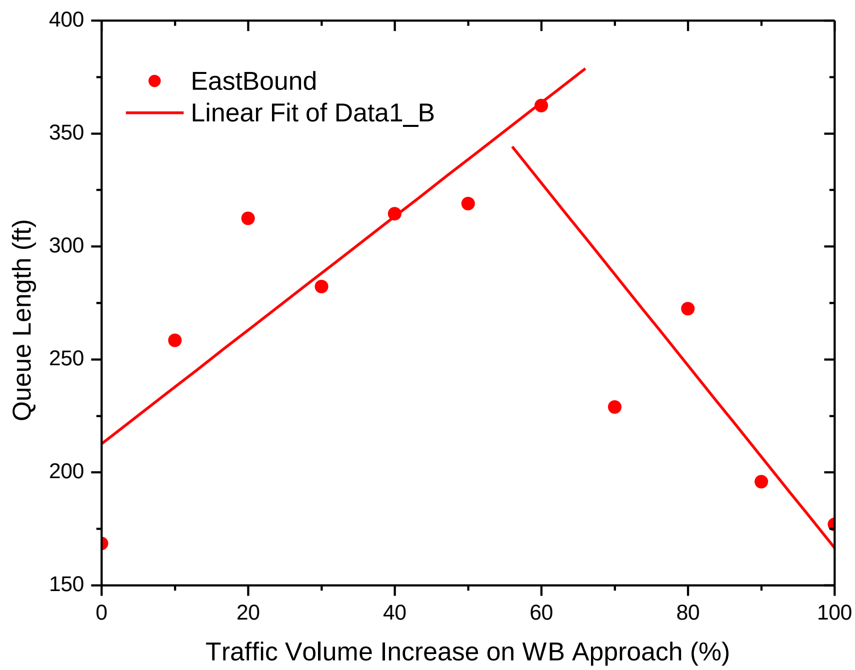

Figure 69 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-1 (EB)

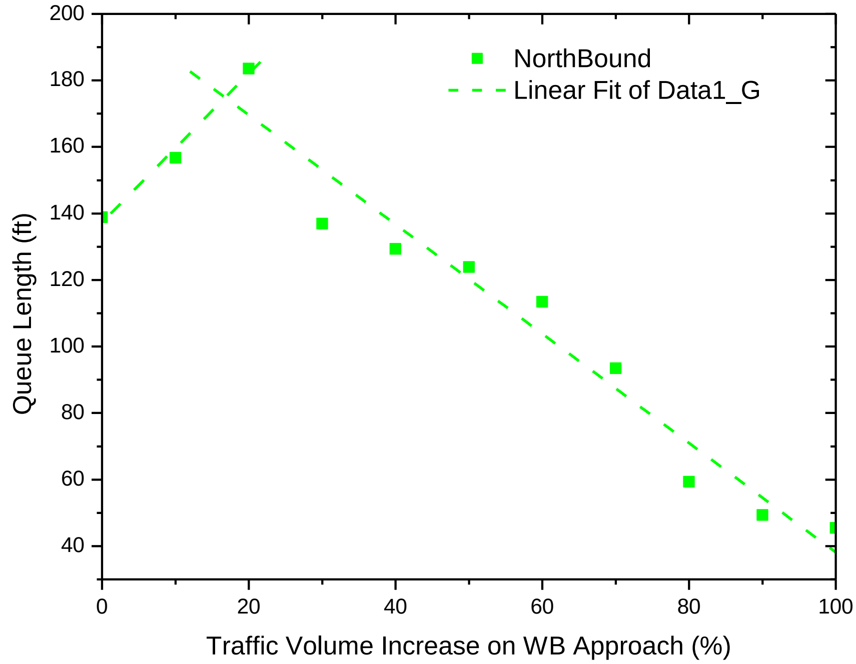

Figure 70 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-1 (NB)

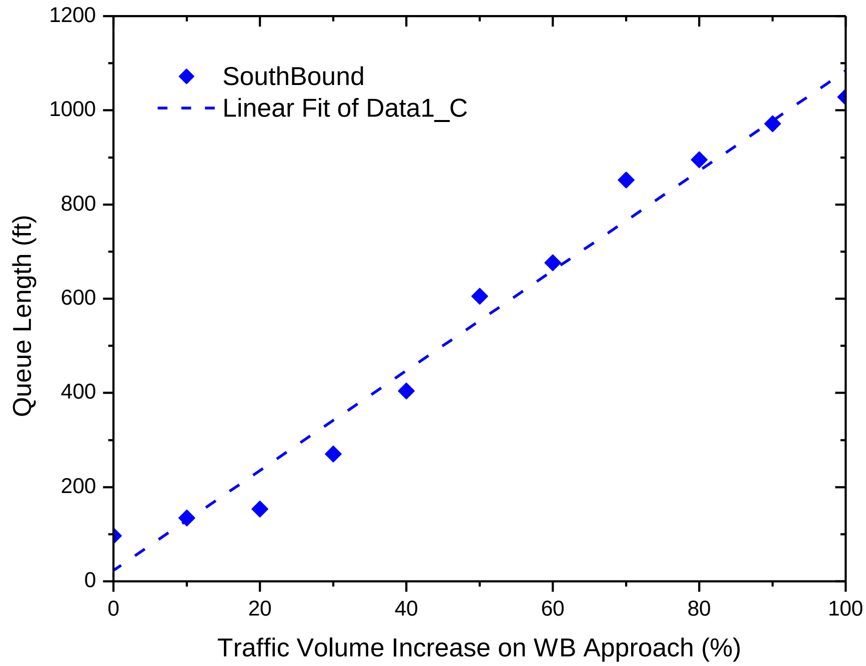

Figure 71 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-1 (SB)

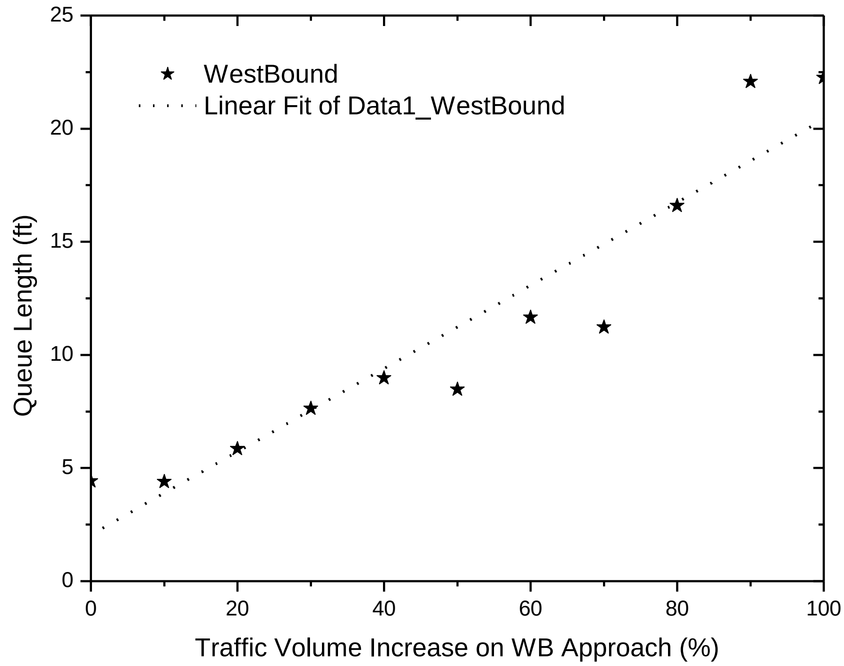

Figure 72 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-1 (WB)

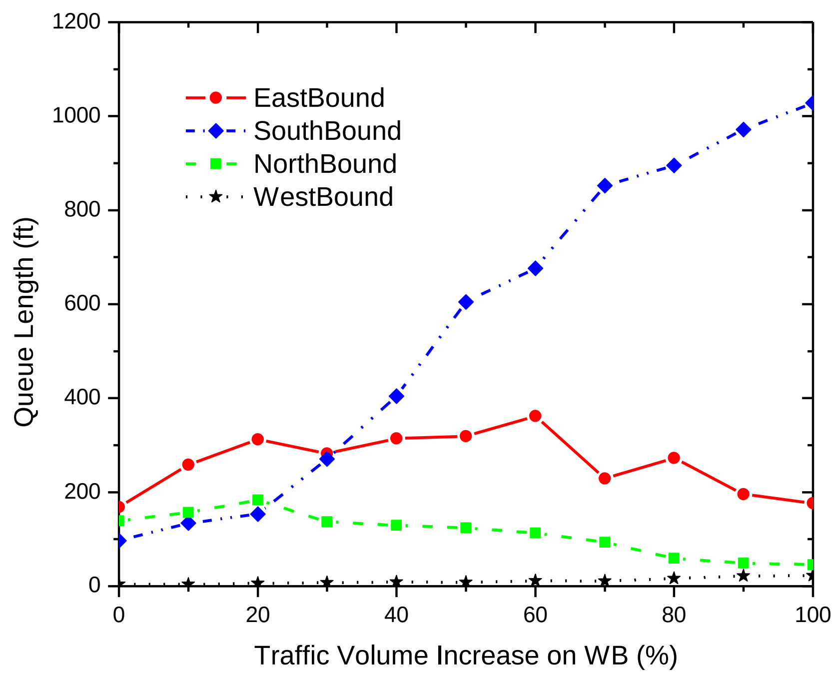

Figure 73 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-1 (EB, NB, SB and WB)

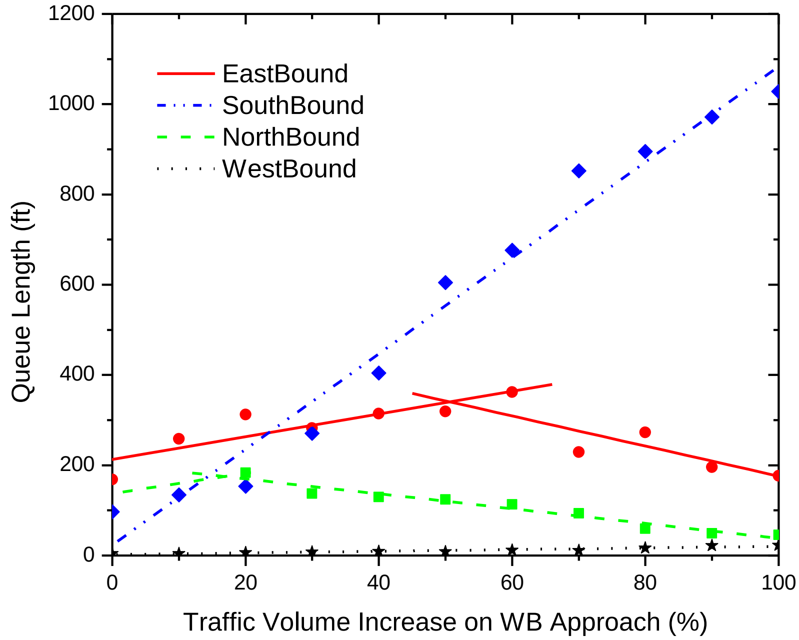

Figure 74 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-1 (EB, NB, SB and WB)

As the LT and through traffic volumes from the WB approach increased there was initial increase followed by reduction in queue lengths as exhibited on the EB (Figure 69) and NB (Figure 70) approaches. The initial increase was due to the fact that as the traffic volume from the WB approach merging onto the circulatory lane increased, the volume of vehicle that conflicted with the SB, EB, and WB approaches also increased. With further increase of traffic on the circulatory lane, vehicles from the SB approach experienced more conflicts which resulted in an increase in merging opportunities for vehicles on the EB and NB approaches. These therefore resulted in reduced queue lengths on the two approaches. The NB and EB approaches experienced queue length reductions after 20 percent and 60 percent increase in WB approach traffic respectively. The queue length on the EB approach experienced reduction after 60 percent because the LT traffic from the WB approach also conflicted with it. Reduction occurred after the conflicts to the SB approach had increased substantially thus resulting in the availability of more downstream gaps.

The queue lengths on the SB (Figure 71) and WB (Figure 72) approaches showed continued increase with increase in WB approach traffic. This was expected since the queue lengths were shorter because of the low traffic volume from the WB approach merging onto the circulatory lanes. Figures 73 and 74 showed the queue length data plots for all the approaches against traffic volume increase on the WB approach. It was seen that the SB approach experienced a rapid queue length increase as the traffic from the WB approach increased.

Travel Time Plots and Discussions for S4-1

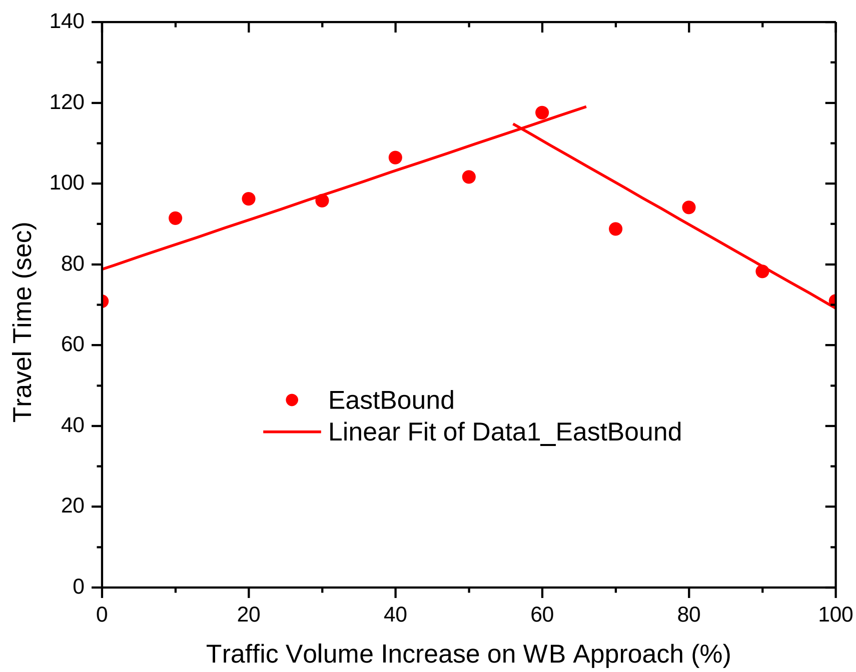

Figure 75 Change of Travel Time with Traffic Volume Increase on WB Approach – S4-1 (EB)

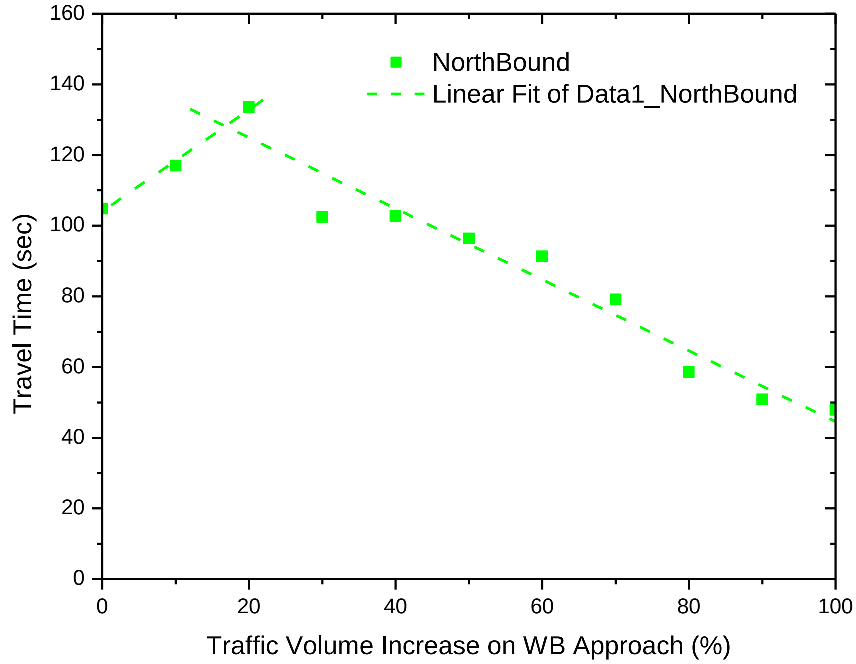

Figure 76 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-1 (NB)

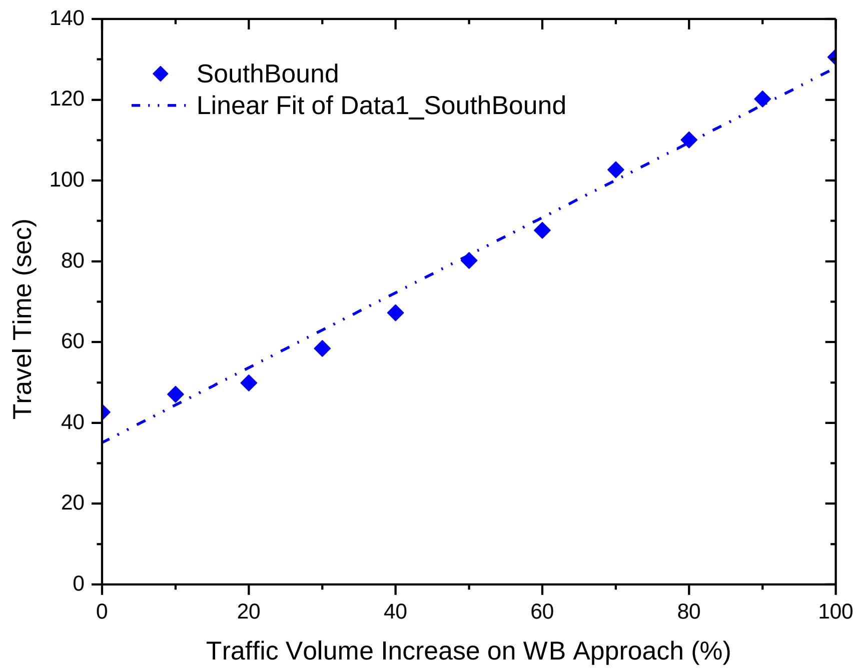

Figure 77 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-1 (SB)

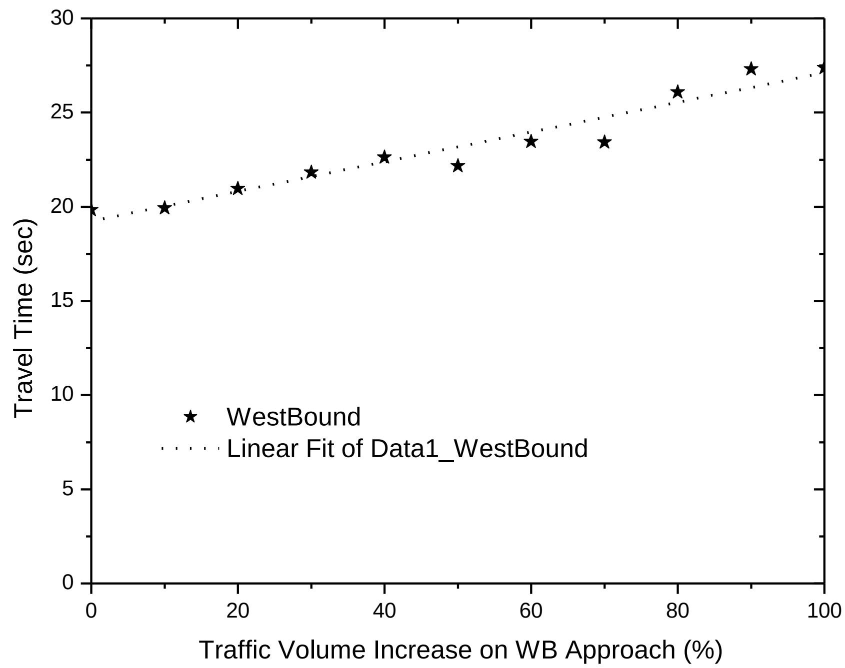

Figure 78 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-1 (WB)

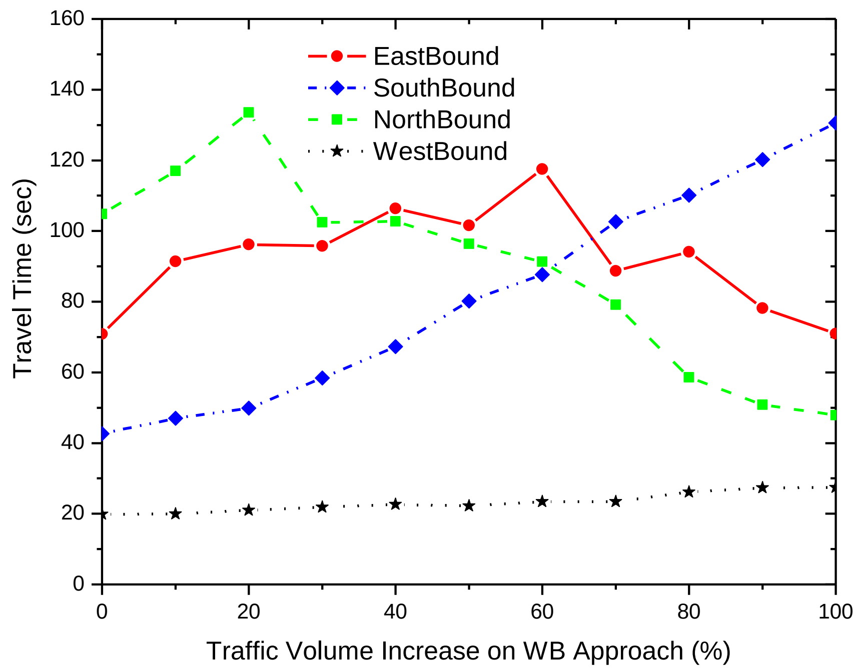

Figure 79 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-1 (EB, NB, SB and WB)

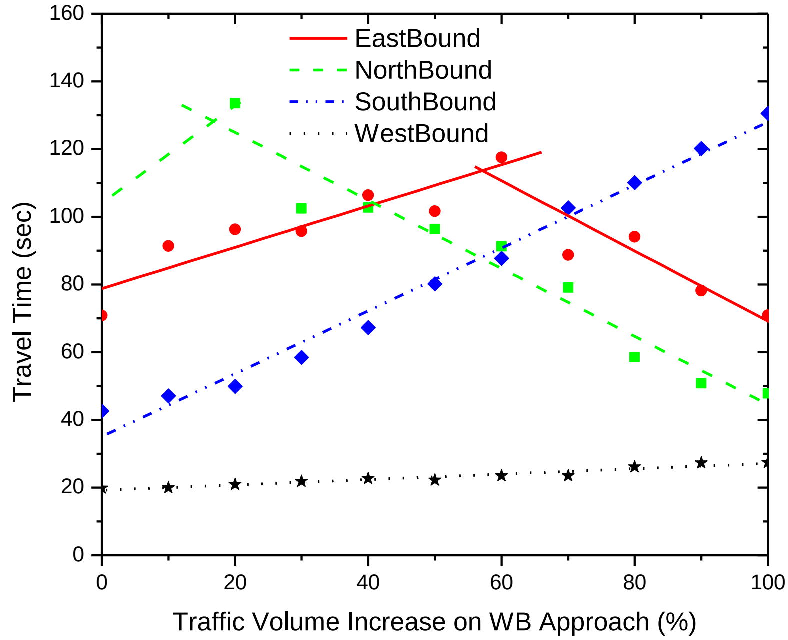

Figure 80 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-1 (EB, NB, SB and WB)

The travel times recorded for the simulations followed similar patterns as observed for the delays. The EB (Figure 73) and NB (Figure 74) approaches showed initial increased travel time followed by reductions as the WB approach traffic volume increased. The initial increase was explained by the fact that as the traffic from the WB approach increased the volume of vehicle that conflicted with the SB, EB, and NB approaches also increased. With further increase in LT and through traffic from the WB approach, the SB approach experienced more conflicts and therefore more gaps became available for the EB and NB approaches to merge onto the circulatory lanes. The NB approach experienced travel time reduction ahead of the EB approach. This was because the LT vehicles from the WB approach conflicted with the EB approach until the SB approach conflicts were substantially high and more gaps were available to the EB approach. The travel time on the SB (Figure 77) and WB (Figure 78) approaches increased continually since they experienced increased conflicts. Figures 79 and 80 show the travel time data plots against WB approach traffic volume increase for all approaches. The rates of travel time increase and decrease on the EB, NB and SB approaches were approximately the same.

5.2 SCENARIO 2: UNEQUAL DIRECTIONAL DISTRIBUTION OF TRAFFIC VOLUME INCREASE (S4-2)

In this simulation scenario (S4-2) the WB approach traffic volume increase was distributed as follows: RT – 30 percent, through – 30 percent, and LT – 40 percent. Car1 proportion was kept at 10 percent. The delay, queue length, and travel time data plots are presented in Figures 81 – 86, Figures 87 – 92, and Figures 93 – 98 respectively.

Delay Plots and Discussions for S4-2

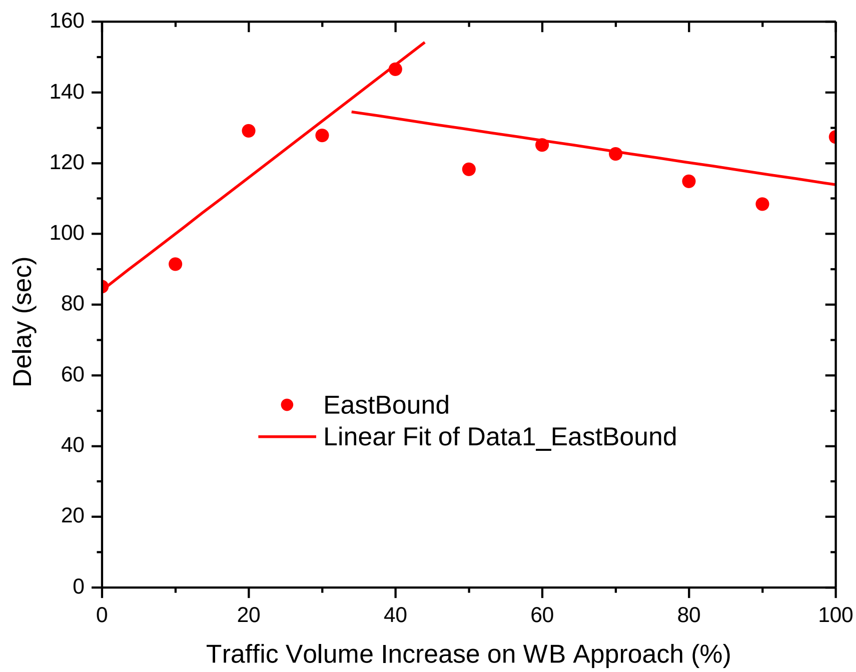

Figure 81 Change of Delay with Traffic Volume Increase on WB Approach – S4-2 (EB)

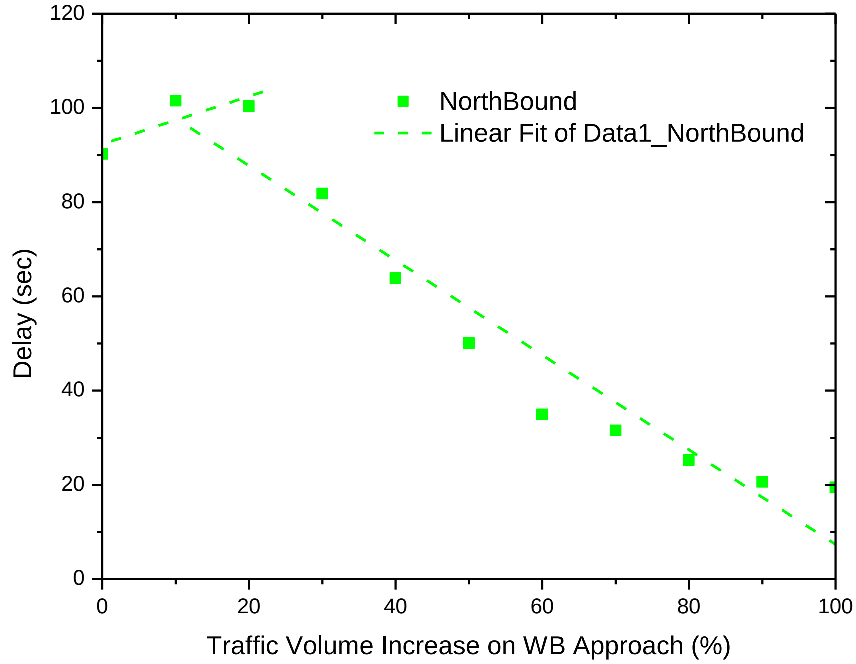

Figure 82 Change of Delay with Traffic Volume Increase on WB Approach – S4-2 (NB)

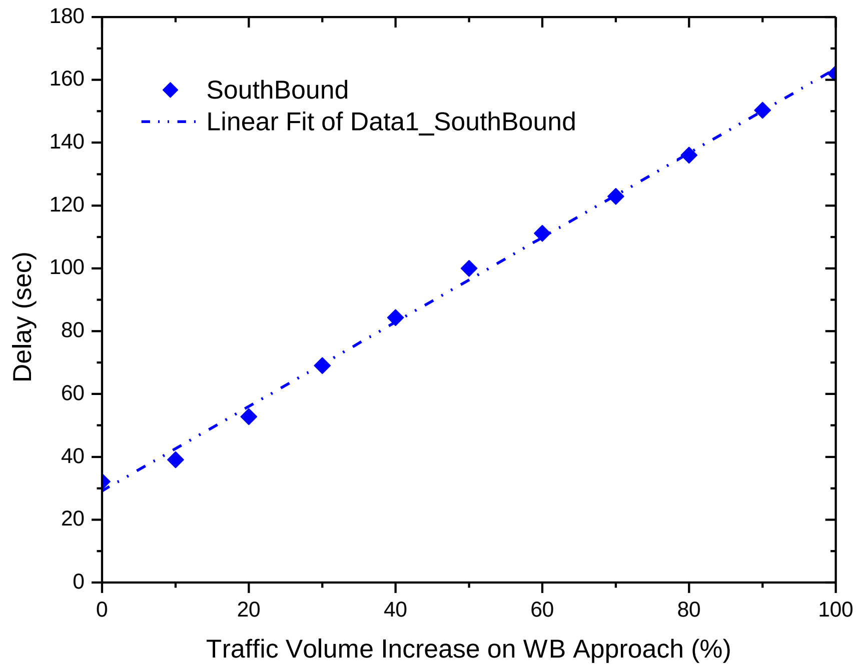

Figure 83 Change of Delay with Traffic Volume Increase on WB Approach – S4-2 (SB)

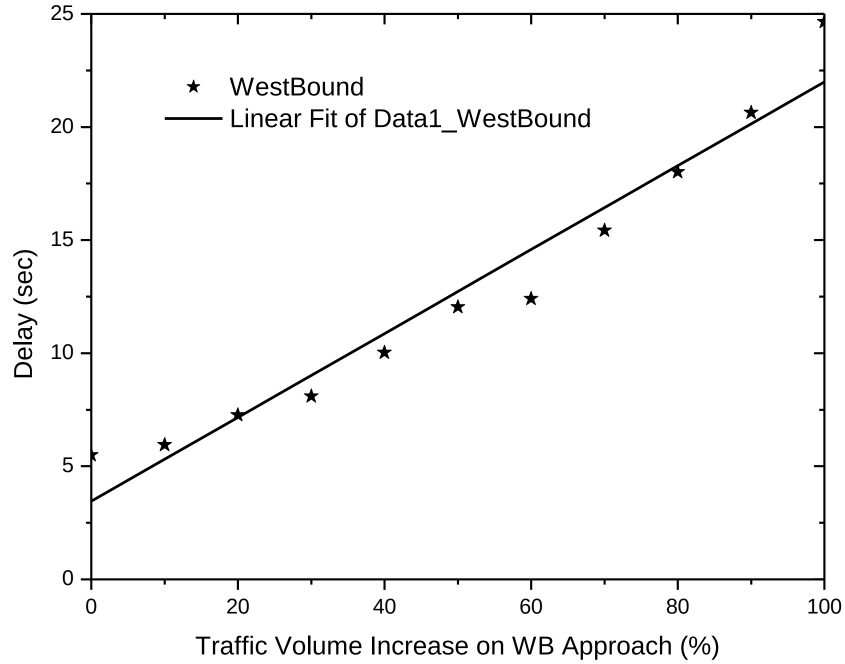

Figure 84 Change of Delay with Traffic Volume Increase on WB Approach – S4-2 (WB)

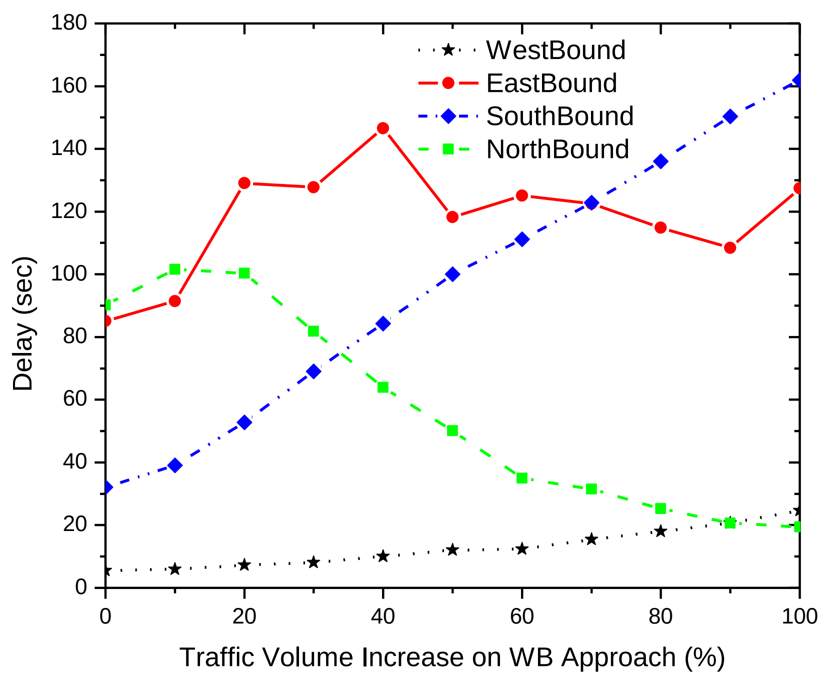

Figure 85 Change of Delay with Traffic Volume Increase on WB Approach – S4-2 (EB, NB, SB and WB)

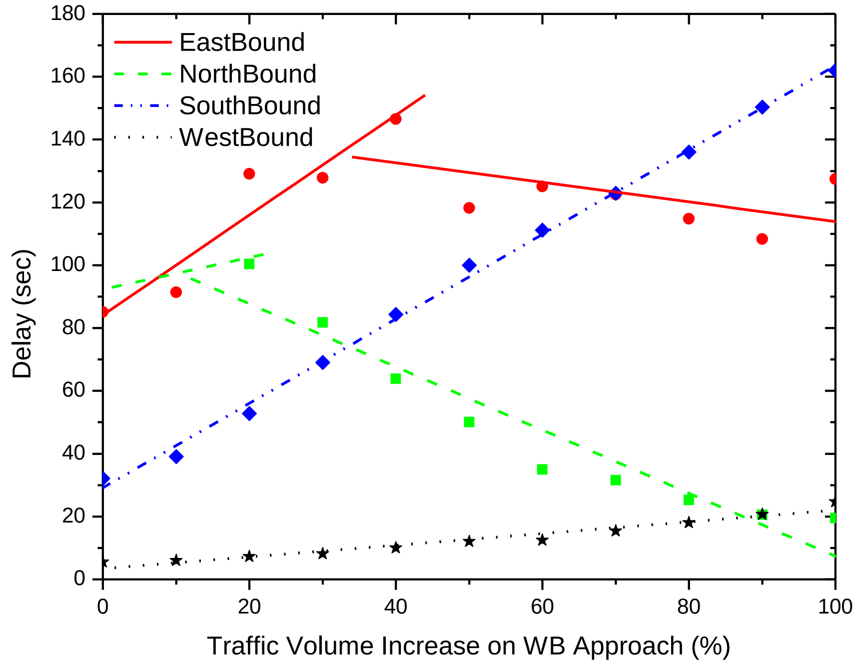

Figure 86 Change of Delay with Traffic Volume Increase on WB Approach – S4-2 (EB, NB, SB and WB)

Delay on the EB (Figure 79) and NB (Figure 80) approaches showed initial delay increases followed by reductions with traffic volume increase on the WB approach. The initial delay increases observed are due to the traffic volume increase from the WB approach that resulted in conflict increase as the circulatory traffic increased. With further increase in LT and through traffic from the WB approach, the SB approach experienced more conflicts which resulted in more gaps becoming available to the EB and NB approaches and therefore a reduction in delay.

The two curves were similar to those obtained for S4-1 simulations except that the rates of change varied. However with this scenario, the LT traffic from the WB was higher therefore the SB and EB approaches experienced more delays and the rates of delay increase and decrease were higher. The higher LT traffic increase resulted in the NB approach delay reduction commencing at a 10 percent increase in WB approach traffic.

The delay on the SB (Figure 81) and WB (Figure 82) approaches showed continual delay increment as in the case of S4-1, but the rates of increment were higher. Figures 83 and 84 show the data plots of delay against traffic volume increase on the WB approach for the four approaches.

Queue Length Plots and Discussions

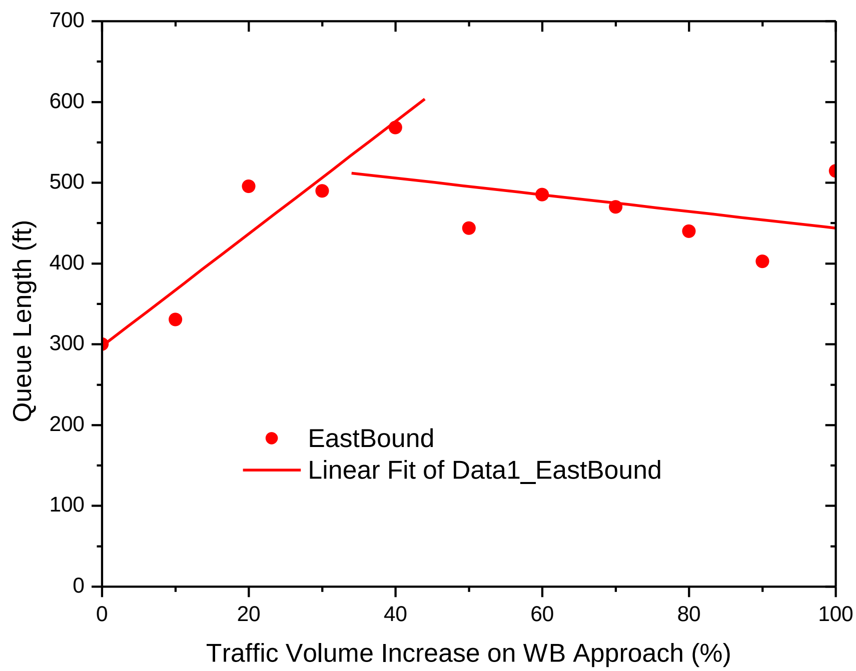

Figure 87 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-2 (EB)

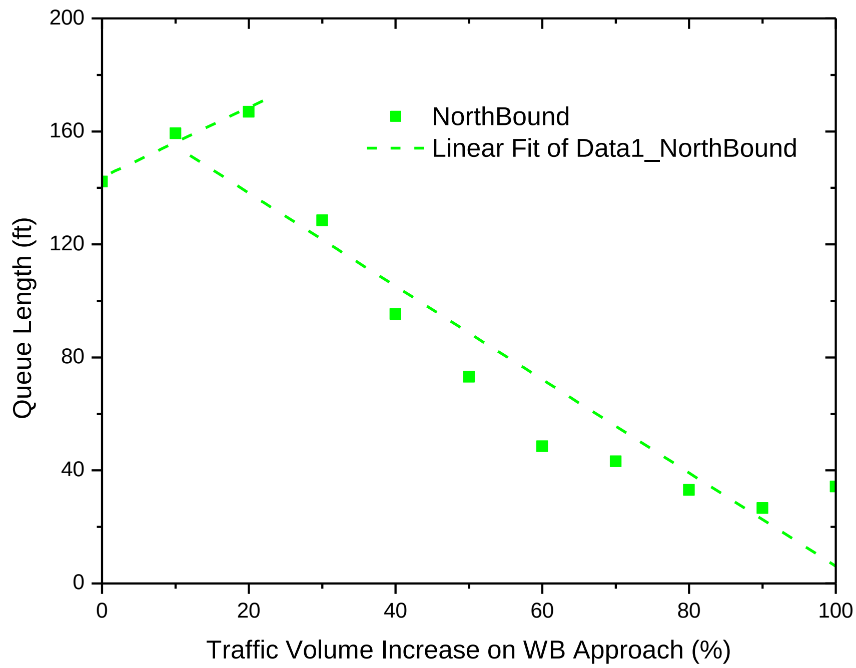

Figure 88 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-2 (NB)

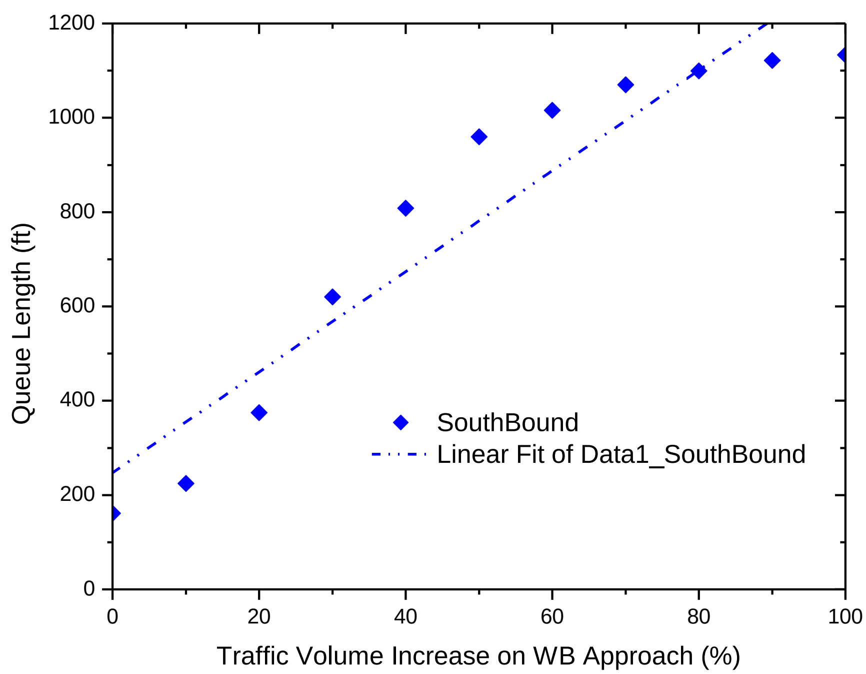

Figure 89 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-2 (SB)

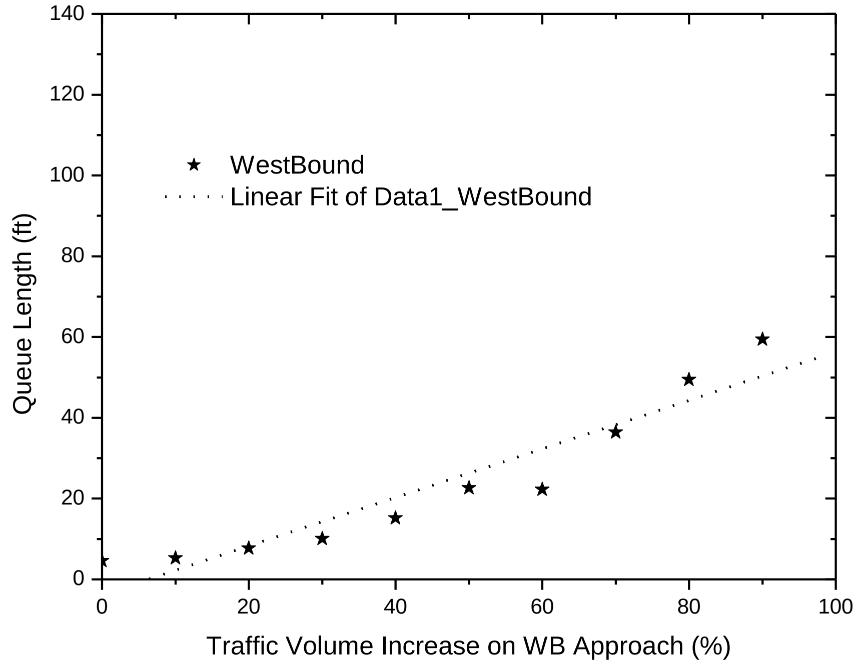

Figure 90 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-2 (WB)

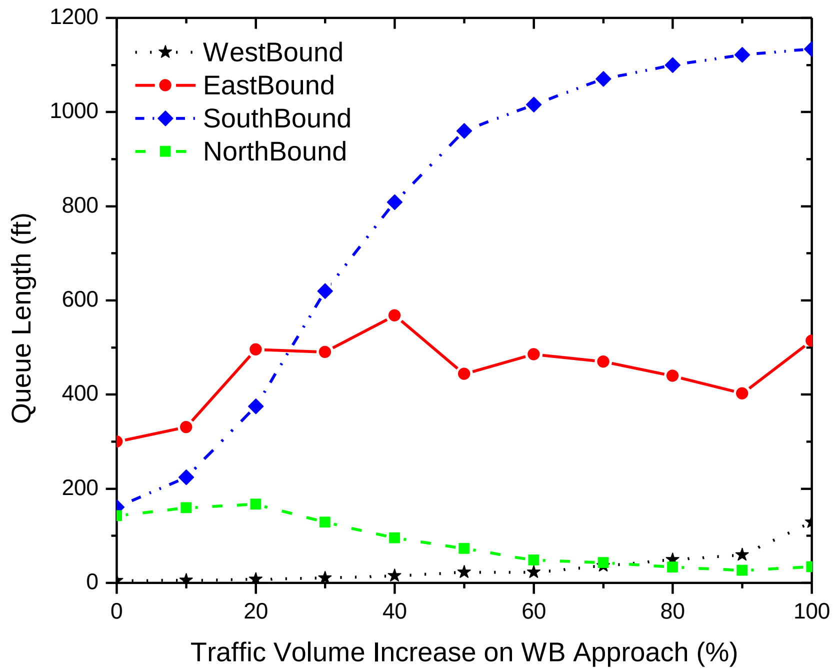

Figure 91 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-2 (EB, NB, SB and WB)

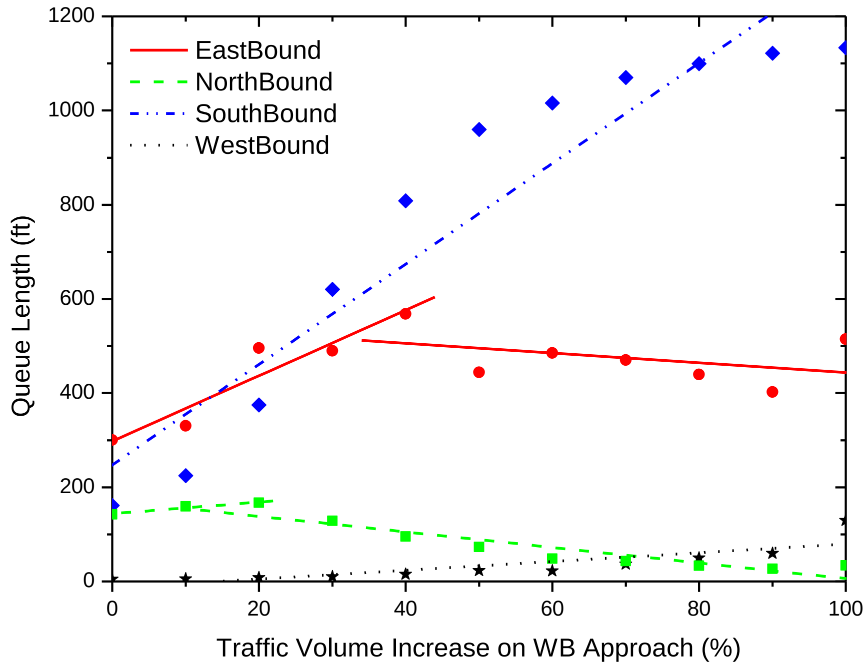

Figure 92 Change of Queue Length with Traffic Volume Increase on WB Approach – S4-2 (EB, NB, SB and WB)

The queue lengths on the EB (Figure 87) and NB (Figure 88) approaches showed initial increases followed by reductions as traffic volume increased on the WB approach. The initial increase was due to increased traffic volume from the WB approach that resulted in an increased conflicting traffic directly in front of the SB, EB, and NB approaches. With further increase in LT and through traffic volume from the WB approach, vehicles on the SB approach experienced more frequent conflicts which created increased merging opportunities for vehicles on the NB and EB approaches. This situation resulted in queue length reductions on the NB and EB approaches. The queue length reduction commenced earlier on the NB approach because the EB approach was also affected by the LT traffic from the WB approach. The reduction on the EB approach commenced when the SB approach experienced substantial increase in conflicts from the WB approach traffic.

The queue lengths on the SB (Figures 89) and WB (Figure 90) approaches showed continued increase as the traffic volume on the WB approach increased. This was due to the approaches being conflicted by increasing circulatory lane traffic which hitherto was low.

Figures 91 and 92 showed the data plots of queue length against WB approach traffic volume increase on all four approaches. It can also be seen that the queue length increase on the SB approach was very rapid which was due to the high traffic volume on that approach.

Travel Time Plots and Discussions for S4-2

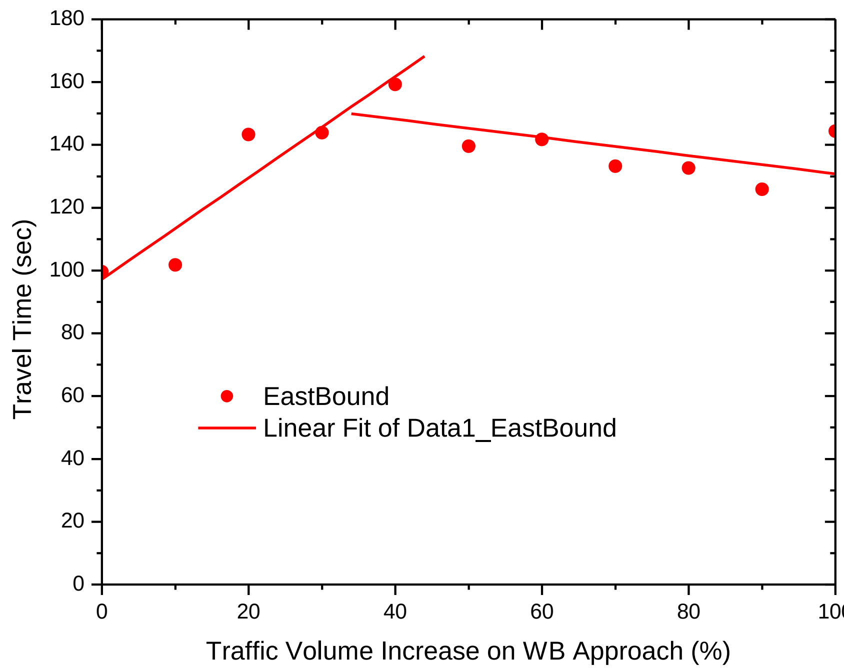

Figure 93 Change of Travel Time with Traffic Volume Increase on WB Approach – S4-2 (EB)

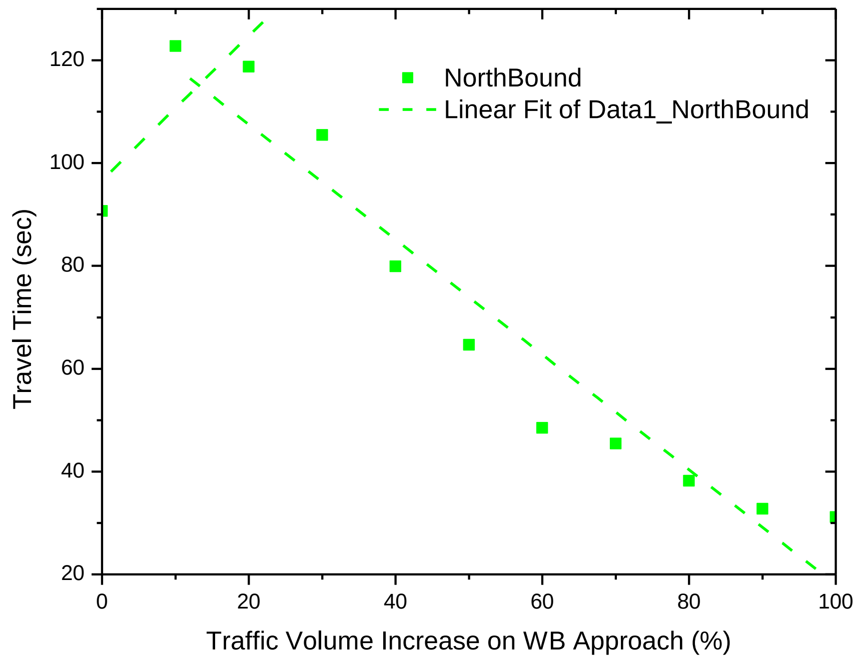

Figure 94 Change of Travel Time with Traffic Volume Increase on WB Approach – S4-2 (NB)

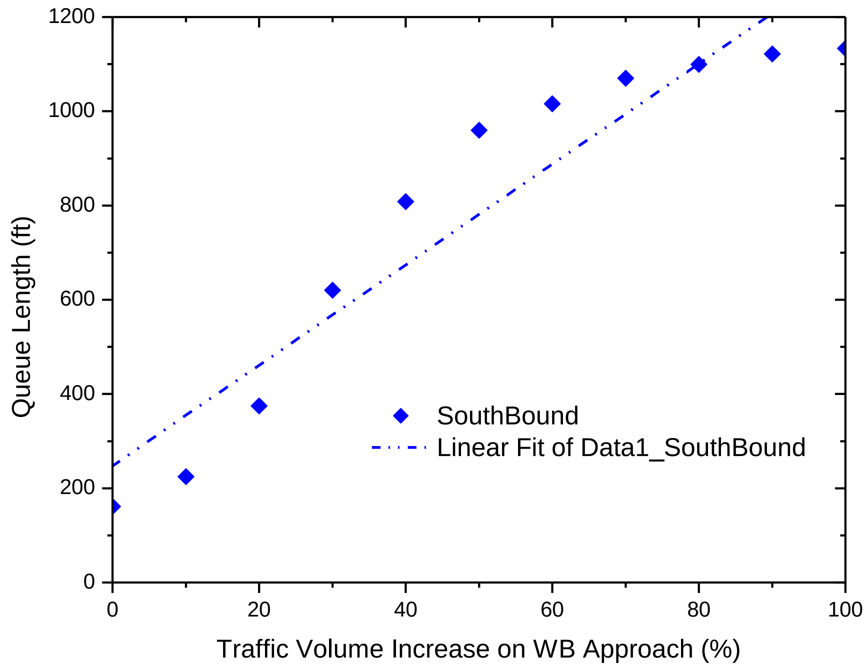

Figure 95 Change of Travel Time with Traffic Volume Increase on WB Approach – S4-2 (SB)

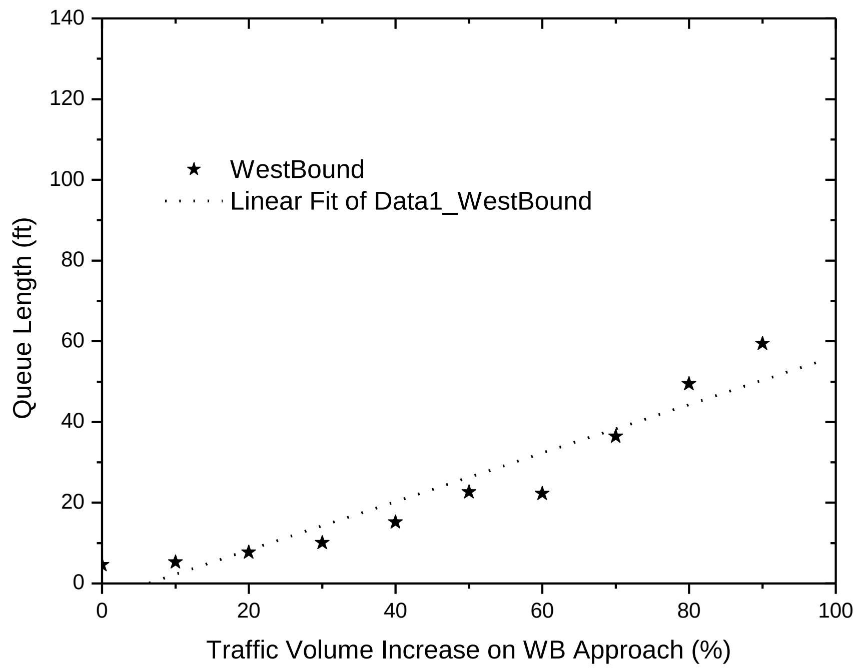

Figure 96 Change of Travel Time with Traffic Volume Increase on WB Approach – S4-2 (WB)

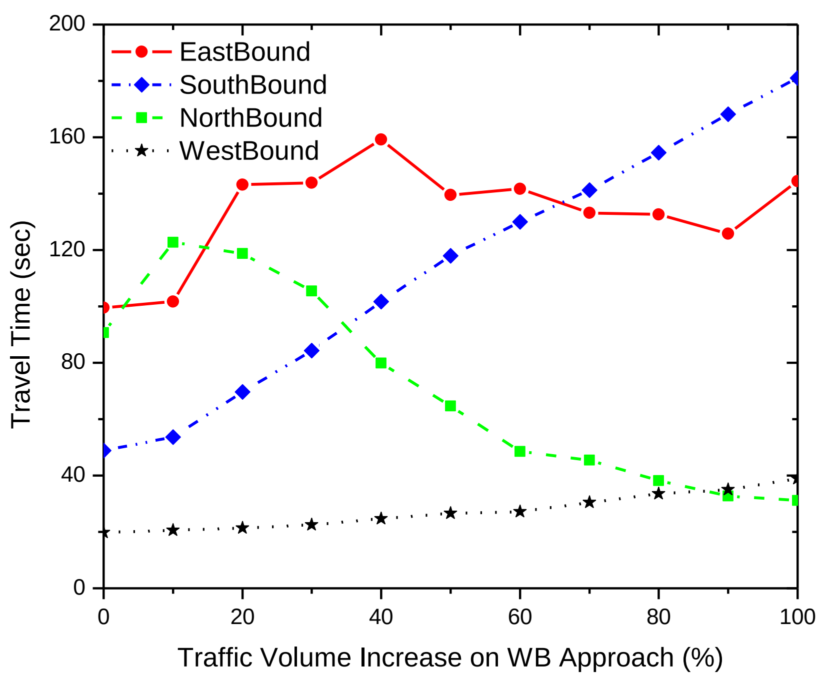

Figure 97 Change of Travel Time with Traffic Volume Increase on WB Approach – S4-2 (EB, NB, SB and WB)

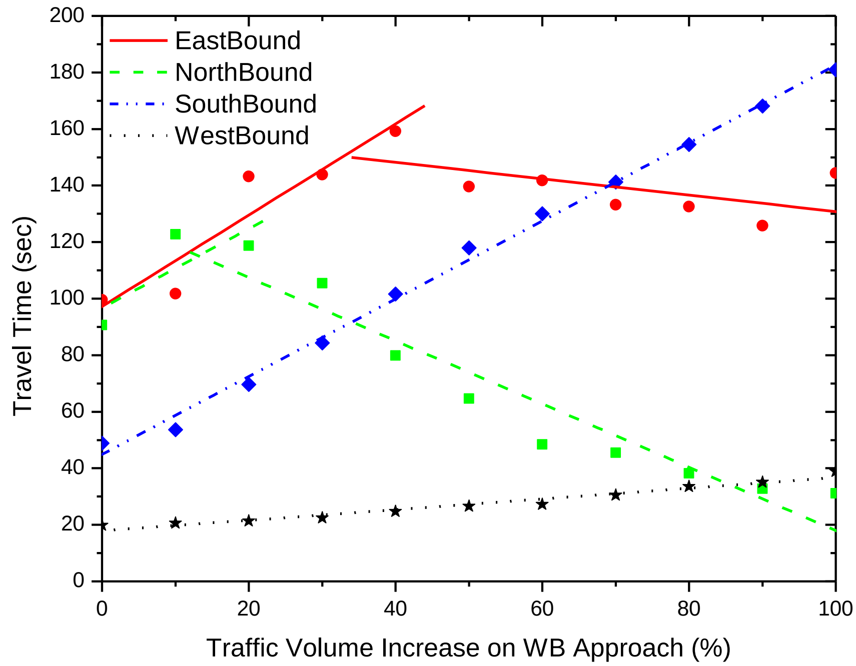

Figure 98 Change of Travel Time with Traffic Volume Increase on WB Approach – S4-2 (EB, NB, SB and WB)

The travel time along the EB (Figure 93) and NB (Figure 94) approaches showed initial increases followed by reductions as the WB approach traffic volume increased. The travel times followed a similar pattern as observed for the delays. The initial increase can be explained by the increased left-turn and through traffic from the WB approach which resulted in an increased conflict with the SB, EB and NB approaches. With further increase in the left-turn and through traffic from the WB approach, the SB approach experienced increased conflicts therefore creating more merging opportunities for the EB and NB approaches downstream which resulted in the travel time reduction. The travel time reduction on the EB approach did not begin until the circulatory traffic causing conflicts with the SB approach increased substantially. This was because the EB approach was also conflicted by the left-turn traffic from the WB approach.

The travel time for the SB (Figure 95) and WB (Figure 96) approaches showed continued increase with increase in WB approach traffic. This was due to the increased conflict with circulatory lane traffic due to the increasing LT and through traffic from the WB approach.

Figures 97 and 98 showed travel time data plotted against traffic increase on the WB approach for all four approaches. It can be seen that whereas the NB approach experienced rapid reduction in travel time the SB approach experience rapid increase in travel time. This was due to the SB approach experiencing more conflicts and therefore creating greater merge opportunities for the NB approach as a result of the increased LT and through traffic volumes from the WB approach.

5.3 SUMMARY

This chapter examined the sensitivity of the model to changes in traffic volume from a single approach. From the two types of traffic volume sensitivity analyses carried out, it was revealed that the four approaches responded differently to any increase in volume from a single approach. Two approaches showed an initial increase in measured MOE followed by reductions while the other two approaches showed continuous increase in measured MOE. It was also observed that, the directional distribution of the traffic volume did have an effect on the performance of the approaches.

6 CHAPTER SIX - MULTI-CRITERIA ANALYSIS TOOL

Multi-criteria decision analysis is recognized for its ability to take into consideration the critical criteria necessary for real-world competing decisions when deciding between competing alternatives. Competing criteria are usually considered concurrently and often decision makers can be overwhelmed because of the volume of information to be processed. Using a multi-criteria analysis approach allows the selection of the most appropriate solution in a consistent manner devoid of obvious biases. This is because MCDA methods have rigorous inherent comparison systems that allow fairness. MCDAs have found several uses in roadway decision making but in the field of traffic engineering, the application is limited (*114*). Most applications of MCDA to traffic engineering are still in the developmental stages (*115*) and it is hoped that with further research advancement, the principles will find practical applications.

This chapter describes the MCDA approach used to develop the framework for roundabout comparison to other intersection controls (TWSC, AWSC and signal) when medium volumes and long delays/ queues are estimated. The objective here was that with capacity, delay and queue accurately estimated roundabouts might be preferable to signals for borderline cases.

6.1 METHODOLOGY FOR DEVELOPING THE MCDA

Clearly no single MCDA method can satisfactorily evaluate all the complex aspects of any given traffic alternatives. The Analytical Hierarchy Process (AHP) was used to develop the evaluation model for comparing roundabouts to the other controls. The AHP was chosen because of its pair-wise comparison between criteria and options. It is also well established and widely applied, making it easier to be followed and adjusted by decision makers whenever necessary. Four levels of processes were completed to develop a good comparison between roundabout, signal, AWSC and TWSC for a final decision. The processes are listed below as:

1. Clear definition of the problem and identification of criteria
2. Definition of the criteria and sub-criteria decision matrices
3. Scores and weights assignments to the criteria and sub-criteria, and
4. Combination of the weights and scores to obtain a global score for ranking the alternatives

The AHP method considers the pair-wise comparisons adequately consistent if the CR is less than 10 percent (*116*). To compute the CR, the CI is first estimated. This was done by adding the columns in the matrix and multiplying the resulting vector by the vector of priorities (the approximated eigenvector) obtained earlier. This was approximately the maximum eigenvalue denoted by λ_{max}.

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{32}$$

Where,

λ_{max} = maximum eigenvalue (sum of eigenvalues), and

n = number of factors.

$$CR = CI \times RCI \tag{33}$$

Where,

RCI = Random Consistency index and given in Table 7

Table 7 RCI Values for Different Values of n

n	RCI
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45

The flowchart for the four process levels is presented in Figure 97 and the scale for the determination of relative importance for criteria and sub-criteria comparison is shown in Table 8 (*117*).

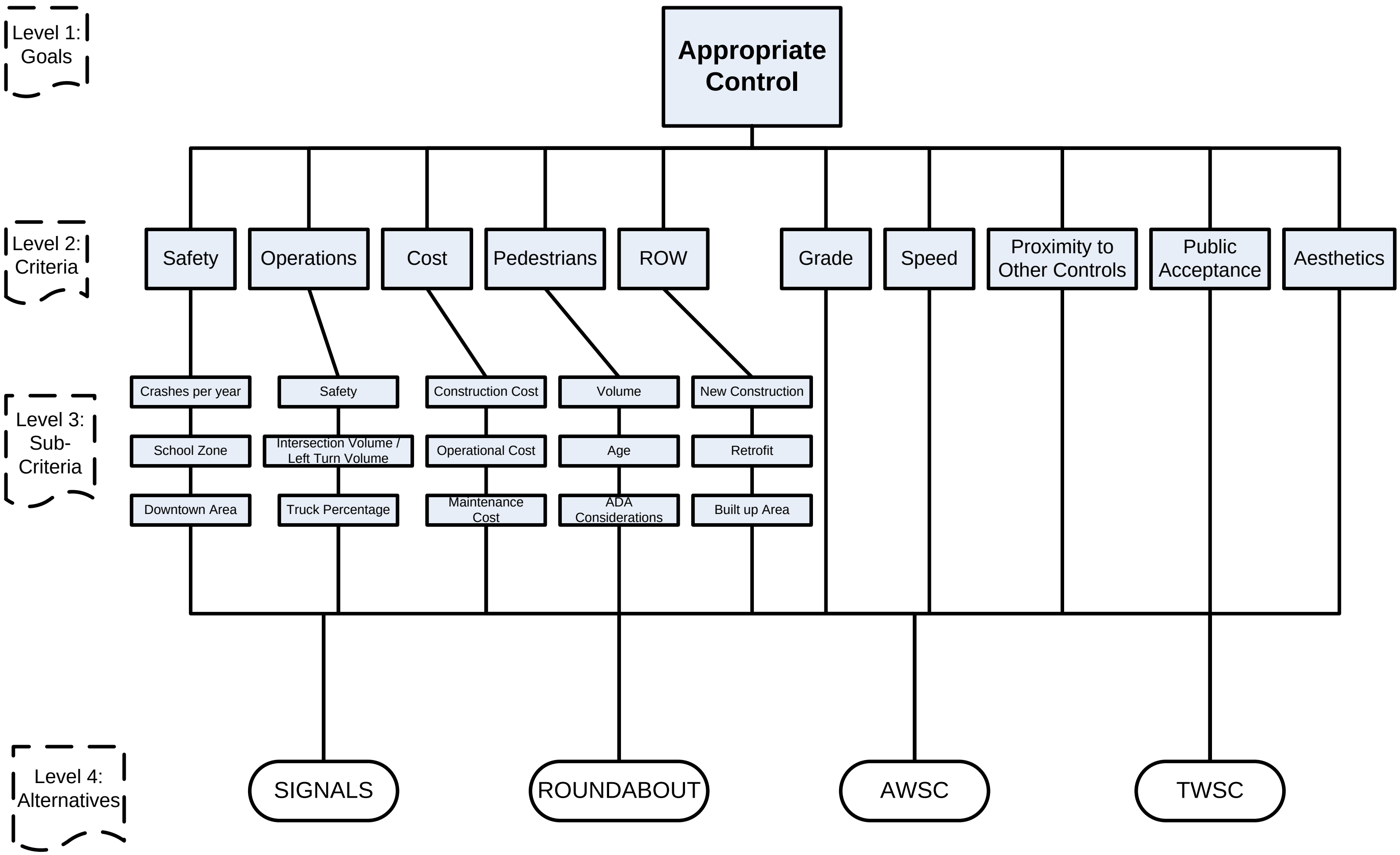

Figure 99 Hierarchy Structure for AHP Development

Table 8 Fundamental Scale for Pair-wise Comparison (after Saaty)

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate Importance	Experince and judgement slightly favor one activity over another
4	Moderate plus	
5	Strong Importance	Experince and judgement slightly favor one activity over another
6	Strong plus	
7	Very Strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very Very Strong	
9	Extreme Importance	The evidence favoring one acitivity over another is os the highest possible order of affirmation
Reciprocal of Above	If Activity I has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	
1.1-1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities, the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

6.1.1 Identification of criteria

The factors for selection of the optimal control were obtained from an extensive literature review and a survey conducted using select engineers who were known to have experience with roundabouts at the Nevada Department of Transportation (NDOT). The

Survey involved asking specific questions about the factors to be considered and ranking the degree of importance. Safety, delay, capacity and pedestrian related issues were the highest ranking. In total, ten factors were identified as being critical to the decision making. The factors are safety, operations, cost, pedestrians, right-of-way, grade, speed, "proximity to other controls", public-acceptance and aesthetics. Safety, operations, cost, pedestrians, and right-of-way had sub criteria which were used to decide their ranking.

6.1.2 Sub Matrices

Using the AHP method, ten criteria matrices and five sub criteria matrices were generated for determining the overall performance of the alternatives. The five sub-criteria matrices are shown in Table 9-13. The consistency indices (CI) and consistency ratios (CR) were also computed for each criteria and sub criteria. Table 14 shows the comparison matrix for the main criteria.

Table 9 Sub-Criteria Matrix for Safety

Safety					
	Crashes per year	School Zone	Downtown Area		
Crashes per year	1	0.5	2	1.000	0.311
School Zone	2	1	2	1.587	0.493
Downtown Area	0.5	0.5	1	0.630	0.196
	3.5	2	5	3.217	1.000
	1.088	0.987	0.979		
	Lamda	CI	CR		
	3.054	0.027	0.046		

Table 10 Sub-Criteria Matrix for Operations

Operation					
	Safety	Intersection Volume/ left	Truck Percentage		
Safety	1	2	4	2.000	0.571
Intersection Volume/ Left	0.5	1	2	1.000	0.286
Truck Percentage	0.25	0.5	1	0.500	0.143
	1.75	3.5	7	3.500	1.000
	1	1	1		
	Lamda	CI	CR		
	3.000	0.000	0.000		

Table 11 Sub-Criteria Matrix for Cost

Cost					
	Construction Cost	Operational Cost	Maintenace Cost		
Construction Cost	1	3	2	1.817	0.550
Operational Cost	0.333	1	1	0.693	0.210
Maintenance Cost	0.5	1	1	0.794	0.240
	1.833	5	4	3.304	1.000
	1.008	1.049	0.961		
	Lamda	CI	CR		
	3.018	0.009	0.016		

Table 12 Sub-Criteria Matrix for Pedestrians

Pedestrian					
	Volume	Age	ADA		
Volume	1	4	1	1.587	0.474
Age	0.25	1	0.5	0.500	0.149
ADA	1	2	1	1.260	0.376
	2.25	7	2.5	3.347	1.000
	1.067	1.046	0.941		
	Lamda	CI	CR		
	3.054	0.027	0.046		

Table 13 Sub-Criteria Matrix for Right-of-Way

Right-of-Way					
	New Construction	Retrofit	Built-up Area		
New Construction	1	0.5	0.3	0.500	0.143
Retrofit	2	1	0.5	1.000	0.286
Built-up Area	4	2	1	2.000	0.571
	7	3.5	1.75	3.500	1.000
	1	1	1		
	Lamda	CI	CR		
	3.000	0.000	0.000		

Table 14 Main Criteria Matrix

	Safety	Operations	Cost	Pedestrians	Right-of-Way	Grade	Speed	Proximity to other controls	Public Acceptance	Aesthetics		
Safety	1	1	3	1	4	5	5	2	2	4	2.885	0.246
Operations	1	1	3	1	3	3	4	2	2	4	2.539	0.216
Cost	0.33	0.33	1	0.5	1	2	3	2	1	1	0.951	0.081
Pedestrians	1	1	2	1	0.5	0.5	0.5	0.5	0.5	0.5	0.648	0.055
Right-of-Way	0.25	0.33	1	2	1	0.5	2	1	0.5	2	0.799	0.068
Grade	0.2	0.33	0.5	2	2	1	0.5	0.5	0.5	1	0.599	0.051
Speed	0.2	0.25	0.33	2	0.5	2	1	0.5	0.5	1	0.550	0.047
Proximity to other controls	0.5	0.5	0.5	2	1	2	2	1	2	2	1.189	0.101
Public Acceptance	0.5	0.5	1	2	2	2	0.5	0.5	1	3	1.052	0.090
Aesthetics	0.25	0.25	1	2	0.5	1	0.5	0.5	0.33	1	0.518	0.044
											11.731	1.000

The number shown to the far right of Tables 9 – 14 are the geometric mean of each row. Meaning the numbers are multiplied by each other and the n^{th} root is taken before the numbers are normalized by dividing them with the sum (eigenvector) where n is the number of elements in the row.

6.1.3 Assignment of Weights and Scores

For this AHP, each factor in the criteria or sub criteria was scored using a value between 0 – 10 (117). The score represented the level of preference for the control type. A score of 10 suggested a strong preference. Weights were assigned to each factor to help estimate their relative importance for the main matrix or sub matrices levels. The survey conducted with the traffic engineers was a good guide which was used with information from literature to assign weights to each factor. It must be noted that from the survey carried out, various engineers placed different emphasis on the levels of importance of the individual factors. However, the core factors (safety, operations, cost and ROW) were in almost all cases agreed on as ranking highest in deciding the appropriate controls.

6.1.4 Overall Performance

The synthesis stage was performed after the alternatives had been compared with each other with reference to each decision criteria and the individual priority vectors derived. The columns of the decision matrix represent the priority vectors. The pair-wise comparison approach is used to determine the weights of importance for the criteria. The final priorities of the alternatives are derived using equation 34 and are given as:

$$A_{AHP}^{i} = \sum_{j=1}^{N} a_{ij} w_j \text{ , } for\ i = 1,2,3,, \ldots .M. \tag{34}$$

Where,

A^{i}_{AHP} = final priority,

a_{ij} = performance value of the i^{th} alternative (A_i) in terms of the j^{th} criterion (C_j), and

w_j = weight for criterion $C_{j.}$

The overall performances of the four alternatives were obtained by the matrix given in Table 15 Parts A, B and C. (Table 15 was split in three parts because of the length):

Table 15 Overall Synthesis Matrix (Part A)

Roundabouts

	Safety			Operations		
		0.246			0.216	
	Crashes per year	School Zone	Downtown Area	Safety	Intersection Volume/ left Turn Volume	Truck Percentage
	0.311	0.493	0.196	0.571	0.286	0.143
Signals	0.303	0.303	0.303	0.232	0.232	0.232
AWSC	0.259	0.259	0.259	0.229	0.229	0.229
TWSC	0.208	0.208	0.208	0.207	0.207	0.207
Roundabouts	0.230	0.230	0.230	0.332	0.332	0.332

Overall Synthesis Matrix (Part B)

Cost			Pedestrians			Right-of-Way		
	0.081			0.055			0.068	
Construction Cost	Operational Cost	Maintenace Cost	Volume	Age	ADA	New Construction	Retrofit	Built-up Area
0.550	0.210	0.240	0.474	0.149	0.376	0.143	0.286	0.571
0.155	0.113	0.091	0.319	0.319	0.319	0.324	0.324	0.324
0.296	0.284	0.273	0.190	0.190	0.190	0.246	0.246	0.246
0.296	0.284	0.273	0.190	0.190	0.190	0.229	0.229	0.229
0.253	0.319	0.364	0.301	0.301	0.301	0.201	0.201	0.201

Overall Synthesis Matrix (Part C)

Grade	Speed	Proximity to other controls	Public Acceptance	Aesthetics		
0.051	0.047	0.101	0.090	0.044		
0.051	0.047	0.101	0.090	0.044		
0.143	0.141	0.317	0.250	0.266		0.255
0.286	0.237	0.183	0.250	0.220		0.24
0.286	0.262	0.183	0.250	0.208		0.222
0.286	0.360	0.317	0.250	0.306		0.282

6.2 SUMMARY

This chapter described the process of using the AHP method to develop a tool for comparing roundabouts to other intersections based on determined factors that are used for selection and installation of intersection controls. The use of this AHP tool greatly eliminates bias that might be introduced especially when the performance of roundabouts are accurately estimated. A major advantage of this tool is the ease with which it can be modified depending on the needs of an agency. The weights and scores can also be adjusted to reflect new inputs from the decision making body.

7 CHAPTER SEVEN - SUMMARY AND CONCLUSIONS

7.1 SUMMARY OF FINDINGS

From the research carried out, it can be deduced that priority reversal frequently occurs at roundabouts when they are operating at high traffic volumes. This phenomenon has a significant influence on the performance criteria measured at roundabouts. Therefore, it must be taken into consideration during analyses of locations with high traffic volumes. From the single-lane roundabout simulation studies conducted, the following findings were concluded regarding the effects of priority reversal on the performance of roundabouts:

1. An average of 10 percent of vehicles was determined to cause priority reversal when traffic volumes were at saturation.
2. There was a reduction in delay, queue length, and travel time with an increase in periods of priority reversal. All three performance measures followed an exponential decay curve with R^2 of over 0.90.
3. Approach lane delays were reduced between 8-16 percent for every 10 percent increase in reversed priority periods.
4. Approach lane queue lengths were shortened between 10-20 percent for every 10 percent increase in reversed priority periods.
5. Speed of vehicles causing priority reversal had insignificant effects on the delay, queue length, and travel time measured.

6. Increased periods of reversed priority occurrences resulted in a general reduction in delay, queue length, and travel time at the approaches lanes.
7. The size of the inscribed circle diameter affected the operations of roundabouts. The bigger the diameter, the lesser the delay, queue length, and travel time.
8. There was a bigger reduction in performance measures at roundabouts with a smaller inscribed diameter than those with larger inscribed diameters, though the percentage reductions were comparable.
9. As the percentage of vehicles causing priority reversal increased, the influence of the size of the inscribed diameter reduced.
10. With a good estimate of the percentage of reversed priority periods, a more accurate performance of roundabouts can be estimated from the performance reduction curves. From the simulation results, the highest performance reductions occurred between 0-30 percent periods of reversed priority.
11. There was a reduction in the delay and travel time measured on the circulatory lane during higher periods of priority reversals. However, the changes were insignificant and should not adversely affect the operation of the roundabout.
12. Sensitivity analyses revealed that the four approaches responded differently to any increase in volume from a single approach. It was also observed that the directional distribution in traffic increase had significant effects on the performance of the approaches.

13. AHP has a good potential for assisting in the selection process of roundabouts based on a sound comparison analyses to other controls devoid of biases.

7.2 CONTRIBUTION TO KNOWLEDGE

Roundabouts have been identified as an important intersection control in the U.S. A reliable estimation of roundabout performance at high traffic locations will greatly promote roundabout applications. A comprehensive selection process that allows a fair comparison between roundabouts and established controls like signals will be useful in situations of marginal preferences.

Priority reversal is a very important phenomenon that affects the performance of roundabouts when operating at high volumes. However, the impact of this phenomenon has not been factored into the current 2010 HCM performance models. The opportunity to study the phenomenon by use of empirical data is not readily available in the United States. This is because most roundabouts are located at low to medium traffic volume areas, but priority reversal usually occurs at roundabouts operating at or near saturation. In this research however, a single-lane roundabout with high traffic volume and occurrence of priority reversal was identified. Using the data extracted and the geometric information, a micro-simulation model was developed and four scenarios were investigated. The information gathered from the simulation led to the following contributions to knowledge:

1. Priority reversal occurs at roundabouts in the U.S. An estimated 10 percent of vehicles were measured as causing priority reversal when operations are near saturation. This was determined from field data.
2. Priority reversal resulted in significant performance improvement on the approach lanes of a roundabout. Delay, queue length, and travel times were all reduced and was proportional to the percentage of priority reversal occurring.
3. Priority reversal has minimal effect on the circulatory lane operations at roundabouts. There was approximately a one second delay increase for the range of priority reversal investigated.
4. Multi-criteria decision analysis has a potential for developing a comprehensive tool for the selection of appropriate intersection control as demonstrated using the AHP for comparing roundabouts, signals, TWSC and AWSC. This process was very efficient and easy to adjust in the presence of additional information relating to the criteria used.

7.3 RECOMMENDED FUTURE RESEARCH

Although this research made a good study of priority reversal at roundabouts, during the analyses, several potential future studies were identified. Two of the suggested areas for future studies are:

1. This research was carried out using field data from one single-lane roundabout. From the general statistical view point, it will be useful to identify additional roundabouts across United States to verify the

observations reported here. The results will help appropriately adjust the delay and queue length models presented in the HCM to accommodate roundabouts that operate at high traffic volumes during the peak periods.

2. The phenomenon was studied for a single-lane roundabout. It will be beneficial to observe what occurs at double-lane and multi-lane roundabouts in order to verify or alter the findings from a single-lane roundabout.

REFERENCES

1 Vlahos, E., Polus, A., Lacombe, D., Ranjitkar, P., Faghri, A., Fortunato, B. R. (2008), Evaluating the Conversion of All-Way Stop-Controlled Intersections into Roundabout, Transportation Research Record, Journal of the Transportation Research Board, 2078(-1), 80-89, 2008

2 Elvik, R., Effects on road safety of converting intersections to roundabouts: review of evidence from non-US studies, Transportation Research Record: journal of the Transportation research Board, 1847(-1), 1-10, 2003

3 Brilon, W., Vandehey, M., Roundabouts-The State of The Art in Germany, ITE Journal, 68(11), 1998

4 Pokorný, P., Cost-Benefit Analysis for the Implementation of Four-arm Roundabouts in Urban Areas, Transactions on Transport Sciences, 4-1, 25-30, 2011

5 Persaud, B. N., Retting, R. A., Garder, P. E., Lord, D., Safety Effect of Roundabout Conversions in the United States: Empirical Bayes Observational Before-After Study, Transportation Research Record: Journal of the Transportation Research Board, 1751(-1), 1-8, 2001

6 Persaud, B.N, Retting, R.A., Garder, P.E., Lord, D., Crash Reductions Following Installation of Roundabouts in the United States, Insurance Institute for Highway Safety, 2001

7 Hoglund, P.G., Case Study: Performance Effects of Changing a Traffic Signal Intersection to Roundabout, In Intersections without Traffic Signals, Springer-Verlag, Berlin, 1991

8 Jacquemart, G., Synthesis of Highway Practice 264: Modern Roundabout Practice in the United States, National Cooperative Highway Research Program, National Academy Press, Washington, D.C., 1998

9 Rodegerdts, L., Bansen, J., Tiesler, C., Knudsen, J., Myers, E., Johnson, M., Persaud, B., Lyon, C., Hallmark, S., Isebrands, H., Crown, R., Guichet, B, O'Brien, A., "Roundabouts: An informational guide Second Edition", NCHRP Report 672.Transportation Research Board, Washington D.C., 2010

10 Robinson, B W., Rodegerdts, L., Scarbrough, W., Kittelson, W., Troutbeck, R., Brilon, W., Bondzio, L., Courage, K., Kyte, M., Mason, J., Flannery, A., Myers, E., Bunker, J., and Jacquemart, G., "Roundabouts: An Informational Guide", Report No. FHWA-RD-00-067, Washington, DC: USDOT, FHWA, June 2000

11 Rodegerdts, L., Blogg, M., Wemple, E., Myers, E, Kyte, M., Dixon, M., List, G., Flannery, A., Troutbeck, R., Brilon, B., Wu, N., Persaud, B., Lyon, C., Harkey, D., Carter, D., Roundabouts in the United States, NCHRP Report 572, Transportation Research Board, 2007 .

12 TRB, Highway Capacity Manual, Transportation Research Board, National Research Council, Washington DC, in corporation with the U.S. Department of Transportation, Federal Highway Administration, 2010

13 Troutbeck, R. J., and Kako, S. Limited Priority Merge at Unsignalized Intersections, Transportation Research Part A: Policy and Practice, 33(3), 291-304, 1999

14 Troutbeck, R. The performance of Uncontrolled Merges Using a Limited Priority Process, Transportation and Traffic Theory in the 21st Century, Proceedings of the 15th International Symposium on Transportation and Traffic Theory, 2002

15 Kimber, R.M., The Traffic Capacity of Roundabouts, Transport and Road Research Laboratory Report LR942, 1980

16 Tian, Z.Z., Troutbeck, R., Kyte, M., Brilon, W., Vandehey, M., Kettelson, W., Robinson, B., A Further Investigation on Critical Gap and Follow-up Time, Proceedings of the 4th International Symposium on Highway Capacity, Maui/Hawaii, Transportation Research Circular E-C018, 2000

17 Brilon, W, Koenig, R., and Troutbeck, J., Useful Estimation Procedures for Critical Gaps. Transportation Research Part A: Policy and Practice 33.3, pp 161-186, 1999

18 Horman, C.H, and Turnbull, H.H., Design and Analysis of Roundabouts, Proc. 7th ARRB Conference, 1974, 7(4), pp 58-82

19 Troutbeck, R.J. Does Gap Acceptance Theory Adequately Predict the Capacity of a Roundabout?, Proc. 12 ARRB Conference, 1984, 12(4) pp 62-75

20 Troutbeck, R.J, Kako, S., Limited Priority Merge at Unsignalized Intersections, Transportation Research Part A 33 pp 291-304, 1999

21 Kimber, R.M., Gap Acceptance and Empiricism in Capacity Prediction, Transportation Science Vol 23, No 2 pp 100-111, 1989

22 Troutbeck, R.J., Roundabout Capacity and the Associated Delay, In: Koshii, M. (Ed), Transportation and Traffic Theory-Proceeding of the 11th International Symposium on Transportation and Traffic Theory. Elsevier Science Publishing, New York, PP 39-57

23 Dodgson, J. S., Spackman, M., Pearman, A., and Phillips, L. D., Multi-Criteria Analysis: A Manual. ISBN: 978-1-4098-1023-0, 2009

24 Greco, S. (Ed.), Multiple Criteria Decision Analysis: State-of-the-Art Surveys, Vol. 78, Springer, 2004

25 Saaty, T.L., The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. New York, McGraw-Hill, 1980

26 Semmens M.C., The Capacity of Some Grade-Separated Roundabout Entries, Transport and Road Research Laboratory Supplementary Report 721, 1982

27 VISSIM 5.30 User Manual, PTV Planung Transport Verkehr AG, Stumpfstraße,1

28 Akcelik, R., Evaluating Roundabout Capacity, Level of Service and Performance, Paper presented at ITE 2009 Annual Meeting, San Antonio, Texas, USA, 2009

29 Kennedy, J.V., The UK Standards for Roundabouts and Mini-Roundabouts, National Roundabout Conference, Kansas City, Missouri, 2008

30 Todd, K. “A History of Roundabouts in Britain” Transportation Quarterly, Volume 45, No1, 1991

31 Persaud, B.N, Retting, R.A., Garder, P.E., Lord, D., “Crash Reductions Following Installation of Roundabouts in the United States”, Insurance Institute for Highway Safety

32 Hoglund, P.G., Case Study: Performance Effects of Changing a Traffic Signal Intersection to Roundabout, In Intersections without Traffic Signals, Springer-Verlag, Berlin

33 Giuffre, O., Guerrieri, M., & Grana, A., Evaluating Capacity and Efficiency of Turbo Roundabouts, In Transportation Research Board 88th Annual Meeting, No. 09-2461, 2009

34 Jacquemart, G., 1998, Synthesis of Highway Practice 264: Modern Roundabout Practice in the United States, National Cooperative Highway Research Program, National Academy Press, Washington, D.C.

35 Al-Masaeid, H. R., Capacity and Performance of Roundabouts, Canadian Journal of Civil Engineering, 26(5), 597-605, 1999

36 Kimber, R. M., The Traffic Capacity of Roundabouts, TRRL Laboratory, Report 942, Crowthorne, Berkshire, 1980

37 Brilon, W., (Editor), Intersections Without Traffic Signals, Vol. II, Springer-Verlag, Berlin, 1991

38 Kimber, R. M., & Hollis, E. M., Traffic queues and delays at road junctions, No LR 909 Monograph, 1979

39 Brilon, W., Bondzio, L., Wu, N., Unsignalized Intersections in Germany – A State-Of-the-Art, 2nd International Symposium for Unsignalized Intersections, Portland/Oregon, 1997

40 Brilon, W., Roundabouts: A State-Of-the-Art in Germany, paper presented at the National Roundabout Conference, Vail, Colorado; May, 2005

41 Mauro, R., Calculation of Roundabouts: Problem Definition. In Calculation of Roundabouts, pp 1-13, Springer Berlin Heidelberg, 2010

42 Guichet, B., Roundabouts in France: Development, safety, design, and capacity, In Third International Symposium on Intersections Without Traffic Signals, 1997

43 Troutbeck, R. J., Evaluating the Performance of a Roundabout, No. SR No. 45. 1989

44 Bovy, H., Dietrich, K. and Harmann, A., Guide Suisse des Giratoires, Lausanne, Switzerland, 1991

45 Troutbeck, R. J., and Brilon, W., Unsignalized intersection theory, Traffic Flow Theory, TRB, 1997

46 Xu, F., Tian, Z. Z., Driver behavior and gap acceptance characteristics at roundabouts in California, Transportation Research Record: Journal of the Transportation Research Board, 2071(1), 117-124, 2008.

47 Kearney, J. K., Grechkin, T., Cremer, J., & Plumert, J., Traffic Generation for Studies of Gap Acceptance, In Proc. DSC (pp. 177-186), October 2006.

48 Daganzo, C. F., Estimation of gap acceptance parameters within and across the population from direct roadside observation, Transportation Research Part B: Methodological, 15(1), 1-15, 1981.

49 Cooper, P. J., & Zheng, Y., Turning Gap Acceptance Decision-Making: the Impact of Driver Distraction, Journal of safety research, 33(3), 321-335, 2002.

50 Kettelson W.K. & Vandehey, M.A., Delay Effects on Driver Gap Acceptance Characteristics at Two-Way Stop-Controlled Intersections, Transportation Research Record 1320, TRB, National Research Council, 154-159, 1991.

51 Adebisi, O., & Sama, G. N., Influence of Stopped Delay on Driver Gap Acceptance Behavior, Journal of Transportation Engineering, 115(3), 305-315, 1989.

52 Davis, G. A., & Swenson, T., Field Study of Gap Acceptance by Left-Turning Drivers, Transportation Research Record: Journal of the Transportation Research Board, 1899(1), 71-75, 2004

53 Yan, X., Radwan, E., and Guo, D., Effects of Major-Road Vehicle Speed and Driver Age and Gender on Left-Turn Gap Acceptance, Accident Analysis and Prevention, 39(4), 843-852, 2007

54 Bottom, C. G., & Ashworth, R., Factors Affecting the Variability of Driver Gap Acceptance behavior, Ergonomics, 21(9), 721-734 1978.

55 Ashworth, R., & Bottom, C. G., Some Observations of Driver Gap Acceptance Behavior at a Priority Intersection, Traffic Engineering and Control, 18(12), 569-571, 1977

56 Troutbeck, R. J., Capacity and Design of Traffic Circles in Australia, Transportation Research Record, (1398), 1993

57 Tian, Z., Vandehey, M., Robinson, B. W., Kittelson, W., Kyte, M., Troutbeck, R., and Wu, N., Implementing the Maximum likelihood methodology to measure a driver's critical gap, Transportation Research Part A: Policy and Practice,, 33(3), 187-197, 1999

58 Plank, A. W., and Catchpole E. A., A general capacity formula for an uncontrolled intersection, Traffic engineering & control 25.6, pp. 327-329,1984

59 Troutbeck, R. J., Current and Future Australian Practices for the Design of Unsignalized Intersections: In Intersections without Traffic Signals, pp. 1-19, Springer Berlin Heidelberg. 1988

60 Wegmann, H., A General Capacity Formula for Unsignalized Intersections: In Intersections without Traffic Signals II (pp. 177-191), Springer Berlin Heidelberg, 1991

61 Harders, J., Critical Gaps and Move-Up Times as the Basis of Capacity Calculations for Rural Roads, Schriftenreihe Strassenbau und Strassenverkehrstechnik, 216, 1976

62 Brilon, W., & Ning, W. U., Capacity at Unsignalized Intersections Derived by Conflict Technique, Transportation Research Record, (1776), 82-90 2001.

63 Mahmassani, H., and Sheffi, Y., Using Gap Sequences to Estimate Gap Acceptance Functions, Transportation Research Part B: Methodological, 15(3), 143-148, 1981

64 Miller, A. J., and Pretty, R. L., Overtaking on two-lane rural roads, In Australian Road Research Board (ARRB) Conference, 4th, Paper No 419, 1968

65 Troutbeck, R. J., N. Szwed, and Miller, A. J., Overtaking Sight Distances on a Two Lane Rural Road, In Australian Road Research Board (ARRB) Conference, 6th, 1972, Canberra, vol. 6, no. 3. 1972

66 Troutbeck, R.J., Estimating the Critical Acceptance Gap from Traffic Movement, Physical Infrastructure Centre Report 92/3, Queensland University of Technology, March, 1992

67 Miller, A. J., Nine estimators of gap-acceptance parameters. Publication of: Traffic Flow and Transportation, 1972

68 Siegloch, W., Die Leistungsermittlung an Knotenpunkten ohne Lichtsignalanlagen (Capacity Calculations at Unsignalized Intersections) (in German), Series Strassenbau und Strassenverkehrstechnik, No. 154, 1973

69 Raff, M. S. and Hart, J. W., A volume warrant for urban stop signs, Eno foundation for highway traffic control: Saugatuck, Connecticut, 1950

70 Ashworth, R., The analysis and interpretation of gap acceptance data, Transportation Research, pp. 270±280, 1979

71 Harders, J., Die LeistungsfaÈ higkeit nicht signalgeregelter staedtischer Verkehrsknotenpunkte. (Capacity of Urban Unsignalized Intersections) (in German), Series Strassenbau und Strassenverkehrstechnik, No. 76, 1968.

72 Bunker, J., & Troutbeck, R., Prediction of Minor Stream Delays at a Limited Priority Freeway Merge, Transportation Research Part B: Methodological, 37(8), 719-735, 2003.

73 Cowan, R., The Uncontrolled Traffic Merge, Journal of Applied Probability, 384-392, 1979

74 Semmens M.C., Fairweather, P.J., Harrison, I, B., Roundabout Capacity: Public Road Experiment at Wincheap, Transport and Road Research Laboratory Supplementary Report 554, 1980

75 Akcelik, R., An Assessment of the Highway Capacity Manual 2010 Roundabout Capacity Model, Paper presented at the International Roundabout Conference, TRB, Carmel, Indiana, 2011

76 Polus, A., Lazar, S. S., & Livneh, M., Critical Gap as a Function of Waiting Time in Determining Roundabout Capacity, Journal of Transportation Engineering, 129(5), 504-509, 2003

77 Troutbeck, R., Capacity of limited-priority merge, Transportation Research Record: Journal of the Transportation Research Board, 1678(1), 269-276, 1999.

78 Robinson, B., Rodegerdts, L.A., Capacity and Performance of Roundabouts: A Summary of Recommendations in the FWHA Roundabout Guide, Transportation Research Circular E-C018: 4th International Symposium on Highway Capacity, 2000

79 Flannery, A., Datta, T., Operational Performance Measures of American Roundabouts, Transportation Research Record No. 1572, 1997

80 Hels, T., Orozova-Bekkevold, I., The Effect of Roundabout Design Features on Cyclist Accident Rate, Elsevier, Accident Analysis and Prevention Vol. 39, Issue 2, pp 300–307, 2007

81 Eisenman, S. Josselyn, J., List, G., Persaud, B., Lyon, C., Robinson, B., Blogg, M., Waltman, E., Troutbeck, R., Operational and Safety Performance of Modern Roundabouts and Other Intersection Types” Final Report, Project NYSDOT C-01-47, 2004

82 Akcelik, R, Evaluating Roundabout Capacity, Level of Service and Performance, ITE Annual Meeting, 2009

83 Fisk, C.S., Traffic Performance Analysis at Roundabouts. Transportation Research Board, Volume 25B, Nos 2/3, pp 89-102, 1991

84 Washington State Department of Transportation, Washington State Highway Design Manual Chapter 1320

85 Highway Capacity Manual, Proposed Draft Chapter 17, Part C January 16, 2006

86 Akcelik, R, Capacity and Performance Analysis of Roundabout Metering Signals, National Roundabout Conference, Vail, Colorado 2005

87 Akcelik, R., A Roundabout Case Study Comparing Capacity Estimates from Alternative Analytical Models, Urban Street Symposium, Anaheim, California, USA, 2003

88 Stanek, D., Milam, R.T., High Capacity Roundabout Intersection Analysis: Going Round in Circles, 2004

89 Bloomberg, L., & Dale, J., Comparison of VISSIM and CORSIM traffic simulation models on a congested network, Transportation Research Record: Journal of the Transportation Research Board, 1727(1), 52-60, 2000

90 Yin, D., & Qiu, T. Z., Comparison of Macroscopic and Microscopic Simulation Models in Modern Roundabout Analysis, Transportation Research Record: Journal of the Transportation Research Board, 2265(1), 244-252, 2011

91 RODEL. RODEL Software limited and Staffordshire County Council, 2002

92 RODEL. http://rodel-interactive.com/index.php/rodel

93 Kimber, R.M. "The Traffic Capacity of Roundabouts" TRRL Laboratory Report 942, (1980)

94 ARCADY. Details from www.trlsoftware.co.uk

95 SIDRA. http://www.sidrasolutions.com/

96 Akcelik, R., SIDRA Intersections 4.0 User Guide, Akcelik & Associates Pty Ltd., Greythorn, Australia, 2010

97 Aty, M.A., Hosni, Y., State of the Art Report on Roundabout Design, Modeling and Simulation, 2001

98 HCS. http://mctrans.ce.ufl.edu/hcs/

99 VISSIM Version 5.40 Users Manual, Planung Transport Verkehr AG, Karlsruhe, Germany, 2012

100 CORSIM. http://mctrans.ce.ufl.edu/featured/tsis/

101 PARAMICS. http://www.sias.com/2013/sp/sparamicshome.htm

102 Burley M, "Roundabout and Traffic Signals – Guidelines for the Selection of Intersection Control", Traffic Management Note No. 22 Nov 2005

103 State of Wisconsin DOT, "Facilities Development manual, Chapter 11, Sect 26, Subject 5" April 2004

104 State of Maryland Department of Transportation, Roundabout Design Guidelines, 1995

105 Kittelson & Associates Incorporated and TranSystems Corporation, Kansas Roundabout Guide: A Supplement to FHWA's Roundabouts: An Informational Guide, Topeka, Kansas: Kansas Department of Transportation, 2003

106 Raiffa, H., & Keeney, R. Decisions with multiple objectives: Preferences and value tradeoffs. Decisions with multiple objectives: Preferences and Value Tradeoffs, 1976

107 Belton, V., & Stewart, T. J. Multiple criteria decision analysis: an integrated approach. Springer.2002

108 Korhonen, P., Moskowitz, H., and Wallenius, J., Multiple criteria decision support-A review, European Journal of Operational Research, 63(3), 361-375, 1992

109 Belton, V., and Stewart, T. J., Multiple criteria decision analysis: an integrated approach. Springer, 2002

110 Dodgson, J. S., Spackman, M., Pearman, A., and Phillips, L. D., Multi-criteria analysis: a manual, Department for Communities and Local Government: London, 2009

111 Kyte, M., Dixon, M., List, G., Flannery, A., Rodegerdts, L. NCRHP 3-65: Data Collection and Extraction, Transportation Research Circular, (E-C083), 2005, 36p-36p.

112 Troutbeck, R.J., Estimating the Critical Acceptance Gap from Traffic Movement, Physical Infrastructure Centre Report 92/3, Queensland University of Technology, March, 1992

113 Troutbeck, R. J. Traffic interactions at roundabouts, In Australian Road Research Board (ARRB) Conference, 15th, Darwin, Northern Territory, Vol. 15, No. 5, 1990

114 Frohwein, H. I., Lambert, J. H., Haimes, Y. Y., and Schiff, L. A., Multicriteria Framework to Aid Comparison of Roadway Improvement Projects, Journal of Transportation Engineering, 125(3), 224-230, 1999

115 Ozmen, O., Tian, Z. Z., and Gibby, R., Guidelines for Multicriterion Decision-Based Left-Turn Signal Control, Transportation Research Record: Journal of the Transportation Research Board, 2128(1), 96-104, 2009

116 Saaty, T.L., The Analytical Hierarchy Process, McGraw-Hill International, New York, NY, USA. 1980

117 Saaty, T. L., How to make a decision: the analytic hierarchy process.European journal of operational research, 48(1), 9-26 1990

APPENDICES

APPENDIX 1: RESULTS FOR S1 SIMULATION SCENARIO

Simulation Data for 0 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	76.2	59.3	128	3.9	3.4
2	53.4	37.6	149.3	3.8	3.4
3	169.9	38.3	200.7	3.8	3.4
4	72.5	48.6	120.1	3.9	3.4
5	133.5	45.1	115.2	3.9	3.4
6	76.5	34.5	107.9	3.9	3.4
7	53.4	37.6	149.3	3.8	3.4
8	122.3	43.3	214.6	3.9	3.4
9	82.4	45.6	102.7	3.9	3.4
10	91.5	47.3	177.4	3.9	3.5
Average	93.16	43.72	146.5	3.87	3.41

Delay

No	EB	SB	NB	Pt1	Pt2
1	57.6	40.1	115.5	0.7	0.5
2	34.7	18.3	137	0.6	0.5
3	151.5	19	188.3	0.6	0.5
4	53.9	29.4	107.7	0.7	0.5
5	114.9	25.9	102.7	0.7	0.5
6	57.9	15.1	95.5	0.7	0.5
7	86.9	40.2	117.4	0.7	0.6
8	103.7	24.1	202.3	0.6	0.5
9	63.8	26.3	90.3	0.7	0.5
10	72.9	28	165.1	0.7	0.6
Average	79.78	26.64	132.2	0.67	0.52

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	174.3	268.3	0	0	178.3
2	92.25	78	0	0	253.5
3	616.5	59	0	0	247.3
4	148	127.3	0	0	167.5
5	469	101.5	0	0	154.8
6	168	33.5	0	0	154.5
7	277	244.3	0	0	171.5
8	378.3	90.25	0	0	391.3
9	204.5	87	0	0	149.3
10	237	114.5	0	0	320.8
Average	276.5	120.4	0	0	218.9

Simulation Data for 2 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	51	47.1	94.1	3.8	3.3
2	70.6	41.1	118.4	3.8	3.4
3	138.5	46.6	179	3.9	3.4
4	55.7	52	88.6	3.8	3.3
5	164.1	49.5	131.2	3.9	3.4
6	85.4	40.1	56.1	3.9	3.4
7	70.6	41.1	118.4	3.8	3.4
8	116.1	44.8	189.3	3.9	3.4
9	104.9	37.8	102.7	3.8	3.5
10	70.6	47.5	93.9	3.8	3.4
Ave	92.75	44.76	117.2	3.84	3.39

Delay

No	EB	SB	NB	Pt1	Pt2
1	32.6	28	81.8	0.6	0.5
2	52	21.9	106.1	0.6	0.6
3	120.2	27.4	166.8	0.7	0.5
4	37.1	32.8	76.2	0.6	0.5
5	145.7	30.4	118.8	0.7	0.5
6	66.9	21	43.7	0.7	0.5
7	80.9	27.7	91.2	0.6	0.6
8	97.6	25.6	177	0.7	0.5
9	86.4	18.6	90.5	0.6	0.6
10	52.1	28.3	81.5	0.6	0.5
Ave	77.15	26.17	103.4	0.64	0.53

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	77.75	134	0	0	123
2	167.8	83	0	0	183.5
3	473.5	119.8	0	0	212.5
4	95.75	169.8	0	0	118.8
5	641	160.8	0	0	195.5
6	207.8	59.5	0	0	65
7	256.5	126.3	0	0	136.5
8	351.8	114.3	0	0	324.8
9	298.3	57.25	0	0	133.3
10	152.3	146.5	0	0	115.8
Ave	272.2	117.1	0	0	160.9

Simulation Data for 4 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	68.9	41.9	90.6	3.8	3.3
2	80.6	33.8	142.2	3.8	3.4
3	127.3	39	198.9	3.9	3.4
4	66.8	52.4	138	3.9	3.4
5	123.3	47.1	164.3	4	3.5
6	85.6	35.9	85.3	3.8	3.5
7	80.6	33.8	142.2	3.8	3.4
8	112.4	41.9	201.1	3.9	3.5
9	97.8	39	107.7	3.9	3.4
10	56.7	44.4	150.8	3.8	3.3
Average	90	40.92	142.1	3.86	3.41

Delay

No	EB	SB	NB	Pt1	Pt2
1	50.6	22.9	78.3	0.6	0.5
2	62.1	14.7	129.9	0.6	0.6
3	109	20	186.6	0.7	0.6
4	48.3	33.4	125.7	0.7	0.5
5	104.9	28	152	0.8	0.6
6	67.3	16.7	73	0.7	0.6
7	56.5	21.3	87.2	0.8	0.6
8	94	22.9	188.8	0.7	0.6
9	79.3	19.9	95.5	0.7	0.5
10	38.2	25.3	138.5	0.6	0.5
Average	71.02	22.51	125.6	0.69	0.56

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	138.3	99	0	0	113.8
2	206.3	35.5	0	0	222.3
3	402.3	65.25	0	0	242.8
4	130.5	178	0	0	200.8
5	442.5	129	0	0	221.5
6	222.5	46.25	0	0	120
7	169.8	66	0	0	122.8
8	310	76	0	0	371.8
9	304.8	70	0	0	127.8
10	102	100.5	0	0	214.5
Average	242.9	86.55	0	0	195.8

Simulation Data for 6 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	58.6	56.7	101.6	3.8	3.4
2	63.3	37.8	87.8	3.8	3.4
3	156.7	39.6	101.8	3.9	3.5
4	56.4	48.3	179.4	3.9	3.4
5	100.6	45	122.9	3.9	3.4
6	76.4	35.8	90.6	3.9	3.5
7	63.3	37.8	87.8	3.8	3.4
8	102.6	43.9	185.6	3.9	3.4
9	94.1	40	104.1	3.9	3.4
10	71	42.7	149.8	3.8	3.4
Average	84.3	42.76	121.1	3.86	3.42

Delay

No	EB	SB	NB	Pt1	Pt2
1	40.4	37.7	89.4	0.6	0.5
2	44.9	18.7	75.5	0.7	0.6
3	138.5	20.6	89.5	0.7	0.6
4	37.9	29.4	167.1	0.7	0.6
5	82.3	26.1	110.6	0.8	0.6
6	58.1	16.8	78.4	0.7	0.6
7	76.4	24.8	50.1	0.8	0.6
8	84.4	24.9	173.3	0.7	0.6
9	75.7	21.1	92	0.7	0.6
10	52.6	23.7	137.6	0.7	0.6
Average	69.12	24.38	106.4	0.71	0.59

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	102.8	226	0	0	136
2	140.8	64	0	0	116.8
3	553.5	74	0	0	111.5
4	98.5	162.8	0	0	272.5
5	279.5	81	0	0	160.3
6	173.3	43.75	0	0	110.5
7	248	109.8	0	0	68.5
8	283.3	138.3	0	0	341
9	282	63	0	0	118.5
10	158.8	93.25	0	0	229
Average	232	105.6	0	0	166.5

Simulation Data for 8 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	62.5	47	94.6	3.8	3.4
2	57.1	37.1	113.9	3.8	3.4
3	126.8	45.4	110.8	4	3.5
4	86.5	38.2	169.1	3.8	3.4
5	111.1	47.1	148.6	3.9	3.5
6	69.4	36.9	67.5	4	3.6
7	57.1	37.1	113.9	3.8	3.4
8	79.2	42	226.4	3.9	3.4
9	79	43.1	62.9	3.9	3.5
10	60.7	45.9	154.3	3.9	3.5
Average	78.94	41.98	126.2	3.88	3.46

Delay

No	EB	SB	NB	Pt1	Pt2
1	44.3	28	82.3	0.7	0.6
2	38.7	18.2	101.7	0.7	0.6
3	108.6	26.6	98.6	0.9	0.7
4	68.1	19.3	156.9	0.7	0.6
5	92.9	28.2	136.4	0.8	0.6
6	51.2	18	55.4	0.8	0.7
7	63	18.6	58.4	0.7	0.6
8	61	23.1	214.2	0.8	0.6
9	60.7	24.2	50.8	0.8	0.7
10	42.5	26.9	142.1	0.7	0.6
Average	63.1	23.11	109.7	0.76	0.63

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	113.5	107.3	0	0	125.8
2	109.5	54.25	0	0	167.8
3	433.8	105.8	0	0	120
4	199.3	66.5	0	0	261.8
5	329.5	132	0	0	218
6	150	46.25	0	0	75.25
7	198.5	66.25	0	0	79
8	177.3	91.5	0	0	420.5
9	207.3	82.25	0	0	62
10	118.5	94.5	0	0	235.5
Average	203.7	84.65	0	0	176.6

Simulation Data for 10 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	55.8	48.8	77	3.9	3.4
2	66.8	38.8	118.5	3.9	3.5
3	104.8	34.9	181.7	3.8	3.4
4	64.7	36.3	163.5	3.8	3.4
5	88.3	43.7	166.4	3.9	3.4
6	57.7	33.7	70.8	3.9	3.4
7	66.8	38.8	118.5	3.9	3.5
8	83.2	36.1	180.2	3.9	3.4
9	74.2	39	77.8	3.9	3.4
10	74.2	41.1	200.1	3.9	3.5
Average	73.65	39.12	135.5	3.88	3.43

Delay

No	EB	SB	NB	Pt1	Pt2
1	37.7	30	64.8	0.7	0.6
2	48.6	20	106.4	0.8	0.7
3	86.8	16.1	169.6	0.7	0.6
4	46.4	17.4	151.3	0.7	0.6
5	70.1	24.9	154.4	0.8	0.6
6	39.6	14.9	58.8	0.8	0.6
7	70.8	22.8	52	0.9	0.7
8	65.1	17.3	168.1	0.7	0.6
9	56.1	20.2	65.7	0.8	0.6
10	56.1	22.3	188	0.8	0.7
Average	57.73	20.59	117.9	0.77	0.63

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	91.25	163	0	0	94.25
2	148	63.5	0	0	185.5
3	306.8	53	0	0	212.5
4	124.3	53.5	0	0	240.8
5	243.3	111.3	0	0	244.5
6	103	30	0	0	82.25
7	222	78.75	0	0	70.5
8	185	49.5	0	0	344
9	177.5	55.25	0	0	90.25
10	169.3	69	0	0	330.3
Average	177	72.68	0	0	189.5

Simulation Data for 12 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	60	50.4	91.6	3.9	3.4
2	63.1	36.8	113.9	3.9	3.4
3	91.4	41.8	132	3.9	3.4
4	70.7	38.9	107.4	3.8	3.5
5	79.2	46.4	134	3.9	3.4
6	64.2	36.7	75.7	3.9	3.5
7	63.1	36.8	113.9	3.9	3.4
8	118.1	40.2	174.7	3.9	3.4
9	79	39.1	55.2	3.9	3.4
10	71.5	48.8	86.2	3.9	3.4
Average	76.03	41.59	108.5	3.89	3.42

Delay

No	EB	SB	NB	Pt1	Pt2
1	42	31.6	79.4	0.8	0.7
2	44.9	18.1	101.8	0.8	0.6
3	73.3	23.1	119.9	0.8	0.6
4	52.4	20.1	95.2	0.7	0.7
5	61	27.8	122	0.8	0.7
6	46.2	17.9	63.7	0.8	0.7
7	68.7	19.8	57.9	0.8	0.6
8	100	21.6	162.7	0.8	0.6
9	61	20.3	43.2	0.8	0.7
10	53.5	30.1	74.1	0.8	0.6
Average	60.3	23.04	91.99	0.79	0.65

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	104	153.8	0	0	114
2	137	47.5	0	0	174.8
3	257.3	90.5	0	0	150.5
4	145.3	70	0	0	144.8
5	200.5	120.3	0	0	180.8
6	130.3	60.25	0	0	96.5
7	218.5	70.25	0	0	81
8	376.8	79.25	0	0	315.5
9	207	59.75	0	0	53.5
10	159	151.8	0	0	111.5
Average	193.6	90.33	0	0	142.3

Simulation Data for 14 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	70.7	45.7	67	3.8	3.3
2	68.5	34.5	104.2	3.9	3.4
3	100.4	39.8	72.7	4	3.5
4	48.6	43.7	111.4	4	3.5
5	70.5	41.9	138.3	3.9	3.4
6	53.3	37.7	61.4	4	3.5
7	68.5	34.5	104.2	3.9	3.4
8	93.2	42	137.6	3.9	3.4
9	86.8	38.5	53.3	3.9	3.4
10	61	39.1	77.7	3.9	3.4
Average	72.15	39.74	92.78	3.92	3.42

Delay

No	EB	SB	NB	Pt1	Pt2
1	52.8	27.1	54.9	0.8	0.6
2	50.4	15.8	92.2	0.8	0.6
3	82.5	21.1	60.6	0.9	0.7
4	30.4	25.2	99.2	0.9	0.7
5	52.4	23.3	126.3	0.8	0.7
6	35.3	19	49.6	0.9	0.7
7	64.2	27.9	63	0.9	0.7
8	75.2	23.5	125.6	0.8	0.6
9	68.8	19.8	41.3	0.8	0.6
10	43.2	20.4	65.7	0.8	0.6
Average	55.52	22.31	77.84	0.84	0.65

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	145	133.5	0	0	76.75
2	152	47.5	0	0	146.3
3	287.5	63.75	0	0	73.25
4	76.25	97.25	0.25	0.25	157
5	165.8	94.25	0	0	186
6	91.25	52.75	0	0	66.25
7	199.8	87.5	0	0	90
8	251.8	97	0	0	219.8
9	264.8	68.75	0	0	51
10	117.5	72.75	0.25	0.25	97.25
Average	175.2	81.5	0.05	0.05	116.4

Simulation Data for 16 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	56.6	47.5	52.9	3.9	3.4
2	70	36.9	99.8	3.9	3.4
3	117	36.9	114	3.9	3.4
4	56.1	42.9	92.4	3.8	3.4
5	88	35.9	166.9	4	3.5
6	70.7	37.9	83.4	4	3.5
7	70	36.9	99.8	3.9	3.4
8	99.2	51.4	227.4	4.1	3.6
9	105.6	38.6	63.6	4	3.4
10	54.6	40.5	105.4	3.9	3.4
Average	78.78	40.54	110.6	3.94	3.44

Delay

No	EB	SB	NB	Pt1	Pt2
1	38.8	29	40.8	0.8	0.6
2	52	18.3	87.8	0.8	0.7
3	99.1	18.3	101.9	0.8	0.6
4	38.1	24.4	80.3	0.8	0.6
5	70	17.3	154.9	0.9	0.7
6	52.8	19.3	71.6	0.9	0.7
7	67.4	27.8	53.7	1.1	0.8
8	81.4	32.9	215.4	1	0.8
9	87.7	20.1	51.8	0.9	0.7
10	36.8	22	93.4	0.8	0.7
Average	62.41	22.94	95.16	0.88	0.69

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	99.75	131.3	0	0	55.75
2	161.8	54.25	0	0	142.8
3	366.8	53	0	0	124.8
4	98.25	104	0	0	121.8
5	235.5	47.75	0	0	265.8
6	148	65.5	0	0	99.25
7	215.5	99.5	0	0	75.75
8	272.8	200.3	0	0	419.3
9	329	44.5	0	0	65
10	102	80.75	0	0	140.5
Average	202.9	88.08	0	0	151.1

Simulation Data for 18 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	54.8	46	80.1	3.8	3.4
2	59.5	37.4	106.1	3.9	3.4
3	165.4	41.9	60	3.9	3.5
4	52.3	42.4	88.1	3.9	3.3
5	59.8	43.4	91	3.9	3.4
6	51.5	38	50.4	3.9	3.4
7	59.5	37.4	106.1	3.9	3.4
8	67.9	41.9	160	3.9	3.4
9	88.1	35.7	78.1	3.9	3.4
10	73.5	44	133.2	3.9	3.4
Average	73.23	40.81	95.31	3.89	3.4

Delay

No	EB	SB	NB	Pt1	Pt2
1	37	27.6	68	0.8	0.7
2	41.5	18.8	94.2	0.9	0.7
3	147.7	23.4	47.9	0.8	0.7
4	34.3	24.1	76.1	0.9	0.7
5	41.8	25.1	79	0.9	0.7
6	33.7	19.5	38.6	0.9	0.7
7	48.4	19.2	38.5	0.8	0.7
8	50.1	23.5	148	0.9	0.7
9	70.2	17.3	66.4	0.9	0.7
10	55.8	25.4	121.4	0.9	0.7
Average	56.05	22.39	77.81	0.87	0.7

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	89.5	116	0	0	97
2	124.8	67.75	0	0	171.8
3	598.5	98.75	0.25	0.25	58.25
4	87	106.3	0	0	118.8
5	87	106.3	0	0	118.8
6	85.5	48.5	0	0	50
7	135.3	56.25	0	0	49.5
8	142	109	0.25	0.25	316
9	250	40	0	0	83
10	170.5	117.3	0.25	0.25	205
Average	177	86.6	0.075	0.075	126.8

Simulation Data for 20 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	47.2	47.7	67.1	3.9	3.4
2	59.3	35.8	110.6	3.8	3.3
3	122.3	41.1	91.2	4	3.5
4	61.8	41.1	126.8	3.9	3.4
5	64.2	46.2	107.7	3.9	3.5
6	51.1	33	66.6	3.8	3.4
7	59.3	35.8	110.6	3.8	3.3
8	51.8	36.7	147.3	3.8	3.4
9	51.8	36.7	147.3	3.8	3.4
10	58.5	38.5	85.4	3.8	3.4
Average	62.73	39.26	106.1	3.85	3.4

Delay

No	EB	SB	NB	Pt1	Pt2
1	29.5	29.4	55	0.9	0.7
2	41.5	17.4	98.8	0.8	0.6
3	104.6	22.8	79.2	1	0.8
4	44	22.9	114.9	0.9	0.7
5	46.3	27.8	95.8	0.9	0.8
6	33.3	14.6	54.9	0.8	0.7
7	54.6	22.8	53.7	1	0.8
8	34.1	18.5	135.4	0.9	0.7
9	31.4	19.6	27.9	0.9	0.7
10	40.8	20.2	73.7	0.9	0.7
Average	46.01	21.6	78.93	0.9	0.72

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	70.75	140.8	0	0	79.75
2	125.8	47.25	0	0	179
3	403.3	73.75	0	0	97.75
4	117.5	92	0	0	185.3
5	141.3	120.3	0	0	139.5
6	85.25	40.75	0	0	73
7	168	112.3	0.25	0.25	70.5
8	86.5	62	0	0	240.8
9	84	44.75	0	0	33.5
10	116.3	71.25	0	0	107.3
Average	139.9	80.5	0.025	0.025	120.6

Simulation Data for 25 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	61.5	44.8	54.8	3.9	3.5
2	62.4	40.4	82.6	3.8	3.4
3	110	39.5	65.5	3.9	3.4
4	43	41.3	63.2	3.9	3.4
5	98.7	42.1	112.7	4	3.5
6	54	34.9	65.7	4	3.4
7	62.4	40.4	82.6	3.8	3.4
8	62.5	41.2	159.9	3.8	3.4
9	73.6	37.9	39.1	3.9	3.4
10	48.1	36.3	62.5	3.9	3.3
Average	67.62	39.88	78.86	3.89	3.41

Delay

No	EB	SB	NB	Pt1	Pt2
1	44	26.6	43	0.9	0.8
2	44.7	22.3	70.9	0.8	0.7
3	92.5	21.5	53.7	1	0.7
4	25.4	23.2	51.3	1	0.8
5	81.2	23.9	100.9	1	0.9
6	36.5	16.6	54	1	0.8
7	44.9	13.7	43.8	0.9	0.8
8	44.9	23.2	148	0.9	0.7
9	55.9	19.7	27.6	0.9	0.7
10	30.7	18.1	50.9	0.9	0.7
Average	50.07	20.88	64.41	0.93	0.76

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	110.3	99.5	0	0	58.25
2	142.5	88.75	0	0	113.3
3	336.5	71.25	0	0	65
4	60.5	84.75	0.25	0.25	77
5	288.8	100	0	0	153.5
6	95.25	38.25	0	0	75
7	125	19.5	0	0	59.5
8	123.5	111.3	0	0	299.5
9	176	58.75	0	0	32
10	79.5	53.75	0	0	72
Average	153.8	72.58	0.025	0.025	100.5

Simulation Data for 30 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	48.6	42.2	50.4	3.9	3.4
2	64.7	34.4	76.4	3.9	3.4
3	109.9	31.2	166.9	4.1	3.5
4	42.7	35.3	102.5	4	3.4
5	60.1	44.5	81.3	4.1	3.6
6	45.4	31.5	46.8	4	3.5
7	64.7	34.4	76.4	3.9	3.4
8	50.6	38.4	113.8	4	3.5
9	75.7	34.5	54.6	4	3.5
10	47	39.2	77	4	3.3
Average	60.94	36.56	84.61	3.99	3.45

Delay

No	EB	SB	NB	Pt1	Pt2
1	31.3	24.3	38.5	1	0.8
2	47.2	16.3	64.7	0.9	0.8
3	92.6	13.2	155.3	1.2	0.9
4	25.4	17.5	90.8	1.1	0.9
5	42.6	26.6	69.7	1.1	0.9
6	28.1	13.4	35.3	1.1	0.9
7	49.4	16.3	30.1	1	0.8
8	33.2	20.6	102.1	1.1	0.9
9	58.2	16.5	43.2	1	0.9
10	29.9	21.3	65.4	1	0.7
Average	43.79	18.6	69.51	1.05	0.85

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	72.5	95.25	0	0	54.25
2	142	39.25	0	0	109.3
3	336.8	22.25	0.25	0	199.8
4	60.75	49.75	0	0	146.5
5	124.5	121.3	0.25	0.25	95.5
6	66.75	27.75	0.25	0.25	45.5
7	144.3	49.5	0	0	39.5
8	84	87.75	0	0	167.3
9	179.3	39.75	0.25	0.25	53.75
10	78.5	80.75	0	0	97.25
Average	128.9	61.33	0.1	0.075	100.9

Simulation Data for 40 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	34.4	36.7	40.5	3.9	3.3
2	68.5	32.3	60.2	3.9	3.5
3	69.9	32.1	53	3.9	3.4
4	42.4	33.4	62.2	3.9	3.4
5	54.7	32.4	29.9	3.9	3.3
6	45.5	29	44	4	3.5
7	68.5	32.3	60.2	3.9	3.5
8	56.1	42.9	109.1	4.2	3.6
9	72.4	35.2	29.9	3.9	3.4
10	47.5	37.3	59	3.9	3.5
Average	55.99	34.36	54.8	3.94	3.44

Delay

No	EB	SB	NB	Pt1	Pt2
1	17.6	19.2	28.9	1.1	0.8
2	51.6	14.8	48.9	1.1	1
3	53	14.7	41.6	1.1	0.9
4	25.4	16.1	50.9	1.1	1
5	37.6	14.9	18.4	1.1	0.8
6	28.6	11.5	32.8	1.2	1
7	31.3	14.2	22.2	1.1	1
8	39.2	25.5	97.7	1.4	1.1
9	55.4	17.7	18.8	1.2	0.8
10	30.7	19.6	47.9	1.1	0.9
Average	37.04	16.82	40.81	1.15	0.93

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	34	53.75	0	0	38.75
2	172.8	43	0	0.75	78.5
3	166.3	42.75	0	0	49.5
4	61	35.25	0	0	78.25
5	110.8	42.75	0	0	21.25
6	72.25	18.25	0	0	41
7	80	31.5	0	0	28
8	103.5	99.25	1.75	1.75	174.5
9	188.8	38.25	0	0	21.25
10	76.5	63.75	0	0	65.75
Average	106.6	46.85	0.175	0.25	59.68

Simulation Data for 50 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	33.2	33.7	32	4	3.4
2	51.6	28	32.1	3.9	3.3
3	54.4	28	76.3	4	3.5
4	34.9	31.8	52.5	4.1	3.5
5	47.2	31.8	34.5	3.9	3.4
6	45	29.9	29.2	4.1	3.4
7	51.6	28	32.1	3.9	3.3
8	41.7	31.9	87.5	4.1	3.5
9	56	29.3	29.3	3.9	3.3
10	46.4	34.4	36.4	4	3.3
Average	46.2	30.68	44.19	3.99	3.39

Delay

No	EB	SB	NB	Pt1	Pt2
1	16.8	16.6	20.8	1.3	1
2	35.1	10.9	21.1	1.2	0.9
3	37.9	11.1	65.2	1.4	1.1
4	18.3	14.7	41.5	1.4	1.1
5	30.7	14.8	23.4	1.2	1
6	28.5	12.7	18.3	1.4	1
7	55.5	13.6	24	1.4	1.1
8	25.1	14.9	76.4	1.4	1.1
9	39.5	12.3	18.3	1.2	0.9
10	30	17.2	25.5	1.3	0.9
Average	31.74	13.88	33.45	1.32	1.01

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	33	38.25	0.25	0	27.5
2	94.5	13.75	0	0	28
3	106.3	20.5	0	0.5	84.5
4	39.75	26.25	0.75	0.75	60.25
5	85.5	33.75	0	0	28
6	69	15.5	0	0	22
7	171	30.25	0.25	0.25	32.5
8	60.5	37	0.5	0.5	123
9	117.3	18.75	0	0	20.25
10	76.5	41.5	0.25	0.25	32.25
Average	85.33	27.55	0.2	0.225	45.83

Simulation Data for 60 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	30.4	34.4	25.5	4	3.4
2	51.3	31.6	24.9	4	3.4
3	44.8	30.3	58.8	4.2	3.4
4	32.7	31.4	27.2	4	3.5
5	43	31.6	32.4	4.2	3.4
6	36.8	26.5	24.5	3.9	3.4
7	51.3	31.6	24.9	4	3.4
8	40.5	32.6	43.6	4.1	3.5
9	37.5	29.7	23.2	3.8	3.2
10	37.5	29.9	33.1	3.9	3.3
Average	40.58	30.96	31.81	4.01	3.39

Delay

No	EB	SB	NB	Pt1	Pt2
1	14.5	17.7	14.6	1.4	1.1
2	35.2	15	14.2	1.4	1.1
3	28.7	13.7	48	1.6	1.1
4	16.5	14.8	16.4	1.4	1.2
5	27	15	21.6	1.6	1.1
6	20.7	9.8	13.8	1.3	1.1
7	23.3	14.5	14.1	1.5	1.1
8	24.2	15.9	32.8	1.5	1.2
9	21.4	13.1	12.5	1.3	0.9
10	21.6	13.2	22.4	1.4	1
Average	23.31	14.27	21.04	1.44	1.09

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	26	58	0.25	0.25	16
2	95.5	37	0.5	0	17.25
3	75.75	24.5	0.5	0	58.25
4	33	43	1	1	20
5	73.75	35	0.5	0.5	25
6	48	11.25	0	0	15
7	53.75	33.25	0.5	0.5	16.5
8	55.5	50	0.75	0.75	46
9	51.25	17.75	0	0	13.25
10	53.75	21.5	0.25	0.25	29.25
Average	56.63	33.13	0.425	0.325	25.65

Simulation Data for 75 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	27.8	27.9	21.6	3.8	3.2
2	29	25.8	22.8	3.7	3.1
3	40.7	29.5	23.7	4	3.3
4	31.2	27.9	34.1	3.8	3.4
5	41.1	28	24.5	4	3.4
6	30.8	25.4	23.2	3.9	3.4
7	29	25.8	22.8	3.7	3.1
8	35.3	28.5	26.9	4	3.3
9	41.1	29.7	20.6	4.3	3.3
10	32.5	33.6	24.8	4.2	3.3
Average	33.85	28.21	24.5	3.94	3.28

Delay

No	EB	SB	NB	Pt1	Pt2
1	12.5	11.9	11.1	1.4	1
2	13.5	9.9	12.5	1.3	1
3	25.2	13.7	13.4	1.6	1.1
4	15.7	11.9	23.8	1.4	1.2
5	25.5	12	14.2	1.6	1.3
6	15.4	9.6	12.8	1.6	1.2
7	15.8	9.9	8	1.5	1.2
8	19.7	12.7	16.5	1.6	1.1
9	25.8	13.6	10.4	1.8	1.2
10	17.2	17.5	14.5	1.7	1.2
Average	18.63	12.27	13.72	1.55	1.15

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	22.25	29.25	0.75	0.25	12.75
2	26.5	18.75	0	0.25	15
3	65	26.75	0.75	0.25	13.5
4	32.75	26	0	0	33.5
5	66.75	20.75	0.75	0.75	16
6	32.5	10	0.25	0.25	13.5
7	32.25	13	1.25	1.25	8.25
8	46.75	29	1	1	20
9	69.75	21.75	1.5	1.5	10.5
10	39	46.75	0.25	0.25	17.25
Average	43.35	24.2	0.65	0.575	16.03

Simulation Data for 80 % Car1 - Model Scenario S1

Travel Time

%	EB	SB	NB	Pt1	Pt2
1	28.1	26.9	19.1	3.9	3.2
2	29.3	26.5	22.4	4	3.4
3	34.4	26.2	24	4.1	3.4
4	26.2	24.9	31.5	3.9	3.2
5	42.9	33.1	20.3	4.2	3.5
6	32.1	25	21.7	3.7	3.1
7	29.3	26.5	22.4	4	3.4
8	32.8	26.3	22.6	4	3.3
9	39.2	26.3	18.4	3.9	3.3
10	39.2	26.3	18.4	3.9	3.3
Average	33.35	26.8	22.08	3.96	3.31

Delay

No	EB	SB	NB	Pt1	Pt2
1	13	11.3	8.7	1.6	1.1
2	14	10.7	12.2	1.6	1.3
3	19.2	10.5	13.8	1.8	1.3
4	10.8	9.2	21.3	1.5	1.1
5	27.6	17.2	10.1	1.8	1.4
6	16.9	9.4	11.6	1.4	1
7	14.9	9	11.9	1.7	1.1
8	17.4	10.6	12.4	1.7	1.2
9	24	10.5	8.4	1.6	1.2
10	14.3	20.7	9.2	1.7	1.2
Average	17.21	11.91	11.96	1.64	1.19

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	21.25	21.25	0.75	0	8.5
2	29.75	11.25	0.75	0.75	15.25
3	45.75	16	1	1	14.25
4	18	10.5	0	0	28.5
5	76	44.5	1	1	10.5
6	36.75	13	0.25	0.25	13.25
7	29.25	11.75	1	1	13.25
8	38.75	15.75	0.5	0.5	15.5
9	63	14.75	0.25	0.25	7
10	29	78	0.75	0.75	8.75
Average	38.75	23.68	0.625	0.55	13.48

Simulation Data for 90 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	23.8	26.4	17.5	3.6	3
2	36.4	28.5	18.9	4	3.4
3	34.3	26.4	22.4	4.3	3.5
4	24.7	25	24.4	3.8	3.2
5	43.9	27.3	23.6	4.5	3.5
6	27.2	23.3	15.9	3.8	3.2
7	36.4	28.5	18.9	4	3.4
8	29.1	28.3	21.2	4.2	3.4
9	29.9	24.2	15.3	4	3.2
10	25.2	26.1	21	4.1	3.4
Average	31.09	26.4	19.91	4.03	3.32

Delay

No	EB	SB	NB	Pt1	Pt2
1	9	11.1	7.5	1.4	1
2	21.5	13.2	9.1	1.8	1.4
3	19.6	11.1	12.4	2.1	1.5
4	9.8	9.8	14.6	1.6	1.2
5	29.1	12.1	13.6	2.2	1.5
6	12.4	8	6.1	1.5	1.2
7	9.7	7.9	7.7	1.5	1.3
8	14.3	13	11.3	2	1.4
9	15.1	8.9	5.5	1.8	1.2
10	10.5	10.9	11.1	1.9	1.4
Average	15.1	10.6	9.89	1.78	1.31

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	14	23.5	0.25	0	8
2	54.75	37.75	1	0.75	9.75
3	47.25	29.25	4.75	1.25	11.75
4	18	16.25	1.25	1.25	17.25
5	81.25	20.5	2	2	17
6	23	10.5	0.5	0.5	5.25
7	16.75	7	1	1	7.75
8	27.5	20.25	1.5	1.5	12.75
9	33.5	9.25	1.5	1.5	3.75
10	18.25	18.5	1.5	1.5	11.75
Average	33.43	19.28	1.525	1.125	10.5

Simulation Data for 100 % Car1 - Model Scenario S1

Travel Time

No	EB	SB	NB	Pt1	Pt2
1	23.3	23.6	18	3.7	3.2
2	21.3	21.2	15.2	3.5	3
3	27.2	24.4	16	4.1	3.3
4	19.2	21.3	16.3	3.3	2.9
5	26.2	23.1	16.5	3.9	3.1
6	23	21.8	15.8	3.9	3.2
7	21.3	21.2	15.2	3.5	3
8	25.2	23.6	16.9	3.7	3.1
9	26.7	23	14.6	3.7	3
10	38.7	28.9	20.2	4.5	3.5
Average	25.21	23.21	16.47	3.78	3.13

Delay

No	EB	SB	NB	Pt1	Pt2
1	8.9	8.6	8.3	1.6	1.3
2	6.8	6.3	5.6	1.3	1.1
3	12.7	9.3	6.3	1.9	1.3
4	4.7	6.3	6.7	1.2	1
5	11.8	8.1	6.7	1.7	1.2
6	8.5	6.8	6.1	1.7	1.3
7	9.3	6.9	4.4	1.7	1.2
8	10.7	8.7	7.2	1.5	1.2
9	12.2	8	5	1.5	1.1
10	24.3	13.9	10.5	2.3	1.6
Average	10.99	8.29	6.68	1.64	1.23

Queue Length

No	EB	SB	Pt1	Pt2	NB
1	14.75	8.25	0.75	1	9
2	9.75	7	0.25	0.5	5.75
3	26.5	9.25	1	0.75	4.75
4	4.75	10.75	0.5	0.5	6.5
5	25.75	13.25	1.75	1.75	6.5
6	14.5	8.25	1.5	1.5	5.25
7	16.75	6.75	1.5	1.5	2.75
8	19.75	14.5	1.25	1.25	7.5
9	26.5	11	1.25	1.25	3.5
10	70	49	15.75	15.75	12.5
Average	22.9	13.8	2.55	2.575	6.4

Summary of Simulation Data - Model Scenario S1

Travel Time

%	EB	SB	NB	Pt1	Pt2
0	93.16	43.72	146.5	3.87	3.41
2	92.75	44.76	117.2	3.84	3.39
4	90	40.92	142.1	3.86	3.41
6	84.3	42.76	121.1	3.86	3.42
8	78.94	41.98	126.2	3.88	3.46
10	73.65	39.12	135.5	3.88	3.43
12	76.03	41.59	108.5	3.89	3.42
14	72.15	39.74	92.78	3.92	3.42
16	78.78	40.54	110.6	3.94	3.44
18	73.23	40.81	95.31	3.89	3.4
20	62.73	39.26	106.1	3.85	3.4
25	67.62	39.88	78.86	3.89	3.41
30	60.94	36.56	84.61	3.99	3.45
40	55.99	34.36	54.8	3.94	3.44
50	46.2	30.68	44.19	3.99	3.39
60	40.58	30.96	31.81	4.01	3.39
75	33.85	28.21	24.5	3.94	3.28

Delay

%	EB	SB	NB	Pt1	Pt2
0	79.78	26.64	132.2	0.67	0.52
2	77.15	26.17	103.4	0.64	0.53
4	71.02	22.51	125.6	0.69	0.56
6	69.12	24.38	106.4	0.71	0.59
8	63.1	23.11	109.7	0.76	0.63
10	57.73	20.59	117.9	0.77	0.63
12	60.3	23.04	91.99	0.79	0.65
14	55.52	22.31	77.84	0.84	0.65
16	62.41	22.94	95.16	0.88	0.69
18	56.05	22.39	77.81	0.87	0.7
20	46.01	21.6	78.93	0.9	0.72
25	50.07	20.88	64.41	0.93	0.76
30	43.79	18.6	69.51	1.05	0.85
40	37.04	16.82	40.81	1.15	0.93
50	31.74	13.88	33.45	1.32	1.01
60	23.31	14.27	21.04	1.44	1.09
75	18.63	12.27	13.72	1.55	1.15

Queue Length

%	EB	SB	Pt1	Pt2	NB
0	276.5	120.4	0	0	218.9
2	272.2	117.1	0	0	160.9
4	242.9	86.55	0	0	195.8
6	232	105.6	0	0	166.5
8	203.7	84.65	0	0	176.6
10	177	72.68	0	0	189.5
12	193.6	90.33	0	0	142.3
14	175.2	81.5	0.05	0.05	116.4
16	202.9	88.08	0	0	151.1
18	177	86.6	0.075	0.075	126.8
20	139.9	80.5	0.025	0.025	120.6
25	153.8	72.58	0.025	0.025	100.5
30	128.9	61.33	0.1	0.075	100.9
40	106.6	46.85	0.175	0.25	59.68
50	85.33	27.55	0.2	0.225	45.83
60	56.63	33.13	0.425	0.325	25.65
75	43.35	24.2	0.65	0.575	16.03

80	33.35	26.8	22.08	3.96	3.31
90	31.09	26.4	19.91	4.03	3.32
100	25.21	23.21	16.47	3.78	3.13
Average					

80	17.21	11.91	11.96	1.64	1.19
90	15.1	10.6	9.89	1.78	1.31
100	10.99	8.29	6.68	1.64	1.23
Average					

80	38.75	23.68	0.625	0.55	13.48
90	33.43	19.28	1.525	1.125	10.5
100	22.9	13.8	2.55	2.575	6.4
Average					

APPENDIX 2: RESULTS FOR S1I SIMULATION SCENARIO

Simulation Data for 0 % Car1 - Model Scenario S1i

Travel Time

No	EB	SB	NB	Pt1	Pt2
	Link No				
1	76.2	59.3	128	3.9	3.4
2	53.4	37.6	149.3	3.8	3.4
3	169.9	38.3	200.7	3.8	3.4
4	72.5	48.6	120.1	3.9	3.4
5	133.5	45.1	115.2	3.9	3.4
6	76.5	34.5	107.9	3.9	3.4
7	53.4	37.6	149.3	3.8	3.4
8	122.3	43.3	214.6	3.9	3.4
9	82.4	45.6	102.7	3.9	3.4
10	91.5	47.3	177.4	3.9	3.5
Average	93.16	43.72	146.5	3.87	3.41

Delay

No	EB	SB	NB	Pt1	Pt2
	Link No				
1	57.6	40.1	115.5	0.7	0.5
2	34.7	18.3	137	0.6	0.5
3	151.5	19	188.3	0.6	0.5
4	53.9	29.4	107.7	0.7	0.5
5	114.9	25.9	102.7	0.7	0.5
6	57.9	15.1	95.5	0.7	0.5
7	86.9	40.2	117.4	0.7	0.6
8	103.7	24.1	202.3	0.6	0.5
9	63.8	26.3	90.3	0.7	0.5
10	72.9	28	165.1	0.7	0.6
Average	79.78	26.64	132.2	0.67	0.52

Queue Length

No	EB	SB	Pt1	Pt2	NB
	Link No				
1	174.3	268.5	0	0	178.3
2	92.5	78	0	0	253.5
3	616.5	59.25	0	0	247.3
4	148.3	127.3	0	0	167.5
5	469.3	101.5	0	0	154.8
6	168	33.5	0	0	154.5
7	277.3	245.5	0	0	171.5
8	378.3	90.5	0	0	391.3
9	204.8	87	0	0	149.3
10	237	114.5	0	0	320.8
Average	276.6	120.6	0	0	218.9

Simulation Data for 2 % Car1 - Model Scenario S1i

Travel Time

No	Link No EB	SB	NB	Pt1	Pt2
1	50.4	46.6	77	3.8	3.3
2	79.7	40.1	121.7	3.9	3.4
3	146	35.7	140.4	3.9	3.4
4	62.2	40.3	159.7	3.8	3.3
5	156.8	44.1	155.3	3.9	3.4
6	89.7	36.2	147.5	3.8	3.4
7	79.7	40.1	121.7	3.9	3.4
8	80.1	40.4	196.4	3.8	3.4
9	135.7	40.9	97.4	3.9	3.5
10	63.4	49.4	153.7	3.9	3.4
Average	94.37	41.38	137.1	3.86	3.39

Delay

No	Link No EB	SB	NB	Pt1	Pt2
1	31.9	27.3	64.6	0.6	0.5
2	61	20.8	109.4	0.7	0.5
3	127.6	16.4	128	0.6	0.5
4	43.6	21.1	147.3	0.6	0.5
5	138.3	24.8	142.9	0.6	0.5
6	71.1	16.9	135.1	0.6	0.6
7	81.1	28.5	79.9	0.6	0.5
8	61.6	21.1	184	0.6	0.5
9	117.2	21.6	85	0.7	0.6
10	44.8	30.2	141.3	0.6	0.5
Average	77.82	22.87	121.8	0.62	0.52

Queue Length

No	Link No EB	SB	Pt1	Pt2	NB
1	77.25	122	0	0	91
2	212.3	75.25	0	0	186.8
3	530.3	40	0	0	165
4	116	71.5	0	0	237
5	604.8	115.3	0	0	245.3
6	226	42	0	0	225.3
7	261.5	119.3	0	0	113
8	182.8	84.75	0	0	357.8
9	443	76.5	0	0	128.5
10	127.5	156.5	0	0	259.8
Average	278.1	90.3	0	0	200.9

Simulation Data for 4 % Car1 - Model Scenario S1i

Travel Time

No	Link No EB	SB	NB	Pt1	Pt2
1	55.4	50.3	49.4	3.8	3.4
2	88.8	38.3	138	3.8	3.4
3	169.4	44.4	114.4	4	3.5
4	60.4	47.7	122.2	3.9	3.4
5	86.1	47.8	131.8	3.9	3.5
6	78.2	42	82.5	3.8	3.4
7	88.8	38.3	138	3.8	3.4
8	133.3	39.9	187.5	3.9	3.5
9	87.9	44.6	84.4	3.9	3.4
10	58.8	45.8	98.3	3.8	3.4
Average	90.71	43.91	114.7	3.86	3.43

Delay

No	Link No EB	SB	NB	Pt1	Pt2
1	36.8	31.2	36.9	0.6	0.5
2	70.1	19	125.7	0.6	0.5
3	151	25.2	102	0.8	0.6
4	41.8	28.5	109.8	0.7	0.5
5	67.5	28.5	119.4	0.7	0.6
6	59.7	22.7	70.1	0.6	0.5
7	59.5	26.1	105.5	0.7	0.6
8	114.7	20.6	175.1	0.6	0.6
9	69.3	25.3	72.1	0.7	0.5
10	40.2	26.6	85.9	0.6	0.5
Average	71.06	25.37	100.3	0.66	0.54

Queue Length

No	Link No EB	SB	Pt1	Pt2	NB
1	95.75	138.5	0	0	50.5
2	249.3	78.75	0	0	227.8
3	623.8	94.75	0	0	128.3
4	111.5	116.8	0	0	177.5
5	231	144.3	0	0	184
6	181	89.5	0	0	110.3
7	180	91.75	0	0	152.5
8	442.5	59	0	0	349.8
9	237.3	89	0	0	92.5
10	105.3	112.5	0	0	129
Average	245.7	101.5	0	0	160.2

Simulation Data for 6 %t Car1 - Model Scenario S1i

Travel Time

No	Link No EB	SB	NB	Pt1	Pt2
1	51.8	56.7	88.5	3.9	3.4
2	66.5	35.6	106.5	3.9	3.4
3	164.3	38.8	154.7	3.9	3.5
4	64.3	47.7	217.5	3.9	3.4
5	95.2	50.9	180.1	3.9	3.4
6	70.8	39.1	106	3.9	3.5
7	66.5	35.6	106.5	3.9	3.4
8	99.3	45.1	190.7	3.8	3.4
9	99.8	46.5	108.8	3.9	3.4
10	74.7	41.5	128	3.9	3.4
Average	85.32	43.75	138.7	3.89	3.42

Delay

No	Link No EB	SB	NB	Pt1	Pt2
1	33.2	37.5	76.1	0.7	0.5
2	47.8	16.2	94.1	0.7	0.6
3	145.9	19.6	142.3	0.7	0.6
4	45.6	28.5	205.1	0.7	0.6
5	76.6	31.6	167.6	0.7	0.6
6	52.3	19.9	93.6	0.7	0.6
7	57	26.8	104	0.7	0.6
8	80.8	25.8	178.3	0.6	0.6
9	81.2	27.3	96.5	0.7	0.6
10	56.1	22.2	115.7	0.7	0.6
Average	67.65	25.54	127.3	0.69	0.59

Queue Length

No	Link No EB	SB	Pt1	Pt2	NB
1	82	224	0.25	0	109.5
2	151.8	55.5	0	0	148.3
3	596.5	53.5	0	0	188.8
4	124.5	121.3	0	0	355.5
5	273.8	190	0	0	278
6	157	69	0	0	151
7	168.3	127	0	0	148.5
8	249.3	126.3	0	0	357
9	322.3	108.5	0	0	126
10	172	82.5	0	0	185.3
Average	229.7	115.8	0.025	0	204.8

Simulation Data for 8 % Car1 - Model Scenario S1i

Travel Time

No	Link No EB	SB	NB	Pt1	Pt2
1	47.5	50	92.3	3.8	3.4
2	59.8	36	112.8	3.9	3.5
3	171.4	46.9	110.5	3.9	3.4
4	64.5	43.2	146.2	3.8	3.4
5	113	44.6	95.8	4	3.5
6	61.3	37.9	82.5	4	3.5
7	59.8	36	112.8	3.9	3.5
8	112.5	41.5	200.2	3.9	3.4
9	94.3	41.5	83.2	4	3.5
10	56.4	43.2	119.5	3.9	3.4
Average	84.05	42.08	115.6	3.91	3.45

Delay

No	Link No EB	SB	NB	Pt1	Pt2
1	28.9	30.8	79.9	0.6	0.6
2	41.1	16.7	100.4	0.7	0.6
3	153	27.7	98.1	0.7	0.6
4	45.8	24	133.8	0.6	0.5
5	94.5	25.3	83.4	0.8	0.7
6	42.7	18.6	70.1	0.8	0.7
7	68.4	32	87.9	0.7	0.6
8	93.9	22.1	187.8	0.7	0.6
9	75.7	22.2	70.8	0.7	0.6
10	37.8	23.9	107.2	0.7	0.6
Average	68.18	24.33	101.9	0.7	0.61

Queue Length

No	Link No EB	SB	Pt1	Pt2	NB
1	69.25	147.8	0	0	115.5
2	119.3	42.25	0	0	169.5
3	642.5	127	0	0	121
4	124.8	111	0	0	214.3
5	340.3	112.8	0	0	121
6	120.8	56.75	0.25	0.25	99.75
7	208.3	153	0	0	125
8	320.5	89.75	0	0	374.3
9	286	66.75	0	0	91.5
10	106.3	93.5	0	0	173.5
Average	233.8	100.1	0.025	0.025	160.5

Simulation Data for 10 % Car1 - Model Scenario S1i

Travel Time

No	Link No EB	SB	NB	Pt1	Pt2
1	69.3	56.3	69	3.9	3.4
2	80.9	37.3	116	3.9	3.4
3	130.4	43.2	98.8	3.9	3.4
4	64.7	43.5	130.6	3.8	3.4
5	78.7	50.4	151	4	3.5
6	54.2	34.7	63.9	3.9	3.4
7	80.9	37.3	116	3.9	3.4
8	95.1	42.3	182.9	3.8	3.3
9	80.9	43.6	83.6	3.9	3.4
10	63	44	121.8	3.9	3.5
Average	79.81	43.26	113.4	3.89	3.41

Delay

No	Link No EB	SB	NB	Pt1	Pt2
1	50.7	37	56.5	0.7	0.5
2	62.2	18	103.7	0.7	0.6
3	112	23.9	86.5	0.8	0.6
4	46.1	24.2	118.2	0.6	0.6
5	60.1	31.2	138.6	0.8	0.7
6	35.6	15.4	51.5	0.7	0.6
7	91.9	23.9	130	0.7	0.7
8	76.5	23.1	170.5	0.6	0.5
9	62.3	24.3	71.3	0.7	0.6
10	44.4	24.8	109.4	0.8	0.6
Average	64.18	24.58	103.6	0.71	0.6

Queue Length

No	Link No EB	SB	Pt1	Pt2	NB
1	146	209.8	0	0	82.25
2	210.8	54.25	0	0	188.8
3	455.3	86	0.25	0	107.5
4	122.5	111.8	0	0	191.5
5	198	161.8	0	0	209.8
6	95.5	36	0	0	69.75
7	319.8	101.8	0	0	205
8	260.3	92.5	0	0	334.8
9	220	71	0	0	99.25
10	126.5	99	0	0	171.3
Average	215.5	102.4	0.025	0	166

Simulation Data for 12 % Car1 - Model Scenario S1i

Travel Time

No	Link No EB	SB	NB	Pt1	Pt2
1	50.3	49.4	70.6	3.9	3.4
2	55.9	38.1	90.3	3.9	3.4
3	127.9	38.2	127.3	3.9	3.5
4	69.4	45.2	137.2	4	3.5
5	100.1	47.2	157.1	4	3.4
6	70	33.7	107.1	4	3.5
7	55.9	38.1	90.3	3.9	3.4
8	73.8	41.8	175	4	3.5
9	79.5	41.7	67.9	4	3.4
10	75.1	44.7	159	3.9	3.4
Average	75.79	41.81	118.2	3.95	3.44

Delay

No	Link No EB	SB	NB	Pt1	Pt2
1	31.7	30.2	58.1	0.7	0.6
2	37.2	18.8	77.9	0.7	0.5
3	109.5	18.9	115	0.7	0.6
4	50.7	26	124.8	0.8	0.6
5	81.6	28	144.6	0.8	0.6
6	51.4	14.3	94.7	0.8	0.6
7	66.5	20.9	103.6	0.7	0.6
8	55.2	22.6	162.6	0.8	0.6
9	60.8	22.4	55.6	0.8	0.6
10	56.5	25.4	146.6	0.7	0.6
Average	60.11	22.75	108.4	0.75	0.59

Queue Length

No	Link No EB	SB	Pt1	Pt2	NB
1	76	155.5	0	0	82.5
2	117.5	58	0	0	119.3
3	468.3	48.5	0	0	144.3
4	139.5	127.8	0	0	198.8
5	291.5	134.8	0	0	234.5
6	148.3	33.25	0	0	159.3
7	207	62.25	0	0	154.3
8	162.5	104.8	0	0	333.3
9	218.3	94.75	0	0	72.25
10	179.8	98	0	0	251.8
Average	200.9	91.75	0	0	175

Simulation Data for 14 % Car1 - Model Scenario S1i

Travel Time

No	Link No EB	SB	NB	Pt1	Pt2
1	48.5	48.1	38.6	3.8	3.4
2	55.5	40.3	96.7	3.9	3.5
3	118.7	47.9	89.8	3.9	3.4
4	54.9	45.4	137.6	4	3.5
5	81.7	45.2	162.6	4	3.5
6	83.9	37.7	59.6	4	3.5
7	55.5	40.3	96.7	3.9	3.5
8	102.3	34.7	193.5	3.9	3.4
9	80.3	38.2	53.5	3.8	3.4
10	54.6	42.3	81.4	4	3.4
Average	73.59	42.01	101	3.92	3.45

Delay

No	Link No EB	SB	NB	Pt1	Pt2
1	30	28.9	26	0.6	0.5
2	36.8	20.9	84.4	0.8	0.6
3	100.3	28.7	77.4	0.8	0.6
4	36.2	26.2	125.2	0.8	0.7
5	63.1	26	150.2	0.8	0.7
6	65.4	18.5	47.2	0.9	0.7
7	50.6	27.1	80.7	0.7	0.6
8	83.7	15.5	181.1	0.7	0.5
9	61.7	18.8	41.1	0.6	0.5
10	36	23	69	0.8	0.6
Average	56.38	23.36	88.23	0.75	0.6

Queue Length

No	Link No EB	SB	Pt1	Pt2	NB
1	73.25	157.8	0	0	33
2	102.8	79.5	0	0	137.8
3	420.3	129.5	0	0	96.75
4	97	123.8	0	0	201.3
5	206.3	104.5	0.25	0.25	243.8
6	216.8	48.5	0	0	63.75
7	146.8	144	0	0	118
8	284.8	30	0	0	356.5
9	219.5	61.75	0	0	51
10	98	88.5	0.25	0.25	101
Average	186.5	96.78	0.05	0.05	140.3

Simulation Data for 16 % Car1 - Model Scenario S1i

Travel Time

No	Link No				
	EB	SB	NB	Pt1	Pt2
1	40.6	40.6	60.4	3.9	3.4
2	63.1	37	88.4	3.9	3.5
3	104.6	45.8	110.1	3.9	3.4
4	51.4	40.8	83.1	3.9	3.4
5	112.2	37.6	164.3	3.9	3.5
6	65	39.9	85	4	3.5
7	63.1	37	88.4	3.9	3.5
8	91.7	38.2	139.7	4	3.5
9	95.1	38.2	64.7	4	3.5
10	54	38.1	85	3.9	3.4
Average	74.08	39.32	96.91	3.93	3.46

Delay

No	Link No				
	EB	SB	NB	Pt1	Pt2
1	22	21.4	48	0.7	0.6
2	44.4	17.7	76	0.7	0.6
3	86.1	26.5	97.7	0.8	0.6
4	32.7	21.6	70.7	0.7	0.5
5	93.7	18.3	151.9	0.8	0.6
6	46.4	20.6	72.6	0.9	0.7
7	52	23.6	55.7	0.8	0.6
8	73.1	18.9	127.3	0.8	0.7
9	76.5	18.9	52.3	0.9	0.6
10	35.4	18.8	72.7	0.7	0.6
Average	56.23	20.63	82.49	0.78	0.61

Queue Length

No	Link No				
	EB	SB	Pt1	Pt2	NB
1	47.75	52.5	0	0	66.5
2	133.3	61.5	0	0	122.8
3	321.8	105	0	0	122.5
4	83.5	83.5	0	0	110
5	326	62.5	0	0	247.8
6	129.3	59.75	0	0	100.8
7	152.5	80.75	0	0	80.25
8	244.5	71.25	0	0	226.3
9	295.5	54.25	0	0	67
10	94.5	65.25	0	0	111.5
Average	182.9	69.63	0	0	125.5

Simulation Data for 18 % Car1 - Model Scenario S1i

Travel Time

No	EB	SB	NB	Pt1	Pt2
	Link No				
1	52.3	43.6	68.4	3.9	3.4
2	70.4	38.4	97.7	4	3.5
3	126.7	39.1	78.4	4	3.5
4	53.3	44	102.9	4	3.4
5	76.1	46.2	76.1	4.1	3.5
6	61.5	36.1	56.5	4	3.4
7	70.4	38.4	97.7	4	3.5
8	67.7	37.8	190	3.9	3.4
9	89.9	39.5	69.4	4	3.5
10	54.1	46.9	123.5	3.9	3.4
Average	72.24	41	96.06	3.98	3.45

Delay

No	EB	SB	NB	Pt1	Pt2
	Link No				
1	33.7	24.4	55.9	0.8	0.6
2	51.7	19.1	85.4	0.8	0.7
3	108.3	19.9	66	0.8	0.7
4	34.6	24.8	90.4	0.8	0.5
5	57.6	27	63.6	0.9	0.7
6	42.9	16.8	44.1	0.8	0.6
7	57.2	13.4	46.1	0.7	0.6
8	49.1	18.5	177.6	0.8	0.6
9	71.3	20.2	57	0.8	0.6
10	35.5	27.7	111	0.8	0.6
Average	54.19	21.18	79.71	0.8	0.62

Queue Length

No	EB	SB	Pt1	Pt2	NB
	Link No				
1	85.25	93.5	0	0	80
2	172	59.5	0.25	0	140.3
3	437.5	65.25	0	0	80
4	90.75	87.75	0	0	141
5	184	111	0	0	87
6	118.5	45.75	0	0	59
7	175.3	18.25	0	0	62
8	137.5	58	0	0	365.8
9	258	51	0	0	72.5
10	99.5	119	0	0	188.8
Average	175.8	70.9	0.025	0	127.6

Simulation Data for 20 % Car1 - Model Scenario S1i

Travel Time

No	Link No EB	SB	NB	Pt1	Pt2
1	62.5	48.2	45.7	3.9	3.4
2	67.6	36.3	69.5	3.9	3.4
3	118.9	42.5	87.7	4	3.5
4	72.4	42.8	153.8	3.9	3.4
5	60.2	39.7	154.4	3.9	3.4
6	59.9	31	57.3	3.8	3.4
7	67.6	36.3	69.5	3.9	3.4
8	67.6	41.8	161	3.9	3.4
9	81.6	36.6	60.3	4	3.4
10	66.7	38.2	98.2	4	3.5
Average	72.5	39.34	95.74	3.92	3.42

Delay

No	Link No EB	SB	NB	Pt1	Pt2
1	44	29	33.2	0.7	0.6
2	48.9	17	57.1	0.8	0.6
3	100.4	23.2	75.3	0.8	0.7
4	53.7	23.6	141.4	0.8	0.6
5	41.6	20.5	142	0.7	0.6
6	41.4	11.7	44.8	0.7	0.6
7	40.7	20.1	36.6	0.8	0.6
8	49	22.5	148.6	0.8	0.6
9	63	17.3	47.9	0.8	0.6
10	48.1	18.9	85.8	0.9	0.7
Average	53.08	20.38	81.27	0.78	0.62

Queue Length

No	Link No EB	SB	Pt1	Pt2	NB
1	115	140	0	0	46
2	168.8	51.5	0	0	92.75
3	417.8	103.5	0	0	91.75
4	151	121.8	0	0	242.3
5	125	65.5	0	0	225.5
6	111.5	27.75	0	0	61.5
7	114	88	0	0	46.75
8	141.8	90	0	0	275.3
9	208.5	47	0	0	64.75
10	152.3	65.5	0.25	0.25	129.5
Average	170.6	80.05	0.025	0.025	127.6

Simulation Data for 25 % Car1 - Model Scenario S1i

Travel Time

No	Link No				
	EB	SB	NB	Pt1	Pt2
1	55.7	42	43.9	3.9	3.4
2	54.4	37	74.8	3.9	3.5
3	110.2	37.6	133.2	3.9	3.4
4	53.6	36.9	98.9	4	3.6
5	68.6	41	69.3	3.9	3.4
6	60.5	36.3	71	4	3.4
7	54.4	37	74.8	3.9	3.5
8	49.5	35	173.1	3.8	3.4
9	81.6	34.6	43	3.8	3.4
10	57.9	39.9	99.2	3.8	3.4
Average	64.64	37.73	88.12	3.89	3.44

Delay

No	Link No				
	EB	SB	NB	Pt1	Pt2
1	37.1	22.7	31.3	0.7	0.6
2	35.7	17.7	62.4	0.8	0.7
3	91.8	18.3	120.8	0.8	0.6
4	34.9	17.7	86.5	0.9	0.8
5	50	21.8	56.8	0.8	0.6
6	42	17	58.6	0.8	0.7
7	52.8	17.7	53.9	0.9	0.7
8	30.8	15.7	160.7	0.8	0.6
9	63	15.3	30.6	0.7	0.6
10	39.3	20.7	86.7	0.7	0.6
Average	47.74	18.46	74.83	0.79	0.65

Queue Length

No	Link No				
	EB	SB	Pt1	Pt2	NB
1	96	90.5	0	0.25	43.25
2	99.25	46.5	0	0	99
3	347.8	50.25	0	0	154.5
4	89.75	61.25	0.5	0.5	134.5
5	154.5	79.5	0	0	76.75
6	116.5	49	0	0	82
7	159.3	69.75	0.25	0.25	75.25
8	78.75	52.25	0	0	302.3
9	218.3	35.25	0	0	35.75
10	109.5	61.5	0	0	130.8
Average	147	59.58	0.075	0.1	113.4

Simulation Data for 30 % Car1 - Model Scenario S1i

Travel Time

No	EB	SB	NB	Pt1	Pt2
	Link No				
1	40.8	36.1	44.8	3.9	3.4
2	51.1	33.2	65	3.9	3.4
3	152.3	41.3	65.1	4.1	3.6
4	62.1	37.7	81.9	4.1	3.5
5	58.8	39	103.4	4.1	3.5
6	45.7	35.1	38.7	4	3.5
7	51.1	33.2	65	3.9	3.4
8	58.9	34.3	133.8	4	3.6
9	86.4	35	48.7	4.1	3.6
10	55.2	36.2	63.6	4	3.4
Average	66.24	36.11	71	4.01	3.49

Delay

No	EB	SB	NB	Pt1	Pt2
	Link No				
1	22.2	16.9	32.3	0.8	0.6
2	32.4	13.9	52.7	0.8	0.7
3	133.9	22.1	52.6	1	0.8
4	43.4	18.4	69.4	1	0.7
5	40.1	19.7	90.9	1	0.8
6	27	15.8	26.3	0.9	0.7
7	38.5	13.9	29.7	0.8	0.7
8	40.3	15	121.4	0.9	0.8
9	67.8	15.7	36.3	1	0.8
10	36.6	17	51.2	0.9	0.7
Average	48.22	16.84	56.28	0.91	0.73

Queue Length

No	EB	SB	Pt1	Pt2	NB
	Link No				
1	51.25	56	0	0	43.5
2	89.25	32.25	0	0.25	81.5
3	571	70.25	0.25	0	64.75
4	120	62.75	0.25	0.25	106.5
5	118.5	63	0	0	129.8
6	69.75	41.75	0	0	32.25
7	106.8	33.5	0	0	37.5
8	109.3	44.25	0	0	196
9	245.3	34.75	0	0	44.25
10	97.5	48.5	0.25	0.25	74.25
Average	157.9	48.7	0.075	0.075	81.03

Simulation Data for 40 % Car1 - Model Scenario S1i

Travel Time

No	Link No EB	SB	NB	Pt1	Pt2
1	41.1	35.7	37.1	3.9	3.3
2	51.5	36.8	59.5	4	3.4
3	65.5	34	74.4	3.9	3.4
4	39.5	34	66.1	3.9	3.5
5	50.5	37.5	49.5	4	3.5
6	50.7	29.8	33.6	4	3.5
7	51.5	36.8	59.5	4	3.4
8	50.3	31.9	89.1	3.9	3.4
9	67.7	36.1	33.9	4	3.5
10	50.4	35.5	64.3	4	3.5
Average	51.87	34.81	56.7	3.96	3.44

Delay

No	Link No EB	SB	NB	Pt1	Pt2
1	22.5	16.5	24.6	0.8	0.6
2	32.8	17.5	47.1	0.9	0.7
3	46.9	14.8	61.9	0.9	0.7
4	20.7	14.8	53.6	0.9	0.8
5	31.8	18.2	37	1	0.8
6	32.1	10.5	21.1	1	0.8
7	38.4	13.1	29.6	0.9	0.7
8	31.6	12.7	76.8	0.9	0.7
9	49.1	16.7	21.5	0.9	0.7
10	31.8	16.2	51.9	1	0.8
Average	33.77	15.1	42.51	0.92	0.73

Queue Length

No	Link No EB	SB	Pt1	Pt2	NB
1	51.25	47.5	0	0.25	32.25
2	94	69.5	0.5	0.25	76
3	148	50.75	0.25	0.25	78.5
4	49	37	0	0	80
5	95	77.75	0	0	48.25
6	86.75	15.75	0.25	0.25	26.25
7	107.8	35.5	0	0	39.75
8	86.25	26.75	0	0	124.5
9	167	45.75	0	0	23.5
10	85.25	37.5	0	0	74.75
Average	97.03	44.38	0.1	0.1	60.38

Simulation Data for 50 % Car1 - Model Scenario S1i

Travel Time

No	Link No EB	SB	NB	Pt1	Pt2
1	37	35.3	31.6	4	3.4
2	46.5	32.1	45.9	3.8	3.4
3	111.1	31	81.2	4.2	3.5
4	49.4	35.3	49.6	4.1	3.5
5	45.8	35	46.4	4	3.4
6	46.5	29.5	40.1	4	3.5
7	46.5	32.1	45.9	3.8	3.4
8	46.4	40.1	99.4	4	3.5
9	61.7	31.7	36.4	4	3.4
10	41	34.7	45.3	4	3.4
Average	53.19	33.68	52.18	3.99	3.44

Delay

No	Link No EB	SB	NB	Pt1	Pt2
1	18.4	16	19	1	0.7
2	27.8	12.8	33.6	0.8	0.8
3	92.7	11.7	68.8	1.2	0.9
4	30.7	16	37.2	1.1	0.8
5	27.1	15.7	33.9	1	0.8
6	27.9	10.2	27.6	1	0.8
7	37.6	12.4	21.2	1	0.8
8	27.7	20.8	87	1.1	0.8
9	43	12.4	24	1	0.7
10	22.3	15.4	32.8	1.1	0.8
Average	35.52	14.34	38.51	1.03	0.79

Queue Length

No	Link No EB	SB	Pt1	Pt2	NB
1	39.75	51.75	0	0.25	24.5
2	74.25	31	0	0.5	49.75
3	371.5	26.5	0.25	0.25	89
4	79.75	55.75	0	0	55.75
5	75.25	54.5	0.25	0.25	42.75
6	73.75	17	0.25	0.25	35
7	104.8	23	0.25	0.25	26.5
8	71	96.5	0	0	143.5
9	135.8	28.25	0.25	0.25	30.75
10	54	41.75	0.25	0.25	47.5
Average	108	42.6	0.15	0.225	54.5

Simulation Data for 60 % Car1 - Model Scenario S1i

Travel Time

No	EB	SB	NB	Pt1	Pt2
	Link No				
1	34.1	35.7	31.9	4.2	3.4
2	42	33	32.7	4	3.5
3	59.1	31.4	49.8	4.1	3.5
4	41.9	36.7	33.3	4.1	3.5
5	34.1	32.5	43.8	4	3.4
6	40.7	27.4	31.8	3.9	3.4
7	42	33	32.7	4	3.5
8	44.2	30.5	59.6	4	3.5
9	49.9	29.1	27	3.9	3.4
10	38.1	32.3	55.4	4.1	3.5
Average	42.61	32.16	39.8	4.03	3.46

Delay

No	EB	SB	NB	Pt1	Pt2
	Link No				
1	15.5	16.5	19.3	1.2	0.8
2	23.3	13.6	20.3	1	0.8
3	40.6	12.1	37.4	1.2	0.9
4	23.2	17.4	20.8	1.2	0.9
5	15.3	13.1	31.3	1.1	0.8
6	22.1	8	19.3	1	0.8
7	31.7	11.6	18.3	1.1	0.8
8	25.5	11.1	47.2	1.1	0.9
9	31.2	9.8	14.6	1	0.8
10	19.4	13	42.9	1.1	0.9
Average	24.78	12.62	27.14	1.1	0.84

Queue Length

No	EB	SB	Pt1	Pt2	NB
	Link No				
1	32.25	58	1	0	26
2	62.5	42.5	0.25	0.25	27.5
3	122.8	23.25	0	0.75	46.5
4	57.75	47.75	0.25	0.25	29
5	38.75	42	0.25	0.25	41.5
6	54.75	13	0	0	23.5
7	86.75	29.75	0.5	0.5	23.25
8	63.75	22	0.5	0.5	71.75
9	89	18.25	0	0	19
10	47.75	30	0	0	61.75
Average	65.6	32.65	0.275	0.25	36.98

Simulation Data for 75 % Car1 - Model Scenario S1i

Travel Time

No	Link No EB	SB	NB	Pt1	Pt2
1	32.9	31.7	22.9	4.1	3.4
2	32.7	26.5	26.5	3.8	3.3
3	49.9	32.2	39.5	4.2	3.6
4	30.7	29.5	34.6	3.8	3.3
5	34.5	31.4	23.6	4	3.4
6	35.4	27.6	27.9	4.1	3.4
7	32.7	26.5	26.5	3.8	3.3
8	36.2	28.3	35.9	4	3.5
9	42	30.5	24	4	3.4
10	42.4	33.2	30.4	4.5	3.6
Average	36.94	29.74	29.18	4.03	3.42

Delay

No	Link No EB	SB	NB	Pt1	Pt2
1	14.3	12.4	10.3	1.2	0.9
2	13.9	7.1	14.1	0.9	0.7
3	31.3	12.8	27	1.3	1
4	11.9	10.2	22.1	1	0.8
5	15.7	12.1	11.1	1.1	0.8
6	16.7	8.3	15.5	1.2	0.8
7	21.9	12.2	16.2	1.3	0.9
8	17.5	9	23.4	1.1	0.9
9	23.3	11.2	11.6	1.2	0.8
10	23.7	13.9	17.9	1.6	1
Average	19.02	10.92	16.92	1.19	0.86

Queue Length

No	Link No EB	SB	Pt1	Pt2	NB
1	30.75	33.25	0.5	0.5	12
2	31.5	6.5	0	0.25	18.25
3	92	29.25	0.75	0.5	31
4	24.75	26.75	0.25	0.25	30.75
5	40.25	36	0.5	0.5	12.25
6	40	11.75	0.25	0.25	17.75
7	53.25	27	0.5	0.5	20.5
8	41.5	16.5	0.25	0.25	33.5
9	63.75	21.75	0.75	0.75	14.75
10	62.75	36.5	1.75	1.75	25
Average	48.05	24.53	0.55	0.55	21.58

Simulation Data for 80 % Car1 - Model Scenario S1i

Travel Time

No	Link No EB	SB	NB	Pt1	Pt2
1	29.4	27.9	33	3.9	3.3
2	32.3	28.4	24.4	4.2	3.4
3	39.9	29.6	32	4.3	3.4
4	36.7	28.6	28.3	4	3.5
5	41.4	34.8	29.5	4.5	3.7
6	33.1	26.2	22.2	3.9	3.4
7	32.3	28.4	24.4	4.2	3.4
8	33.9	29.4	27.5	4.2	3.5
9	38	30.5	20.7	4.4	3.5
10	34.2	32.9	29.1	4.4	3.6
Average	35.12	29.67	27.11	4.2	3.47

Delay

No	Link No EB	SB	NB	Pt1	Pt2
1	10.8	8.6	20.4	1	0.8
2	13.5	9.1	11.9	1.3	0.9
3	21.3	10.3	19.6	1.4	0.9
4	17.9	9.2	15.8	1.2	1
5	22.7	15.5	16.9	1.6	1.1
6	14.4	6.9	9.7	1	0.8
7	15.8	8.2	9.9	1.2	0.9
8	15.1	10.1	15	1.4	1
9	19.2	11.2	8.2	1.6	0.9
10	15.5	13.6	16.6	1.6	1
Average	16.62	10.27	14.4	1.33	0.93

Queue Length

No	Link No EB	SB	Pt1	Pt2	NB
1	21.5	11.25	1.25	0.5	25.5
2	31.75	19	0.75	0.5	16
3	57.75	30	1	0	23
4	43	17	0.5	0.5	20.5
5	64.25	57.25	2.5	2.5	20.25
6	32.25	6.25	0	0	12.25
7	36.5	16.5	0.75	0.75	12
8	35.75	17.25	1.75	1.75	20.25
9	50.25	19.75	1.75	1.75	7.5
10	38.25	25	1	1	21
Average	41.13	21.93	1.125	0.925	17.83

Simulation Data for 90 % Car1 - Model Scenario S1i

Travel Time

No	EB	SB	NB	Pt1	Pt2
	Link No				
1	28	29.2	19.8	4	3.4
2	34.1	33.7	18.2	4.4	3.5
3	35.2	38.1	20.1	4.7	3.6
4	30.2	29.9	23.3	4.1	3.5
5	60.3	30.4	27.8	4.7	3.8
6	32.8	28	23.4	4.3	3.6
7	34.1	33.7	18.2	4.4	3.5
8	29.8	29.4	21.1	4.5	3.5
9	39.8	28.2	21.5	4.4	3.6
10	30.6	30	29.9	4.4	3.5
Average	35.49	31.06	22.33	4.39	3.55

Delay

No	EB	SB	NB	Pt1	Pt2
	Link No				
1	9.3	9.8	7.2	1.2	0.9
2	15.3	14.4	5.7	1.6	1
3	16.6	18.8	7.5	1.9	1.1
4	11.5	10.5	10.8	1.3	1
5	41.6	11.1	15.2	1.9	1.3
6	14.1	8.6	10.9	1.5	1.1
7	8.3	9.1	6.8	1.2	1
8	11.1	10.1	8.6	1.7	1.1
9	21.1	8.8	9	1.6	1.1
10	11.8	10.7	17.4	1.6	1
Average	16.07	11.19	9.91	1.55	1.06

Queue Length

No	EB	SB	Pt1	Pt2	NB
	Link No				
1	17.75	17.75	1	0.75	8
2	35	42.5	1.75	0.25	6.75
3	42.25	69	3	0.5	7.25
4	25.25	26.75	1	1	13.5
5	141.5	29.25	4.25	4.25	19
6	33.25	12.25	2	2	13
7	14.5	15.5	1	1	7.5
8	23.75	21.75	1.25	1.25	10.5
9	56.75	11.25	2.25	2.25	10
10	27.25	15.5	1.25	1.25	23.75
Average	41.73	26.15	1.875	1.45	11.93

Simulation Data for 100 Car1 - Model Scenario S1i

Travel Time

No	Link No				
	EB	SB	NB	Pt1	Pt2
1	27.9	28.2	18.2	4.2	3.5
2	52.1	28.7	18.8	4.8	3.8
3	43.2	33	25.7	4.9	3.8
4	24.1	26.6	24.6	4	3.5
5	30	28.4	18.9	4.3	3.5
6	29.8	26	16.5	4.2	3.4
7	52.1	28.7	18.8	4.8	3.8
8	27.9	29.7	20.1	4.2	3.4
9	30.3	28.1	17.6	4.2	3.3
10	31.2	28.3	22.4	4.4	3.5
Average	34.86	28.57	20.16	4.4	3.55

Delay

No	Link No				
	EB	SB	NB	Pt1	Pt2
1	9.3	8.9	5.6	1.5	1.1
2	33.3	9.3	6.4	2.1	1.3
3	24.6	13.8	13.2	2.1	1.3
4	5.4	7.2	12.1	1.2	1
5	11.2	9.1	6.3	1.5	1.1
6	11.1	6.6	4	1.4	0.9
7	7.7	7.2	3.8	1.3	0.8
8	9.1	10.4	7.6	1.4	1
9	11.6	8.7	5.1	1.5	0.9
10	12.5	8.9	9.9	1.6	1.1
Average	13.58	9.01	7.4	1.56	1.05

Queue Length

No	Link No				
	EB	SB	Pt1	Pt2	NB
1	17.25	22.25	1.75	1.25	6.5
2	118.8	21.25	11	4	7.25
3	71	38.25	2.5	2.25	15.5
4	9	12	1	1	16.25
5	27	21	1.75	1.75	7
6	25.25	7.25	1.25	1.25	3.75
7	15.5	8	1	1	3.25
8	18.75	18.25	0.75	0.75	9.5
9	27.25	15	1	1	4.75
10	29.5	17.5	2.75	2.75	15
Average	35.93	18.08	2.475	1.7	8.875

Summary of Simulation Data - Model Scenario S1i

Travel Time

%	Link No EB	SB	NB	Pt1	Pt2
0	93.16	43.72	146.5	3.87	3.41
2	94.37	41.38	137.1	3.86	3.39
4	90.71	43.91	114.7	3.86	3.43
6	85.32	43.75	138.7	3.89	3.42
8	84.05	42.08	115.6	3.91	3.45
10	79.81	43.26	113.4	3.89	3.41
12	75.79	41.81	118.2	3.95	3.44
14	73.59	42.01	101	3.92	3.45
16	74.08	39.32	96.91	3.93	3.46
18	72.24	41	96.06	3.98	3.45
20	72.5	39.34	95.74	3.92	3.42
25	64.64	37.73	88.12	3.89	3.44
30	66.24	36.11	71	4.01	3.49
40	51.87	34.81	56.7	3.96	3.44
50	53.19	33.68	52.18	3.99	3.44
60	42.61	32.16	39.8	4.03	3.46

Delay

%	Link No EB	SB	NB	Pt1	Pt2
0	79.78	26.64	132.2	0.67	0.52
2	77.82	22.87	121.8	0.62	0.52
4	71.06	25.37	100.3	0.66	0.54
6	67.65	25.54	127.3	0.69	0.59
8	68.18	24.33	101.9	0.7	0.61
10	64.18	24.58	103.6	0.71	0.6
12	60.11	22.75	108.4	0.75	0.59
14	56.38	23.36	88.23	0.75	0.6
16	56.23	20.63	82.49	0.78	0.61
18	54.19	21.18	79.71	0.8	0.62
20	53.08	20.38	81.27	0.78	0.62
25	47.74	18.46	74.83	0.79	0.65
30	48.22	16.84	56.28	0.91	0.73
40	33.77	15.1	42.51	0.92	0.73
50	35.52	14.34	38.51	1.03	0.79
60	24.78	12.62	27.14	1.1	0.84

Queue Length

%	Link No EB	SB	Pt1	Pt2	NB
0	276.6	120.6	0	0	218.9
2	278.1	90.3	0	0	200.9
4	245.7	101.5	0	0	160.2
6	229.7	115.8	0.025	0	204.8
8	233.8	100.1	0.025	0.025	160.5
10	215.5	102.4	0.025	0	166
12	200.9	91.75	0	0	175
14	186.5	96.78	0.05	0.05	140.3
16	182.9	69.63	0	0	125.5
18	175.8	70.9	0.025	0	127.6
20	170.6	80.05	0.025	0.025	127.6
25	147	59.58	0.075	0.1	113.4
30	157.9	48.7	0.075	0.075	81.03
40	97.03	44.38	0.1	0.1	60.38
50	108	42.6	0.15	0.225	54.5
60	65.6	32.65	0.275	0.25	36.98

75	36.94	29.74	29.18	4.03	3.42
80	35.12	29.67	27.11	4.2	3.47
90	35.49	31.06	22.33	4.39	3.55
100	34.86	28.57	20.16	4.4	3.55
Average					

75	19.02	10.92	16.92	1.19	0.86
80	16.62	10.27	14.4	1.33	0.93
90	16.07	11.19	9.91	1.55	1.06
100	13.58	9.01	7.4	1.56	1.05
Average					

75	48.05	24.53	0.55	0.55	21.58
80	41.13	21.93	1.125	0.925	17.83
90	41.73	26.15	1.875	1.45	11.93
100	35.93	18.08	2.475	1.7	8.875
Average					

APPENDIX 3: RESULTS FOR S2 SIMULATION SCENARIO

Simulation Data for 80 ft Diameter at 0 % Car1 - Model Scenario S2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	61.4	52.1	72	2.2	1.7	27.5
2	84.1	43	105	2.1	1.7	23.3
3	199	45.4	91.4	2.1	1.7	26.5
4	94.9	46.2	151	2.2	1.7	22.7
5	176	46.6	80.5	2.2	1.8	33.7
6	123	36.5	68.7	2.2	1.7	26.4
7	84.1	43	105	2.1	1.7	23.3
8	110	58	127	2.2	1.8	26.4
9	123	44.9	85.3	2.2	1.7	24.2
10	85.1	54.1	147	2.2	1.8	24.1
Average	114	47	103	2.17	1.73	25.8

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	42.5	32.8	58.7	0.4	0.3	12.3
2	65	23.6	92	0.3	0.3	8.1
3	180	26	78.1	0.3	0.3	11.3
4	76	26.9	138	0.4	0.3	7.6
5	157	27.2	67.2	0.4	0.3	18.5
6	104	17.1	55.5	0.4	0.3	11.2
7	119	34.4	83.3	0.4	0.3	8.5
8	91	38.6	114	0.4	0.3	11.3
9	104	25.5	72.2	0.4	0.3	9.1
10	66.2	34.8	134	0.4	0.3	9
Average	100	28.7	89.3	0.38	0.3	10.7

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	105	134	16.5	0	1.75	81
2	211	106	6.25	0	2	141
3	756	92.5	12.3	0	2	95.5
4	219	120	5.75	5.75	1.75	214
5	675	93.5	24	24	2.25	91
6	370	35	12.8	12.8	2.25	72.5
7	411	185	7.5	7.5	1.75	136
8	305	214	11.8	11.8	2	184
9	394	104	8.5	8.5	2	97
10	206	163	9	9	1.75	223
Average	365	125	11.4	7.93	1.95	133

Simulation Data for 100 ft Diameter at 0 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	58.6	49.3	76.8	2.7	2.1	25.6
2	63.8	40	94.5	2.7	2.1	20.8
3	183	44.1	86.8	2.7	2.2	24
4	82.7	50.9	101	2.7	2.2	23.5
5	130	42	158	2.7	2.1	24.7
6	92.2	36.1	64.3	2.7	2.2	23.9
7	63.8	40	94.5	2.7	2.1	20.8
8	130	45.2	126	2.7	2.2	22.3
9	95.3	45.1	64	2.7	2.1	22.2
10	82.7	43.2	70.1	2.8	2.2	22.6
Average	98.2	43.6	93.5	2.71	2.15	23

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	39.9	30	63.8	0.4	0.3	10.8
2	44.9	20.8	81.6	0.5	0.3	5.9
3	164	24.8	73.8	0.5	0.4	9.1
4	63.9	31.7	87.6	0.5	0.4	8.6
5	111	22.8	145	0.5	0.3	9.8
6	73.5	16.8	51.4	0.5	0.4	9
7	60.7	33.9	58	0.4	0.3	9.5
8	112	26	113	0.5	0.3	7.5
9	76.6	25.8	51.2	0.5	0.3	7.3
10	64	24	57.1	0.5	0.4	7.8
Average	81	25.7	78.2	0.48	0.34	8.53

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	98.8	161	12.3	0	0	95.3
2	131	79.5	4.25	0	0	138
3	664	81	8.75	0	0	99
4	183	197	8	8	0	143
5	421	86.5	10.8	10.8	0	218
6	224	40	8.75	8.75	0	75.3
7	179	177	8.25	8.25	0	83.8
8	414	77	5.5	5.5	0	208
9	257	104	6	6	0	71.5
10	200	99.3	7.25	7.25	0	87.3
Average	277	110	7.98	5.45	0	122

Simulation Data for 120 ft Diameter at 0 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	67.6	48.2	83.4	3.3	0	18.9
2	68.6	42.3	87.6	3.3	0	19
3	115	44.5	179	3.3	0	21.5
4	65.4	46.3	84	3.3	0	19.7
5	105	40.8	189	3.3	0	21.1
6	117	37.4	56	3.4	0	21.3
7	68.6	42.3	87.6	3.3	0	19
8	110	62.6	164	3.4	0	19.2
9	91.4	43.1	85.7	3.3	0	18.8
10	73.8	56.9	149	3.4	0	19.7
Average	88.2	46.4	117	3.33	0	19.8

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	49.3	29.2	71	0.6	0	4.4
2	50.2	23.3	75.2	0.6	0	4.4
3	96.4	25.5	167	0.6	0	7
4	47	27.3	71.6	0.6	0	5.2
5	86.7	21.9	177	0.6	0	6.6
6	98.6	18.3	43.5	0.6	0	6.8
7	53.8	32.3	78.8	0.6	0	5.2
8	92	43.7	152	0.6	0	4.8
9	73.1	24.1	73.5	0.6	0	4.2
10	55.5	38	137	0.6	0	5.2
Average	70.3	28.4	105	0.6	0	5.38

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	134	103	3	0	0	110
2	155	79.8	2.5	0	0	128
3	389	93.5	6	0	0	227
4	129	126	3.5	3.5	0	120
5	312	90.8	5.5	5.5	0	325
6	361	59.8	6.25	6.25	0	71.8
7	156	142	3.75	3.75	0	120
8	347	324	2.75	2.75	0	324
9	253	90	2.75	2.75	0	111
10	165	188	3.75	3.75	0	236
Average	240	130	3.98	2.83	0	177

Simulation Data for 140 ft Diameter at 0 % Car1 - Model Scenario S2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	75.9	43.7	105	3.9	3.4	20.2
2	59.3	43.4	128	3.8	3.4	17.9
3	158	44	155	3.8	3.4	18.5
4	74.1	51.1	135	3.8	3.4	18.3
5	161	38.4	104	3.9	3.4	18.9
6	70.8	37.3	118	3.8	3.4	18.6
7	59.3	43.4	128	3.8	3.4	17.9
8	123	48.9	192	3.8	3.4	17.4
9	93.1	40.1	95.4	3.8	3.4	18
10	80	47.6	174	3.9	3.5	17.7
Average	95.5	43.8	133	3.83	3.41	18.3

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	57.8	25	93.3	0.6	0.5	5.8
2	41.1	24.8	116	0.6	0.5	3.6
3	140	25.4	143	0.6	0.5	4.2
4	55.9	32.4	123	0.6	0.5	4
5	143	19.8	91.4	0.6	0.5	4.6
6	52.7	18.6	106	0.6	0.5	4.3
7	78.6	31.6	75.3	0.6	0.5	4.2
8	105	30.3	180	0.6	0.5	3.2
9	75	21.5	83.4	0.6	0.5	3.7
10	61.9	29	162	0.6	0.6	3.5
Average	81.2	25.8	117	0.6	0.51	4.11

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	162	104	6.25	0	0	133
2	116	106	2.75	0	0	204
3	545	139	3.75	0	0	181
4	151	184	3.5	3.5	0	192
5	650	61.3	3.25	3.25	0	139
6	153	63.5	2.5	2.5	0	150
7	239	142	4	4	0	104
8	391	172	1.5	1.5	0	349
9	258	70.5	2.75	2.75	0	116
10	187	141	2.5	2.5	0	320
Average	285	118	3.28	2	0	189

Simulation Data for 160 ft Diameter at 0 % Car1 - Model Scenario S2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	45.6	40.5	56.1	4.2	3.7	19.1
2	61.8	34.2	102	4.2	3.6	16.9
3	103	34.3	72.2	4.2	3.7	17.8
4	54.6	36.4	85.6	4.3	3.7	17.2
5	107	42.8	120	4.2	3.7	18.7
6	62.4	32.3	66.6	4.2	3.7	17.6
7	61.8	34.2	102	4.2	3.6	16.9
8	73.6	43.8	140	4.3	3.7	17.1
9	66	34.2	71.7	4.2	3.7	16.7
10	61.1	48.5	85.2	4.4	3.8	16.9
Average	69.6	38.1	90.1	4.24	3.69	17.5

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	27.7	22	44.1	0.7	0.5	4.9
2	43.8	15.6	89.8	0.6	0.5	2.8
3	85.1	15.8	60.2	0.6	0.5	3.7
4	36.6	17.8	73.6	0.7	0.5	3.1
5	88.7	24.3	108	0.6	0.5	4.6
6	44.5	13.7	54.6	0.6	0.5	3.5
7	62.8	20.6	57	0.6	0.5	3.3
8	55.6	25.4	128	0.7	0.6	3.2
9	48	15.7	59.8	0.6	0.5	2.6
10	43.2	30	73.3	0.8	0.6	2.9
Average	53.6	20.1	74.8	0.65	0.52	3.46

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	66	83.3	5.25	0	0	61.5
2	136	49.3	2.25	0	0.25	144
3	354	40.8	3.5	0	0	73
4	98.8	49	2.75	2.75	0	112
5	347	124	5	5	0	164
6	128	30	3.5	3.5	0	76.8
7	191	77.8	3	3	0	79
8	174	103	3	3	0	248
9	152	36.8	2.25	2.25	0	80
10	131	135	2.75	2.75	0	120
Average	178	72.8	3.33	2.23	0.03	116

Simulation Data for 180 ft Diameter at 0 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	46.8	31	40.5	4.5	3.8	19.1
2	74.3	29.3	45.9	4.5	3.9	17.1
3	110	29.1	53.7	4.5	3.9	18.3
4	64.5	30.8	63	4.5	3.9	17.6
5	122	28.5	132	4.5	3.9	18
6	57.4	24.8	52.1	4.6	4	18.3
7	74.3	29.3	45.9	4.5	3.9	17.1
8	55.9	32.9	112	4.5	3.9	17.4
9	71.1	28	47.4	4.5	3.9	17.4
10	61.5	33.2	70.1	4.6	4	16.5
Average	73.8	29.7	66.2	4.52	3.91	17.7

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	28.9	12.6	28.5	0.8	0.4	5.1
2	56.3	10.8	34.1	0.8	0.5	3.1
3	92.3	10.7	41.9	0.9	0.5	4.2
4	46.6	12.4	51.1	0.8	0.5	3.6
5	104	10.1	120	0.8	0.5	3.9
6	39.5	6.3	40.3	0.9	0.6	4.2
7	43.9	13.6	30.2	0.9	0.5	3.6
8	37.9	14.5	99.8	0.8	0.6	3.5
9	53.2	9.6	35.7	0.8	0.5	3.4
10	43.6	14.8	58.3	0.9	0.6	2.6
Average	54.6	11.5	54	0.84	0.52	3.72

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	65.3	40.8	3.75	0	0	36.5
2	181	33	1.5	0	0	48
3	348	21.3	2.5	0	0	48.5
4	124	37	2	2	0	73
5	288	28.8	3	3	0	104
6	104	7	2.25	2.25	0	52.8
7	120	44.5	2	2	0	35.8
8	98.8	40.5	1.75	1.75	0	161
9	161	11.5	1.75	1.75	0	41.5
10	132	36.3	1.25	1.25	0	84
Average	162	30.1	2.18	1.4	0	68.5

Simulation Data for 200 ft Diameter at 0 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	39.9	31	34.7	5	4.2	17.5
2	53.9	29.2	51	4.9	4.2	15.8
3	104	28.9	54.2	5	4.3	17.6
4	47.5	28.8	65.1	5	4.4	17
5	58.7	28	78.5	4.9	4.3	16.8
6	53.7	26.1	53.2	4.9	4.3	17.3
7	53.9	29.2	51	4.9	4.2	15.8
8	78.1	31	100	5	4.3	17.4
9	61.8	27	36.6	4.9	4.2	15.8
10	53.9	32.2	54.2	5.1	4.4	16.8
Average	60.5	29.1	57.9	4.96	4.28	16.8

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	22.1	12.6	23.1	0.9	0.5	3.7
2	36.1	10.8	39.5	0.9	0.6	1.9
3	86.4	10.5	42.6	0.9	0.6	3.7
4	29.7	10.4	53.6	0.9	0.6	3.2
5	40.9	9.6	66.9	0.9	0.6	3
6	35.9	7.6	41.6	0.8	0.6	3.4
7	37.5	14.2	27.3	1	0.6	3.1
8	60.3	12.5	88.6	0.9	0.6	3.6
9	44.1	8.5	25.2	0.8	0.5	2
10	36.2	13.8	42.7	1	0.7	3
Average	42.9	11.1	45.1	0.9	0.59	3.06

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	47.5	35.8	2	0	0	27.5
2	100	31.3	0.75	0	0	56.3
3	310	21.8	2.25	0	0	48.5
4	73	22.3	2	2	0	76.3
5	128	20	1.25	1.25	0	91
6	97	11.3	1.75	1.75	0	55
7	101	31.3	1.25	1.25	0	32
8	194	35	2	2	0	143
9	129	8.5	0.75	0.75	0	27.8
10	98.8	33	1.25	1.25	0	58.3
Average	128	25	1.53	1.03	0	61.6

Summary of Simulation Data for 0 % Car1 - Model Scenario S2

Travel Time

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
80	114	47	103	2.17	1.73	25.8
100	98.2	43.6	93.5	2.71	2.15	23
120	88.2	46.4	117	3.33	3.15	19.8
140	95.5	43.8	133	3.83	3.41	18.3
160	69.6	38.1	90.1	4.24	3.69	17.5
180	73.8	29.7	66.2	4.52	3.91	17.7
200	60.5	29.1	57.9	4.96	4.28	16.8
Average						

Delay

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
80	100	28.7	89.3	0.38	0.3	10.7
100	81	25.7	78.2	0.48	0.34	8.53
120	70.3	28.4	105	0.6	0.6	5.38
140	81.2	25.8	117	0.6	0.51	4.11
160	53.6	20.1	74.8	0.65	0.52	3.46
180	54.6	11.5	54	0.84	0.52	3.72
200	42.9	11.1	45.1	0.9	0.59	3.06
Average						

Queue Length

	Link No					
Average	EB	SB	WB	Pt1	Pt2	NB
80	365	125	11.4	7.93	1.95	133
100	277	110	7.98	5.45	0	122
120	240	130	3.98	2.83	0	177
140	285	118	3.28	2	0	189
160	178	72.8	3.33	2.23	0.03	116
180	162	30.1	2.18	1.4	0	68.5
200	128	25	1.53	1.03	0	61.6
Average						

Simulation Data for 80 ft Diameter at 10 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	75.1	47.9	52.4	2.2	1.7	33.4
2	69.5	38.9	125	2.2	1.8	23.7
3	174	45.9	70.1	2.1	1.7	22.1
4	70.2	46	116	2.1	1.7	24.3
5	123	51.3	105	2.2	1.8	27
6	82	36.1	66.9	2.1	1.7	25.1
7	69.5	38.9	125	2.2	1.8	23.7
8	124	36.8	175	2.1	1.7	24.4
9	129	52.1	62.5	2.2	1.7	23.6
10	78.9	44.7	163	2.2	1.8	23.6
Average	99.4	43.9	106	2.16	1.74	25.1

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	56.7	28.9	39.3	0.4	0.4	18.6
2	50.9	19.9	112	0.5	0.4	8.7
3	155	27	57.1	0.4	0.4	7.3
4	51.5	27.1	103	0.4	0.3	9.4
5	104	32.3	91.8	0.5	0.4	12
6	63.6	17	54	0.4	0.4	10.2
7	86	33.6	64.4	0.5	0.4	8.7
8	105	17.9	162	0.4	0.3	9.6
9	111	33.1	49.7	0.4	0.4	8.8
10	60.4	25.7	151	0.4	0.4	8.7
Average	84.4	26.3	88.4	0.43	0.38	10.2

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	159	103	28.8	0	2	52.3
2	154	57.3	7.75	0	1.75	187
3	629	114	6	0	2	65.3
4	139	128	8.5	8.5	2	154
5	372	149	13	13	2.5	126
6	187	33	9.5	9.5	2	71.5
7	275	181	7.75	7.75	2.25	90.5
8	345	48.5	8.75	8.75	2.5	300
9	402	143	7.75	7.75	2.25	65.5
10	188	96	9	9	1.75	239
Average	285	105	10.7	6.43	2.1	135

Simulation Data for 100 ft Diameter at 10 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	64.8	63.2	40.5	2.8	3.1	19.9
2	65.3	42.1	56	2.8	3	19.4
3	160	45.8	65.6	2.8	3.1	20.2
4	56.9	50.2	85.6	2.7	3	20.8
5	155	44.6	48.7	2.8	3.1	20.4
6	65.9	39	44.4	2.8	3.1	22
7	65.3	42.1	56	2.8	3	19.4
8	113	42.3	125	2.8	3	20.5
9	77.6	46.2	36.3	2.8	3	20.2
10	66.4	49	58.8	2.8	3.1	19.9
Average	89	46.5	61.6	2.79	3.05	20.3

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	46.7	44.3	27.7	0.6	0.8	5.3
2	46.9	23.2	43.4	0.6	0.7	4.6
3	142	26.9	53	0.6	0.7	5.6
4	38.6	31.4	72.9	0.6	0.7	6.3
5	137	25.7	36.1	0.6	0.8	5.7
6	47.8	20.2	31.9	0.6	0.8	7.3
7	60	37.9	30.4	0.7	0.8	6
8	95	23.4	112	0.6	0.7	5.9
9	59.4	27.3	23.7	0.6	0.7	5.7
10	48.1	30.1	46.3	0.6	0.7	5.3
Average	72.1	29	47.7	0.61	0.74	5.77

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	125	219	4	0	0	37
2	147	76.3	2.75	0	0	64
3	581	98.8	4.75	0	0	61.8
4	101	166	5	5	0.25	110
5	591	94	4.5	4.5	0.25	45.8
6	132	63.3	5.25	5.25	0.25	41.3
7	176	200	4.25	4.25	0	38.3
8	309	72.8	3.75	3.75	0	185
9	196	102	4.75	4.75	0	25.8
10	142	125	3.75	3.75	0	64.5
Average	250	122	4.28	3.13	0.08	67.3

Simulation Data for 120 ft Diameter at 10 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	60.7	59.4	53.3	3.4	0	20.6
2	79.8	35.9	98.1	3.3	0	19.6
3	107	39.6	150	3.4	0	18.7
4	57.3	45	75.6	3.3	0	20.2
5	98.9	45.5	165	3.4	0	19.8
6	56.3	35.9	53	3.3	0	20.7
7	79.8	35.9	98.1	3.3	0	19.6
8	70	45.2	161	3.3	0	19
9	86.3	41.4	75.8	3.4	0	18
10	67.2	49.5	139	3.4	0	19.5
Average	76.4	43.3	107	3.35	0	19.6

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	42.9	40.9	41	0.7	0	6.3
2	61.8	17.3	85.9	0.7	0	5.2
3	89.4	21	137	0.7	0	4.5
4	39.3	26.6	63.4	0.7	0	6
5	81	26.9	153	0.7	0	5.4
6	38.4	17.2	41	0.6	0	6.4
7	47.8	31.4	55.2	0.7	0	6.9
8	52.1	26.8	149	0.7	0	4.7
9	68.4	22.8	63.8	0.7	0	3.9
10	49.3	30.8	127	0.7	0	5.2
Average	57	26.2	91.7	0.69	0	5.45

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	128	280	4.75	0	0.25	64
2	211	46.3	3.5	0	0.25	153
3	327	66.8	3	0	0	181
4	106	94.8	4.5	4.5	0	105
5	291	122	3.5	3.5	0	243
6	104	46.5	5	5	0	62
7	131	175	5.75	5.75	0	83.8
8	151	110	3.25	3.25	0	296
9	257	73.8	2.25	2.25	0	95.3
10	151	135	3.25	3.25	0	207
Average	186	115	3.88	2.75	0.05	149

Simulation Data for 140 ft Diameter at 10 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	63.9	45.8	58.5	3.8	3.4	18.2
2	52.7	37.1	118	3.8	3.4	16.7
3	125	39.7	92.7	3.9	3.4	18.2
4	55.9	40.2	103	3.7	3.4	18.8
5	85.4	49.7	138	3.9	3.4	18.8
6	50.9	38.3	68.4	3.8	3.3	19.3
7	52.7	37.1	118	3.8	3.4	16.7
8	62.4	38.3	174	3.7	3.3	18.5
9	81.4	40.6	72.5	3.9	3.4	16.8
10	54.4	43.9	110	3.9	3.5	19
Average	68.4	41.1	105	3.82	3.39	18.1

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	46.3	27.5	46.5	0.6	0.6	4.2
2	34.8	18.9	106	0.7	0.6	2.5
3	107	21.4	80.8	0.7	0.6	4.2
4	38.1	22	90.6	0.6	0.6	4.9
5	67.7	31.5	126	0.7	0.6	4.7
6	33.2	20	56.7	0.7	0.6	5.4
7	54.4	27.9	61	0.8	0.6	5.6
8	44.7	20.2	163	0.6	0.5	4.6
9	63.6	22.3	60.8	0.7	0.6	2.9
10	36.7	25.6	98.2	0.8	0.6	5
Average	52.7	23.7	88.9	0.69	0.59	4.4

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	118	151	3.25	0	0	63.3
2	96	51	1.25	0	0	171
3	427	83.3	3.5	0	0	97.3
4	98	80.8	4	4	0	142
5	228	151	3.75	3.75	0	190
6	82.8	65.8	5.25	5.25	0	77.5
7	149	109	5.5	5.5	0	81.3
8	122	81.8	3.5	3.5	0	304
9	217	62.5	2	2	0	86
10	102	101	4.75	4.75	0	143
Average	164	93.7	3.68	2.88	0	136

Simulation Data for 160 ft Diameter at 10 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	55.1	38.4	45.7	4.2	3.6	18.5
2	56.1	33	57.4	4.2	3.6	17.4
3	111	29.7	94.8	4.2	3.6	17.7
4	49.9	39.3	88	4.1	3.6	17.9
5	61.1	36.1	62.4	4.2	3.7	17.7
6	46.1	30.9	40.8	4.2	3.6	18.5
7	56.1	33	57.4	4.2	3.6	17.4
8	51.4	35.9	151	4.1	3.6	17.5
9	65.8	39.1	43.2	4.3	3.6	17.6
10	50.2	36	70.7	4.3	3.8	17.8
Average	60.3	35.1	71.2	4.2	3.63	17.8

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	37.5	20.1	33.8	0.7	0.6	4.4
2	38.3	14.8	45.6	0.8	0.6	3.3
3	93.7	11.4	83	0.7	0.6	3.7
4	32.1	21	76.2	0.7	0.6	3.9
5	43.4	17.8	50.5	0.8	0.6	3.6
6	28.5	12.6	29.1	0.7	0.6	4.4
7	43.7	17.1	40.7	0.8	0.7	4.5
8	33.8	17.8	139	0.7	0.5	3.4
9	48.1	20.8	31.5	0.8	0.6	3.7
10	32.5	17.7	58.9	0.8	0.7	3.7
Average	43.2	17.1	58.9	0.75	0.61	3.86

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	92.3	78.3	3	0	0	43.8
2	112	38.3	2	0	0	66.3
3	347	26	3	0	0	102
4	82.8	85.3	2.5	2.5	0	114
5	129	61.3	2.5	2.5	0	66
6	71.3	24	3.25	3.25	0	36
7	120	44	3.75	3.75	0	52.3
8	90.8	64.3	2	2	0	258
9	148	56	2.5	2.5	0	36.5
10	85.5	40	3	3	0	84.3
Average	128	51.7	2.75	1.95	0	85.9

Simulation Data for 180 ft Diameter at 10 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	51.6	32.3	40.1	4.5	3.9	17.5
2	57.6	27	52.6	4.5	3.9	16.6
3	83	26.8	53.1	4.6	3.9	17.1
4	47.1	28.5	61	4.5	3.8	17
5	69.6	29.8	46.3	4.6	3.9	18.3
6	48.4	25.5	38.7	4.4	3.8	18.4
7	57.6	27	52.6	4.5	3.9	16.6
8	61.9	28.3	90.2	4.5	3.9	17.7
9	68.8	28.4	50.7	4.5	3.9	16.2
10	56.4	28.8	66.3	4.7	4	18
Average	60.2	28.2	55.2	4.53	3.89	17.3

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	34.2	14.2	28.4	0.9	0.6	3.7
2	40	8.9	41	1	0.7	2.8
3	65.5	8.7	41.4	1	0.6	3.3
4	29.4	10.5	49.3	0.9	0.5	3.3
5	52	11.7	34.7	1	0.6	4.5
6	31	7.4	27.2	0.9	0.5	4.5
7	45.4	13.4	31.3	1.1	0.7	3.9
8	44.4	10.3	78.6	0.9	0.6	4
9	51.3	10.4	39.2	1	0.6	2.6
10	38.9	10.7	54.8	1.1	0.7	4.3
Average	43.2	10.6	42.6	0.98	0.61	3.69

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	80.5	48.8	2.5	0	0	36
2	118	9.75	1.25	0	0	60
3	217	11	2	0	0	47.8
4	71.3	22.3	1.25	1.25	0	70
5	159	31	2.75	2.75	0	44
6	75.8	8.5	3	3	0	33.8
7	125	34.5	2.25	2.25	0	38.8
8	127	16	2.25	2.25	0	138
9	152	10.3	1.25	1.25	0	48.8
10	107	18.5	2.75	2.75	0	78.3
Average	123	21.1	2.13	1.55	0	59.5

Simulation Data for 200 ft Diameter at 10 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	49.9	30.3	34	5	4.2	16.4
2	44.3	26.4	33.8	4.9	4.2	16
3	71.6	26.1	52.6	5	4.2	16.3
4	42.2	28.3	43	4.9	4.2	16.6
5	54.9	28.6	48.5	5	4.3	17.1
6	44.4	25.9	34.6	4.9	4.2	16.9
7	44.3	26.4	33.8	4.9	4.2	16
8	42.4	27.2	39	4.9	4.2	15.9
9	69.1	28.4	34.1	5.1	4.2	15.6
10	43.7	30.7	48.1	5	4.3	17.6
Average	50.7	27.8	40.2	4.96	4.22	16.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	32.6	12.2	22.6	1	0.7	2.9
2	26.8	8.3	22.4	1	0.7	2.3
3	54.3	8.1	41.2	1.1	0.6	2.8
4	24.7	10.3	31.7	1	0.7	3
5	37.4	10.6	37.2	1	0.7	3.4
6	27.1	7.9	23.4	1	0.6	3.3
7	36.5	10.1	26.3	1.2	0.9	4
8	25.1	9.2	27.7	0.9	0.6	2.4
9	51.7	10.3	22.9	1.1	0.6	2.2
10	26.3	12.7	36.9	1	0.7	4
Average	34.3	9.97	29.2	1.03	0.68	3.03

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	78	27	1.5	0	0	27.8
2	66.8	17.3	1	0	0	29.8
3	172	13	1	0	0	48.3
4	56.3	19	1.5	1.5	0	42.5
5	109	31.8	2.25	2.25	0	45.5
6	65.3	8.75	1.75	1.75	0	28.3
7	95.5	22	1.75	1.75	0	31.5
8	60.5	19.3	1	1	0	36.3
9	156	10	1	1	0	24
10	64	22.5	2.25	2.25	0	49.8
Average	92.2	19.1	1.5	1.15	0	36.4

Summary of Simulation Data for 10 % Car1 - Model Scenario S2

Travel Time

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
80	99.4	43.9	106	2.16	1.74	25.1
100	89	46.5	61.6	2.79	3.05	20.3
120	76.4	43.3	107	3.35	3.15	19.6
140	68.4	41.1	105	3.82	3.39	18.1
160	60.3	35.1	71.2	4.2	3.63	17.8
180	60.2	28.2	55.2	4.53	3.89	17.3
200	50.7	27.8	40.2	4.96	4.22	16.4
Average						

Delay

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
80	84.4	26.3	88.4	0.43	0.38	10.2
100	72.1	29	47.7	0.61	0.74	5.77
120	57	26.2	91.7	0.69	0.6	5.45
140	52.7	23.7	88.9	0.69	0.59	4.4
160	43.2	17.1	58.9	0.75	0.61	3.86
180	43.2	10.6	42.6	0.98	0.61	3.69
200	34.3	9.97	29.2	1.03	0.68	3.03
Average						

Queue Length

	Link No					
Average	EB	SB	WB	Pt1	Pt2	NB
80	285	105	10.7	6.43	2.1	135
100	250	122	4.28	3.13	0.08	67.3
120	186	115	3.88	2.75	0.05	149
140	164	93.7	3.68	2.88	0	136
160	128	51.7	2.75	1.95	0	85.9
180	123	21.1	2.13	1.55	0	59.5
200	92.2	19.1	1.5	1.15	0	36.4
Average						

Simulation Data for 80 ft Diameter at 20 % Car1 - Model Scenario S2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	63	49.6	73.9	2.2	1.8	24.2
2	74.7	37.1	65.4	2.2	1.7	22.4
3	148	42.5	107	2.2	1.8	22.9
4	71.4	44.9	130	2.2	1.7	25.5
5	139	43.3	81.5	2.2	1.8	28.9
6	70.1	30.3	46	2.2	1.7	22.5
7	74.7	37.1	65.4	2.2	1.7	22.4
8	78.4	41.5	163	2.2	1.7	23.1
9	74.5	43	54.8	2.2	1.8	21.7
10	54.5	46.5	105	2.2	1.8	25.5
Average	84.9	41.6	89.2	2.2	1.75	23.9

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	44.9	30.9	61	0.5	0.4	9.6
2	56.4	18.5	52.7	0.5	0.4	7.8
3	130	24	94	0.6	0.5	8.3
4	53.2	26.4	117	0.5	0.4	10.9
5	121	24.7	68.8	0.5	0.4	14.4
6	52	11.6	33.4	0.5	0.4	8
7	69.5	23.6	33.5	0.6	0.4	5.8
8	60.3	23.1	151	0.5	0.4	8.7
9	56.3	24.4	42.2	0.6	0.4	7.4
10	36.5	28	92.6	0.6	0.4	10.9
Average	68	23.5	74.6	0.54	0.41	9.18

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	114	144	9.5	0	2.75	85.8
2	186	55.5	5.75	0	2.25	79.8
3	532	68	7.75	0	2.75	116
4	147	133	10.8	10.8	2	181
5	482	91	16.8	16.8	2.25	98.8
6	146	14.3	6.75	6.75	2.25	41
7	222	54.3	4	4	2	40.3
8	171	95.3	6.75	6.75	1.75	251
9	179	72.3	5.75	5.75	2	50.8
10	102	89.8	13	13	2	136
Average	228	81.7	8.68	6.38	2.2	108

Simulation Data for 100 ft Diameter at 20 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	49.6	39.3	56	2.7	2.2	21.2
2	57.3	35.7	66.1	2.7	2.1	20.7
3	130	35.1	88	2.8	2.2	22.1
4	52.8	36.2	101	2.7	2.2	22.6
5	84.4	47.5	54.8	2.7	2.2	24.6
6	58.9	32	41.3	2.7	2.1	21.3
7	57.3	35.7	66.1	2.7	2.1	20.7
8	51.9	38.6	93	2.7	2.2	22
9	67.6	36.1	36.6	2.7	2.1	20.2
10	49.1	40.8	56	2.7	2.2	23.5
Average	65.9	37.7	65.9	2.71	2.16	21.9

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	31.6	20.8	43.4	0.6	0.5	6.9
2	39.2	17.3	53.6	0.6	0.5	6.5
3	112	16.7	75.6	0.7	0.5	7.8
4	34.7	18	88.3	0.6	0.5	8.2
5	66.3	29.1	42.3	0.7	0.5	10.4
6	41	13.5	29	0.6	0.5	7
7	60.9	17.1	28.5	0.6	0.5	5.5
8	33.9	20.3	80.6	0.6	0.5	7.9
9	49.6	17.7	24.3	0.7	0.5	6.2
10	31.2	22.4	43.7	0.6	0.5	9.2
Average	50	19.3	50.9	0.63	0.5	7.56

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	75	58.5	6	0	0	66.3
2	113	29.3	4.5	0	0	94.5
3	447	35.5	7.75	0.25	0	96.5
4	87	58.5	6.5	6.5	0	146
5	222	142	9.75	9.75	0	58.3
6	113	23	5.5	5.5	0	39.8
7	185	45	4	4	0	38.5
8	88.3	67	7	7	0.25	135
9	150	36.3	5.5	5.5	0	32.3
10	78.8	87.3	10.3	10.3	0	65.3
Average	156	58.3	6.68	4.88	0.03	77.1

Simulation Data for 120 ft Diameter at 20 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	46.7	45.9	62	3.4	0	20.9
2	59	39.2	71.2	3.3	0	18.3
3	115	45.4	94.8	3.4	0	19
4	76.3	40.6	121	3.4	0	21.5
5	71.3	48.3	100	3.4	0	20
6	57.6	36.3	49.5	3.3	0	19.1
7	59	39.2	71.2	3.3	0	18.3
8	52.3	42.4	139	3.3	0	19.7
9	64.5	37.1	54.4	3.4	0	18
10	64.1	36.5	108	3.4	0	18.6
Average	66.6	41.1	87.1	3.36	0	19.3

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	29.1	27.7	50	0.8	0	6.9
2	41.3	21	59.3	0.8	0	4.3
3	97.6	27.2	82.8	0.8	0	5
4	58.6	22.5	109	0.9	0	7.5
5	53.6	30.1	88.2	0.8	0	6.1
6	40	18	37.7	0.7	0	5.1
7	43.1	26.4	26.5	0.8	0	4.3
8	34.8	24.3	127	0.8	0	5.9
9	46.9	19	42.6	0.9	0	4.4
10	46.7	18.3	95.9	0.8	0	4.6
Average	49.2	23.5	71.9	0.81	0	5.41

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	69.3	130	5	0	0	78.8
2	130	65.8	2.25	0	0	102
3	371	109	4.25	0	0	109
4	169	107	5.75	5.75	0	185
5	173	133	4	4	0	133
6	111	50.8	3.5	3.5	0.25	57.3
7	126	98.3	2.5	2.5	0	38
8	91	110	4	4	0.25	231
9	145	58.3	2.75	2.75	0	62.8
10	143	44.5	3	3	0	154
Average	153	90.7	3.7	2.55	0.05	115

Simulation Data for 140 ft Diameter at 20 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	60.3	44	57	3.8	3.4	17.7
2	71.5	33	73.5	3.8	3.3	17.5
3	109	41.3	107	4	3.5	18.6
4	58.7	42.1	106	3.9	3.5	18.8
5	58.5	37.3	106	3.8	3.4	18.7
6	58.4	33	50.4	3.9	3.4	18.2
7	71.5	33	73.5	3.8	3.3	17.5
8	50.5	40.4	134	3.8	3.4	17.6
9	59.3	39.6	53.4	3.9	3.3	16.9
10	66.6	37.2	64.3	3.9	3.5	19
Average	66.4	38.1	82.5	3.86	3.4	18.1

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	42.9	26.1	45.2	0.8	0.7	3.9
2	54	15.1	61.8	0.8	0.7	3.8
3	91.8	23.4	95.3	1	0.7	4.9
4	41.2	24.4	94.2	0.9	0.8	5
5	41	19.5	94.3	0.8	0.7	5
6	41	15.1	38.8	0.9	0.7	4.4
7	52.2	21.7	34.5	0.9	0.7	3.7
8	33.1	22.7	122	0.8	0.7	4
9	41.9	21.8	41.9	0.8	0.7	3.5
10	49.4	19.3	52.8	0.9	0.8	5.3
Average	48.9	20.9	68.1	0.86	0.72	4.35

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	105	104	3.25	0	0	61.5
2	187	42.8	2.75	0	0	96.8
3	336	78	5	0	0	114
4	107	124	4.25	4.25	0	144
5	120	61.5	4.25	4.25	0	130
6	107	30.5	3.25	3.25	0	50
7	153	83.5	2.75	2.75	0	41.8
8	82.5	102	2.5	2.5	0	209
9	120	70.5	2.5	2.5	0	50.5
10	143	61.3	5	5	0	71
Average	146	75.8	3.55	2.45	0	96.8

Simulation Data for 160 ft Diameter at 20 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	43.3	37.5	35.9	4.2	3.6	16.7
2	58.8	32	54.7	4.1	3.5	16.6
3	69.5	34.1	52.2	4.3	3.6	18
4	45.9	35.1	65.4	4.2	3.7	16.8
5	57.2	36.6	73.7	4.2	3.7	17.4
6	48.6	29.1	43.2	4.3	3.7	17
7	58.8	32	54.7	4.1	3.5	16.6
8	43.7	34.1	94.6	4.2	3.5	17.1
9	58.2	35	35.1	4.3	3.6	15.8
10	42.2	34.5	59.7	4.3	3.7	17.2
Average	52.6	34	56.9	4.22	3.61	16.9

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	26.1	19.7	24.3	0.9	0.6	3.2
2	41.5	14.2	43.2	0.8	0.6	3.1
3	52.4	16.3	40.6	0.9	0.7	4.4
4	28.7	17.4	53.7	0.9	0.8	3.2
5	39.9	18.8	62.1	0.8	0.7	3.9
6	31.4	11.3	31.8	0.9	0.7	3.5
7	44.3	18.4	23.7	1	0.7	2.6
8	26.5	16.4	83.1	0.8	0.6	3.6
9	41	17.2	23.7	1	0.7	2.6
10	25.1	16.7	48.3	0.9	0.8	3.6
Average	35.7	16.6	43.5	0.89	0.69	3.37

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	61.3	74.5	3	0	0	31.8
2	133	45.8	2	0	0	68
3	171	48	5	0	0	46.8
4	70.5	63	2.5	2.5	0	81.5
5	125	74.5	3	3	0	84.5
6	82.8	19	3.25	3.25	0	41.5
7	139	41.8	2	2	0	28
8	68.8	54.8	4	4	0	130
9	125	37	2	2	0	28
10	66.3	45.5	3.25	3.25	0	69
Average	104	50.4	3	2	0	60.9

Simulation Data for 180 ft Diameter at 20 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	50	27.9	32.5	4.6	3.9	16.8
2	56.6	25.3	38.2	4.5	3.9	16.2
3	84.9	25.5	60.1	4.6	4	16.7
4	40.2	29.2	42.2	4.5	3.9	17.5
5	53.9	29.1	43.8	4.5	3.8	17.8
6	47.6	25.2	31.1	4.4	3.9	17.3
7	56.6	25.3	38.2	4.5	3.9	16.2
8	38.4	28.8	43.3	4.5	3.8	17.1
9	61.4	29.3	30.9	4.6	3.8	15.7
10	53.6	29.3	51.5	4.6	3.9	17
Average	54.3	27.5	41.2	4.53	3.88	16.8

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	32.8	10.2	21	1.1	0.7	3.3
2	39.2	7.6	26.9	1	0.7	2.7
3	67.8	7.8	48.7	1.1	0.8	3.2
4	22.9	11.7	30.8	1	0.7	3.9
5	36.6	11.5	32.4	1	0.6	4.3
6	30.4	7.5	19.8	1	0.7	3.9
7	47.5	10.3	20.6	1.2	0.7	3.6
8	21.2	11.3	31.9	1.1	0.7	3.7
9	44.2	11.7	19.7	1.1	0.7	2.5
10	36.6	11.6	40.2	1.1	0.7	3.5
Average	37.9	10.1	29.2	1.07	0.7	3.46

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	75.8	19.3	1.5	0	0	25
2	116	9.25	1	0	0.25	38
3	231	8.5	1.75	0	0	56.8
4	51.5	32	2	2	0	42
5	105	26.8	2.75	2.75	0	39.8
6	75.8	10.8	2	2	0	22
7	137	15.5	1.75	1.75	0	23.3
8	47.8	19.3	1.75	1.75	0	42.8
9	132	21.8	1	1	0	21.3
10	101	19.8	2	2	0	55
Average	107	18.3	1.75	1.33	0.03	36.6

Simulation Data for 200 ft Diameter at 20 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	41.3	30.7	31.3	5	4.2	16.7
2	33.9	25.3	37.9	4.9	4.2	15.4
3	66.8	26.6	48.6	5.1	4.3	16.6
4	46.2	27.9	58.6	5.1	4.3	16.1
5	43.1	28.1	45.3	4.9	4.2	16.4
6	39.2	25.1	35.9	4.9	4.2	16
7	33.9	25.3	37.9	4.9	4.2	15.4
8	35.9	27.9	43.5	4.9	4.1	17.2
9	54.2	28	30.7	5	4.2	15.1
10	38.9	28.9	52.2	5	4.3	16.6
Average	43.3	27.4	42.2	4.97	4.22	16.2

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	24.2	13.1	20.1	1.2	0.8	3.4
2	16.7	7.6	26.8	1	0.7	2.1
3	49.8	9	37.5	1.3	0.8	3.2
4	29.1	10.4	47.4	1.2	0.8	2.8
5	25.9	10.6	34.2	1.1	0.8	3.1
6	22.2	7.4	25	1.1	0.7	2.8
7	45.7	9.7	18.3	1.3	0.9	2.8
8	18.9	10.4	32.4	1.1	0.7	4
9	37.2	10.4	19.8	1.2	0.8	2.1
10	22	11.3	41.3	1.2	0.8	3.4
Average	29.2	9.99	30.3	1.17	0.78	2.97

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	55	34.8	1.75	0	0	23.5
2	36.3	8.75	1	0	0	37.3
3	151	11.3	2	0	0	42.3
4	69.3	17.5	1	1	0	68.8
5	69.8	25.5	1	1	0	42
6	50.3	10.3	1.25	1.25	0	29.5
7	128	10.5	1.25	1.25	0	20
8	43.8	12.3	2.25	2.25	0	43.8
9	102	15.3	1	1	0	22.8
10	52.3	19.5	2.25	2.25	0	54.5
Average	75.7	16.6	1.48	1	0	38.4

Summary of Simulation Data for 20 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
80	84.9	41.6	89.2	2.2	1.75	23.9
100	65.9	37.7	65.9	2.71	2.16	21.9
120	66.6	41.1	87.1	3.36	3.15	19.3
140	66.4	38.1	82.5	3.86	3.4	18.1
160	52.6	34	56.9	4.22	3.61	16.9
180	54.3	27.5	41.2	4.53	3.88	16.8
200	43.3	27.4	42.2	4.97	4.22	16.2
Average						

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
80	68	23.5	74.6	0.54	0.41	9.18
100	50	19.3	50.9	0.63	0.5	7.56
120	49.2	23.5	71.9	0.81	0.6	5.41
140	48.9	20.9	68.1	0.86	0.72	4.35
160	35.7	16.6	43.5	0.89	0.69	3.37
180	37.9	10.1	29.2	1.07	0.7	3.46
200	29.2	9.99	30.3	1.17	0.78	2.97
Average						

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
80	228	81.7	8.68	6.38	2.2	108
100	156	58.3	6.68	4.88	0.03	77.1
120	153	90.7	3.7	2.55	0.05	115
140	146	75.8	3.55	2.45	0	96.8
160	104	50.4	3	2	0	60.9
180	107	18.3	1.75	1.33	0.03	36.6
200	75.7	16.6	1.48	1	0	38.4
Average						

Simulation Data for 80 ft Diameter at 30 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	45.3	41	56.9	2.2	1.7	22.3
2	65	34.7	64.9	2.2	1.8	21.9
3	113	41.3	87.9	2.3	1.8	21.4
4	67.9	39.1	98.5	2.2	1.8	22.2
5	74.6	48.9	85.7	2.3	1.9	26
6	60.9	34.6	47.7	2.2	1.8	20.4
7	65	34.7	64.9	2.2	1.8	21.9
8	86.1	43.6	94.5	2.2	1.8	22.1
9	72.5	40.9	47.4	2.3	1.8	20.5
10	53.7	42.2	61.8	2.2	1.7	25
Average	70.4	40.1	71	2.23	1.79	22.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	27.6	22.8	44.3	0.6	0.4	8
2	47.1	16.5	52.5	0.6	0.5	7.5
3	95	23.2	75.5	0.7	0.5	7.2
4	50.1	21	86	0.6	0.5	7.9
5	56.8	30.8	73.2	0.7	0.6	11.9
6	43.2	16.4	35.3	0.6	0.5	6.1
7	50.3	17	33	0.6	0.4	8.3
8	68.4	25.5	82	0.6	0.5	7.9
9	54.7	22.8	35.2	0.7	0.5	6.4
10	36.2	24.1	49.4	0.6	0.5	10.8
Average	52.9	22	56.6	0.63	0.49	8.2

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	61.8	87.3	6.75	0	2.25	58.3
2	140	42.3	5.75	0	1.75	77.3
3	324	64	5.75	0	2.25	91
4	139	59	5.75	5.75	2.5	133
5	172	145	12.8	12.8	2.5	99
6	116	29.5	4.75	4.75	2.25	43.5
7	145	37.3	7	7	2	40.3
8	200	96	6.5	6.5	1.75	128
9	171	64.8	5.5	5.5	2.25	39.3
10	96.8	70.3	12.3	12.3	2.5	67.8
Average	157	69.5	7.28	5.45	2.2	77.8

Simulation Data for 100 ft Diameter at 30 % Car1 - Model Scenario S2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	45.1	35.5	37.7	2.6	2.1	21
2	70.8	34	50.6	2.8	2.2	19.8
3	65.6	38.2	83.7	2.8	2.2	21.8
4	43.7	35.2	76.9	2.8	2.2	20.6
5	58.2	39.5	40.9	2.7	2.1	23.6
6	53	31.7	32.2	2.8	2.2	21.9
7	70.8	34	50.6	2.8	2.2	19.8
8	55.7	32.6	74	2.7	2.1	22.8
9	62.8	33.4	38.6	2.7	2.1	19.7
10	52.6	36.5	57.2	2.8	2.2	22.1
Average	57.8	35.1	54.2	2.75	2.16	21.3

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	27.5	17.4	25.2	0.6	0.5	7
2	53	15.9	38.4	0.8	0.5	5.7
3	48	20.3	71.5	0.8	0.6	7.9
4	26	17.2	64.7	0.8	0.6	6.6
5	40.6	21.5	28.7	0.8	0.5	9.8
6	35.5	13.7	20.1	0.8	0.5	7.9
7	42.9	13.3	27.4	0.7	0.5	7.2
8	38.1	14.7	61.8	0.7	0.5	8.8
9	45.2	15.4	26.7	0.7	0.5	5.9
10	35.3	18.5	45.1	0.8	0.6	8.1
Average	39.2	16.8	41	0.75	0.53	7.49

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	83.5	67.5	15	0	0	75
2	136	56.3	5.5	0	0	74
3	484	43	7	0	0	81
4	96.5	103	6.75	6.75	0	75.3
5	356	69.8	7	7	0	51.5
6	151	30	7.25	7.25	0	47.8
7	170	90	8	8	0	39.5
8	165	121	9	9	0	59
9	187	122	5.5	5.5	0	38.8
10	119	84	9.25	9.25	0	82.8
Average	195	78.6	8.03	5.28	0	62.5

Simulation Data for 120 ft Diameter at 30 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	44.1	45.5	55.5	3.4	0	18.4
2	59.3	40.4	64.7	3.4	0	18
3	93	42.5	78.5	3.5	0	18.6
4	55.1	42.7	118	3.5	0	19.5
5	52.2	49.1	74.7	3.4	0	19.5
6	48.7	36.7	56.7	3.5	0	17.8
7	59.3	40.4	64.7	3.4	0	18
8	69.6	39.3	148	3.4	0	19.5
9	61.6	39.6	32	3.4	0	18.7
10	59.1	45.2	68.6	3.4	0	20.9
Average	60.2	42.1	76.1	3.43	0	18.9

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	27	27.7	43.6	0.9	0	4.7
2	42	22.6	53	0.9	0	4.3
3	75.9	24.7	66.7	1	0	4.9
4	37.9	25	107	1	0	5.7
5	34.9	31.3	63.1	0.9	0	6
6	31.6	18.8	45.1	1	0	4.2
7	50.7	20.7	25	0.9	0	5.6
8	52.5	21.6	136	1	0	5.9
9	44.4	21.8	20.5	0.9	0	5.2
10	42.1	27.4	57.1	0.9	0	7.2
Average	43.9	24.2	61.7	0.94	0	5.37

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	62	134	2.75	0	0	65.5
2	129	83.8	2.25	0	1	90.8
3	267	139	3.75	0	0.5	91.3
4	103	125	3.25	3.25	0	188
5	101	145	4.25	4.25	0	94
6	81.8	44.5	2.25	2.25	0	65.8
7	149	69.3	4.5	4.5	0	35.8
8	154	73.5	4.25	4.25	0.25	240
9	132	68.3	4.25	4.25	0	27.8
10	121	110	6.75	6.75	0.25	89.8
Average	130	99.1	3.83	2.95	0.2	98.8

Simulation Data for 140 ft Diameter at 30 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	45.4	36.4	48.2	3.8	3.3	18.1
2	43.6	32.9	69.6	3.8	3.3	16.7
3	106	36.3	60.4	4	3.4	17.1
4	49	38.9	58.8	4	3.4	19.6
5	45.3	42.6	50.7	4	3.5	18.7
6	51.7	31.9	48.3	3.9	3.5	16.9
7	43.6	32.9	69.6	3.8	3.3	16.7
8	58.5	35.4	130	3.9	3.5	18.4
9	65.3	33.8	43	4	3.5	16.9
10	45.7	38.2	95.6	4	3.4	19.2
Average	55.4	35.9	67.4	3.92	3.41	17.8

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	28.5	18.9	36.6	0.9	0.7	4.7
2	26.4	15.4	58.2	0.9	0.7	3.2
3	88.8	18.9	48.9	1.1	0.8	3.7
4	32	21.6	47.3	1.1	0.8	5.9
5	28.3	25.1	39.3	1.1	0.8	5.4
6	34.8	14.3	37	1	0.8	3.4
7	33.8	16.5	35.1	0.9	0.8	4.2
8	41.5	18	118	1	0.9	5
9	48.2	16.3	31.8	1.1	0.8	3.6
10	29	20.7	84.2	1	0.8	5.8
Average	39.1	18.6	53.7	1.01	0.79	4.49

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	64.5	72.8	3.5	0	0	48.5
2	64.8	43.3	2	0	0	87
3	306	61.8	3	0	1.25	58.5
4	76.5	67.8	4.75	4.75	0	68.3
5	72	99	5.5	5.5	0	48.8
6	87.8	28.3	3	3	0	46
7	84.3	39	3.75	3.75	0	44.3
8	107	52	4	4	0	194
9	144	30	2.25	2.25	0	35
10	71.5	65	6.5	6.5	0.25	126
Average	108	55.9	3.83	2.98	0.15	75.5

Simulation Data for 160 ft Diameter at 30 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	37.8	34	28.3	4.4	3.7	17
2	51.1	30.9	60	4.3	3.7	15.8
3	70	28.5	60.6	4.3	3.7	16.5
4	41.3	31	47	4.4	3.7	18.6
5	40.7	36.7	32.6	4.3	3.6	17.1
6	42.2	29.1	33.8	4.3	3.7	15.7
7	51.1	30.9	60	4.3	3.7	15.8
8	48.9	32.7	48.1	4.5	3.8	16.1
9	45.4	31.3	32.3	4.3	3.7	16.2
10	38.6	33.5	49.9	4.3	3.6	17.3
Average	46.7	31.9	45.3	4.34	3.69	16.6

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	21	16.6	16.8	1.1	0.8	3.7
2	34.1	13.6	48.7	1.1	0.8	2.4
3	53.2	11.1	49.3	1.1	0.8	3.4
4	24.4	13.7	35.6	1.2	0.9	5.2
5	23.8	19.4	21.3	1.1	0.8	4
6	25.5	11.7	22.5	1.1	0.9	2.5
7	32.6	12.2	22.5	1.1	0.8	2.4
8	32.1	15.4	36.8	1.3	0.9	2.9
9	28.5	14	21.3	1.1	0.8	3.1
10	22	16.1	38.7	1	0.8	4.1
Average	29.7	14.4	31.4	1.12	0.83	3.37

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	46.8	54	3.25	0	0	20
2	92.5	35.8	1.5	0	0	75.5
3	169	13	3	0	0	60.3
4	61.5	38.8	5	5	0	50
5	63.8	73.3	3	3	0	26.5
6	64.3	15.8	1.75	1.75	0	26.8
7	87	24.5	2	2	0	26
8	83.8	39.8	2.25	2.25	0	54.3
9	76.3	27.8	2.25	2.25	0	23.3
10	57	48	4	4	0.25	54
Average	80.2	37.1	2.8	2.03	0.03	41.7

Simulation Data for 180 ft Diameter at 30 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	38.8	27	30.4	4.6	3.9	16.6
2	42.1	26.4	33.1	4.6	3.9	16.5
3	79.8	25.6	51.3	4.8	4	16.1
4	35.4	27	39.9	4.7	4	16.8
5	45.2	28.4	32.6	4.7	3.9	17.7
6	41.8	25	34.3	4.7	3.9	15.8
7	42.1	26.4	33.1	4.6	3.9	16.5
8	41.3	27.6	41.8	4.7	3.9	16.4
9	56.6	27.4	39.4	4.7	3.9	15.7
10	43.4	27.6	44	4.6	3.9	17.4
Average	46.7	26.8	38	4.67	3.92	16.6

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	22	9.8	19.1	1.2	0.8	3.4
2	25.1	9.1	21.9	1.3	0.8	3.2
3	63	8.4	40.2	1.4	0.9	2.9
4	18.5	9.8	28.7	1.3	0.9	3.6
5	28.3	11.2	21.5	1.3	0.8	4.7
6	25.1	7.7	23.3	1.3	0.9	2.6
7	21.5	8	20	1.2	0.8	3.5
8	24.4	10.5	30.6	1.3	0.9	3.3
9	39.7	10.2	28.4	1.3	0.8	2.7
10	26.8	10.4	33	1.3	0.9	4.2
Average	29.4	9.51	26.7	1.29	0.85	3.41

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	47	17	1.75	0	0	22.3
2	60.5	9.5	1.5	0	0	28
3	210	9.25	1.75	0	0	46.8
4	39.8	26	1.75	1.75	0	38.3
5	75	24	3	3	0	24.3
6	58.8	7	1	1	0	27.3
7	49	7.5	1.75	1.75	0	22.5
8	56.8	25.3	1.5	1.5	0	45.3
9	111	11.8	1.25	1.25	0	32.8
10	64.8	18.3	3	3	0.25	44.3
Average	77.3	15.6	1.83	1.33	0.03	33.2

Simulation Data for 200 ft Diameter at 30 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	34.7	27.2	27.9	4.9	4.2	16.1
2	42	25.4	38.7	5	4.3	15.7
3	76.4	24.5	54.3	5.1	4.3	15.8
4	35.7	27.1	30.5	5.1	4.3	16
5	41	27.4	29.8	5.1	4.2	16.5
6	38.8	25.7	28.5	5	4.3	15.3
7	42	25.4	38.7	5	4.3	15.7
8	35.9	27	42.5	4.8	4.2	15.6
9	48.7	26.7	25.3	5	4.3	15.4
10	33.9	27.7	34.8	5.1	4.2	16.5
Average	42.9	26.4	35.1	5.01	4.26	15.9

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	18.1	10	16.8	1.2	0.8	3.1
2	25.3	8.2	27.9	1.3	0.9	2.6
3	59.8	7.3	43.4	1.4	1	2.8
4	19	9.9	19.5	1.4	1	2.9
5	24.3	10.2	19	1.3	0.9	3.7
6	22.2	8.5	17.7	1.3	1	2.3
7	26.1	6.6	18.9	1.2	0.8	3
8	19.3	9.8	31.6	1.2	0.9	2.6
9	31.9	9.5	14.6	1.3	0.9	2.5
10	17.5	10.4	24	1.3	0.9	3.6
Average	26.4	9.04	23.3	1.29	0.91	2.91

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	36.3	23.5	1.5	0	0	19
2	60	5.5	1	0	0	37
3	195	7.75	1.25	0	0	52.8
4	41	21.5	1.25	1.25	0	24.5
5	62	19.3	2	2	0	20
6	51.8	8.25	0.75	0.75	0	19
7	65.3	5.25	1	1	0	21.8
8	42	29.3	1	1	0	43.3
9	87	13	1	1	0	13.8
10	38.5	12.5	2.75	2.75	0	29.8
Average	67.9	14.6	1.35	0.98	0	28.1

Summary of Simulation Data for 30 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
80	70.4	40.1	71	2.23	1.79	22.4
100	57.8	35.1	54.2	2.75	2.16	21.3
120	60.2	42.1	76.1	3.43	3.15	18.9
140	55.4	35.9	67.4	3.92	3.41	17.8
160	46.7	31.9	45.3	4.34	3.69	16.6
180	46.7	26.8	38	4.67	3.92	16.6
200	42.9	26.4	35.1	5.01	4.26	15.9
Average						

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
80	52.9	22	56.6	0.63	0.49	8.2
100	39.2	16.8	41	0.75	0.53	7.49
120	43.9	24.2	61.7	0.94	0.6	5.37
140	39.1	18.6	53.7	1.01	0.79	4.49
160	29.7	14.4	31.4	1.12	0.83	3.37
180	29.4	9.51	26.7	1.29	0.85	3.41
200	26.4	9.04	23.3	1.29	0.91	2.91
Average						

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
80	157	69.5	7.28	5.45	2.2	77.8
100	195	78.6	8.03	5.28	0	62.5
120	130	99.1	3.83	2.95	0.2	98.8
140	108	55.9	3.83	2.98	0.15	75.5
160	80.2	37.1	2.8	2.03	0.03	41.7
180	77.3	15.6	1.83	1.33	0.03	33.2
200	67.9	14.6	1.35	0.98	0	28.1
Average						

Simulation Data for 80 ft Diameter at 40 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	42.8	40.2	40.7	2.2	1.7	22.4
2	64.1	34.9	45.4	2.2	1.7	20.5
3	97.3	39.8	66.6	2.3	1.8	21.4
4	43.3	33.7	83.9	2.2	1.8	21.8
5	66.8	37.4	70.7	2.3	1.8	20.8
6	68.5	32.2	50.3	2.3	1.8	20.9
7	64.1	34.9	45.4	2.2	1.7	20.5
8	97.7	34.4	126	2.2	1.8	21.3
9	69.7	38.8	37.7	2.2	1.7	19.8
10	49.7	42.5	49	2.1	1.7	22
Average	66.4	36.9	61.6	2.22	1.75	21.1

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	25.6	22.5	28.3	0.6	0.5	8.5
2	46.6	17.1	33.2	0.7	0.5	6.6
3	80	22	54.5	0.8	0.6	7.4
4	25.8	16	71.8	0.7	0.5	7.9
5	49.4	19.7	58.5	0.8	0.6	7
6	51.2	14.3	38.3	0.7	0.6	6.9
7	51.5	22.3	32.2	0.7	0.5	6.5
8	80.4	16.6	114	0.7	0.6	7.5
9	52.3	21	25.8	0.7	0.5	6
10	32.5	24.7	37.1	0.6	0.5	8.3
Average	49.5	19.6	49.4	0.7	0.54	7.26

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	55.5	75	8	0	1.5	34.3
2	140	40.3	4.25	0.25	1.75	46.5
3	274	66.8	6.5	0.25	2.75	63.8
4	60.3	35.5	6	6	2.25	111
5	151	65.3	6	6	2.5	78.5
6	144	30.3	5	5	2.25	50.5
7	147	67.3	4.75	4.75	2.5	40.3
8	250	28.5	6	6	2.5	192
9	167	46.8	4.5	4.5	2	26.5
10	81.5	80.8	8.5	8.5	1.75	48.3
Average	147	53.6	5.95	4.13	2.18	69.1

Simulation Data for 100 ft Diameter at 40 % Car1 - Model Scenario S2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	39.2	36.5	33.7	2.7	2.1	22.8
2	75.8	31	33	2.7	2.1	19.6
3	69.6	29.2	67.5	2.7	2.2	21
4	42.4	33.3	57.8	2.7	2.2	18.6
5	46.8	35.4	43.5	2.7	2.1	20.5
6	41.3	32.5	29.6	2.8	2.1	19.1
7	75.8	31	33	2.7	2.1	19.6
8	59	33	128	2.7	2.1	20.6
9	71.2	34.4	28.4	2.7	2.1	18.2
10	49.2	34.8	40.9	2.7	2.1	21.1
Average	57	33.1	49.6	2.71	2.12	20.1

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	22.1	18.8	21.5	0.8	0.6	9.1
2	58.5	13.3	21	0.8	0.6	5.9
3	52.5	11.7	55.6	0.9	0.6	7.3
4	25.1	15.7	45.9	0.8	0.6	5
5	29.5	17.9	31.6	0.8	0.6	7.1
6	24.2	14.9	17.8	0.8	0.6	5.4
7	37	16	22.3	0.7	0.6	6.4
8	41.8	15.4	117	0.8	0.6	7
9	54	16.9	16.7	0.8	0.5	4.6
10	32.2	17.1	29.2	0.7	0.6	7.6
Average	37.7	15.8	37.8	0.79	0.59	6.54

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	47.3	55.5	8.5	0.25	0	28.3
2	195	19.8	4	0	0	32.3
3	161	19.5	6.5	0.25	0.5	70.3
4	59	43.8	3	3	0	73.8
5	82	56	6.25	6.25	0.25	43.5
6	56.8	25.8	3.5	3.5	0	20.5
7	99	50	5.25	5.25	0.25	30.3
8	115	32.5	5.25	5.25	0	218
9	178	32.8	2.5	2.5	0	19
10	79.5	41.8	8	8	0.25	41
Average	107	37.7	5.28	3.43	0.13	57.7

Simulation Data for 120 ft Diameter at 40 % Car1 - Model Scenario S2

Travel Time

Sim No	Link No					
	EB	SB	NB	Pt1	Pt2	WB
1	34.8	38	33.8	3.3	0	20.2
2	54.6	33.9	78.4	3.3	0	16.5
3	73.9	35.1	117	3.4	0	19
4	41.3	30.7	96.7	3.4	0	18.6
5	82.2	36.1	37.5	3.5	0	18.5
6	49.9	34	47.5	3.4	0	17.9
7	54.6	33.9	78.4	3.3	0	16.5
8	55.9	35.1	159	3.3	0	17.5
9	68.6	37.3	32.4	3.4	0	16.6
10	47	38.1	39.2	3.4	0	19
Average	56.3	35.2	72	3.37	0	18

Delay

Sim No	Link No					
	EB	SB	NB	Pt1	Pt2	WB
1	18.1	20.5	22.1	0.9	0	6.7
2	37.7	16.5	67.1	0.9	0	3.1
3	57.2	17.7	105	1.1	0	5.6
4	24.3	13.4	85.3	1.1	0	5.2
5	65.3	18.7	26.1	1.1	0	5.3
6	33.1	16.6	36.2	1	0	4.5
7	49.3	18.1	17.9	1.1	0	5.1
8	39	17.6	147	1	0	4.2
9	51.7	19.9	21.2	1	0	3.3
10	30.3	20.6	28	1	0	5.8
Average	40.6	18	55.7	1.02	0	4.88

Queue Length

Sim No	Link No					
	EB	SB	WB	Pt1	Pt2	NB
1	38.3	66	5.75	0	0.25	33.5
2	103	34.3	1	0	0	118
3	185	56.8	4.5	0	0.25	144
4	58.5	20	3.25	3.25	0.75	143
5	220	57	3.5	3.5	0	36
6	86.3	44	2.75	2.75	0	54.3
7	152	47.8	3	3	0.25	25.3
8	106	54.8	1.75	1.75	0	274
9	177	64	1.75	1.75	0	27.3
10	76.5	72.8	5	5	0.5	41.3
Average	120	51.7	3.23	2.1	0.2	89.6

Simulation Data for 140 ft Diameter at 40 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	33.2	32.6	37.9	3.9	3.3	17.6
2	46	31.2	53.1	3.8	3.3	15.8
3	52.8	30.2	119	3.8	3.4	19.1
4	43.7	32.4	63.8	3.9	3.5	16.4
5	50.5	33.2	38.4	4	3.5	17.3
6	52.6	30.7	59.2	4	3.5	16.3
7	46	31.2	53.1	3.8	3.3	15.8
8	48.7	35.9	94.1	3.9	3.4	16.9
9	54.7	30.7	30.8	4	3.4	16.9
10	40.7	34.3	53.6	3.9	3.3	17.3
Average	46.9	32.2	60.3	3.9	3.39	16.9

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	16.7	15.5	26.4	1.1	0.9	4.4
2	29.3	14	42	1	0.8	2.7
3	36.2	13.2	108	1	0.9	5.9
4	27	15.4	52.6	1.1	1	3.2
5	33.8	16.1	27.3	1.2	0.9	4.3
6	36.1	13.5	48.1	1.1	1	3.1
7	38.2	14.6	38.3	1.2	0.9	3.7
8	32	18.9	82.9	1.1	0.9	3.8
9	38	13.6	19.7	1.2	0.9	4
10	24.2	17.3	42.6	1.1	0.8	4.3
Average	31.2	15.2	48.8	1.11	0.9	3.94

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	30.8	32.3	3.5	0	0	33.5
2	72.5	38.3	1.75	0	0	62.8
3	100	36	6	0	0	134
4	61.5	36.5	1.75	1.75	0	78.5
5	96.8	37.8	3.5	3.5	0	31.5
6	94.3	27.5	1.5	1.5	0	64.5
7	105	36.5	3.25	3.25	0	50.3
8	80	55.5	2.5	2.5	0.25	133
9	111	23.5	3.25	3.25	0.25	20.5
10	54	39	4.25	4.25	0.25	57
Average	80.6	36.3	3.13	2	0.08	66.6

Simulation Data for 160 ft Diameter at 40 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	30.7	31.4	29.6	4.2	3.5	17
2	39.8	28.3	34.4	4.2	3.6	15.2
3	46.9	28.9	50.9	4.2	3.6	17.1
4	33.9	30.2	53.8	4.3	3.7	16.5
5	41.6	29.8	30	4.4	3.6	15.6
6	41.1	28.4	27	4.4	3.6	16.1
7	39.8	28.3	34.4	4.2	3.6	15.2
8	38.8	32.5	39.2	4.2	3.6	15.9
9	45.6	30.2	27.1	4.3	3.6	15.8
10	37.1	30.3	32.8	4.2	3.6	15.8
Average	39.5	29.8	35.9	4.26	3.6	16

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	14.4	14.4	18.4	1.1	0.8	4.1
2	23.2	11.3	23.3	1.2	0.9	2.2
3	30.5	11.9	39.9	1.1	0.9	4.2
4	17.4	13.3	42.8	1.2	1	3.6
5	25.1	12.8	18.9	1.2	0.9	2.8
6	24.7	11.4	16.1	1.2	0.9	3.1
7	27.3	14.3	20.9	1.2	0.9	2.3
8	22.3	15.5	28.1	1.2	0.9	3.1
9	29.1	13.2	16.3	1.2	0.8	3
10	20.8	13.2	21.9	1.1	0.9	3.1
Average	23.5	13.1	24.7	1.17	0.89	3.15

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	28.5	39.5	3.25	0	0	23
2	57.5	22.8	1.25	0	0	32.5
3	87.8	26	4.75	0	0	46.5
4	38.8	29	2.75	2.75	0	66
5	72.8	27	2	2	0	22
6	63.3	20.3	2	2	0	17.8
7	72.8	43.3	1	1	0	26.8
8	56.8	41.5	2.25	2.25	0	40
9	83.5	25.8	3	3	0.25	16.3
10	47.8	28.5	2.75	2.75	0	28
Average	60.9	30.4	2.5	1.58	0.03	31.9

Simulation Data for 180 ft Diameter at 40 % Car1 - Model Scenario S2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	33.6	27.5	26	4.5	3.8	16.4
2	39.2	25	27.5	4.5	3.9	15.3
3	49.5	24.4	39.7	4.4	3.8	17.3
4	32.4	24.5	32.2	4.6	4	16.6
5	44	24.7	28.1	4.6	3.9	16.3
6	46.2	26.2	33.1	4.8	4	16.6
7	39.2	25	27.5	4.5	3.9	15.3
8	39.9	26.6	50.4	4.6	3.9	17
9	50.5	26.8	22.1	4.5	3.8	15.3
10	34.5	25.5	34.7	4.6	3.8	16.3
Average	40.9	25.6	32.1	4.56	3.88	16.2

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	17.3	10.6	14.9	1.2	0.9	3.5
2	22.7	8.1	16.7	1.3	0.9	2.5
3	33.1	7.6	28.8	1.2	0.9	4.4
4	15.9	7.7	21.3	1.4	1	3.7
5	27.5	7.9	17.2	1.4	0.9	3.7
6	29.8	9.4	22.3	1.5	1	3.6
7	28.8	8.5	15.5	1.3	0.9	3.3
8	23.3	9.8	39.5	1.3	1	4.2
9	33.9	9.8	11.4	1.2	0.8	2.6
10	18.3	8.5	24	1.2	0.9	3.5
Average	25.1	8.79	21.2	1.3	0.92	3.5

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	34	35	1.75	0	0	16.5
2	52.5	8.5	1.25	0	0	21
3	92.8	9	3	0	0	31.8
4	32.8	5.25	1.75	1.75	0.25	27.5
5	74.3	5.75	2.25	2.25	0	18.5
6	75.5	13.5	1.75	1.75	0.5	27
7	72.8	12.8	2.25	2.25	0	17.5
8	56.8	16.3	2.5	2.5	0	58.5
9	97.3	18.5	1	1	0	10.3
10	37.8	9.5	2.5	2.5	0	28.8
Average	62.6	13.4	2	1.4	0.08	25.7

Simulation Data for 200 ft Diameter at 40 % Car1 - Model Scenario S2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	30.9	27.3	23.9	5	4.2	16.6
2	35.6	25.6	26	4.9	4.1	14.8
3	44.3	23.8	36.4	4.8	4.2	16.2
4	29.8	24.5	34.8	5	4.3	15.3
5	42.9	23.8	25.8	5.1	4.3	15.1
6	34.3	24.6	26.3	5.1	4.3	15.2
7	35.6	25.6	26	4.9	4.1	14.8
8	36.4	26.3	42.2	4.9	4.1	15.3
9	49.4	26.4	23.2	5.1	4.2	14.6
10	34.9	26.3	31.1	5	4.2	15.1
Average	37.4	25.4	29.6	4.98	4.2	15.3

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	14.8	10.4	13.1	1.4	1	3.9
2	19.2	8.8	15.4	1.3	0.9	2.1
3	28	7.1	25.8	1.3	1	3.5
4	13.4	7.8	24.1	1.5	1.1	2.6
5	26.6	6.9	15.2	1.5	1	2.6
6	18.1	7.7	15.8	1.5	1.1	2.5
7	22.4	7.1	18.3	1.3	1	2.9
8	20.1	9.5	31.5	1.4	0.9	2.7
9	33	9.5	12.7	1.5	1	2
10	18.8	9.4	20.7	1.4	1	2.6
Average	21.4	8.42	19.3	1.41	1	2.74

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	27	16	2	0	0	14
2	42.3	12.8	0.25	0	0	18.3
3	78	13	1.75	0	0	26.8
4	24.8	7	0.75	0.75	0	31
5	72.8	7.75	1.25	1.25	0	15.8
6	37	6.5	0.75	0.75	0	15.8
7	55.3	7	1.5	1.5	0	21
8	47	11.5	1.25	1.25	0	44
9	91.5	11.5	0.75	0.75	0	12
10	40.5	9.25	1	1	0	24.5
Average	51.6	10.2	1.13	0.73	0	22.3

Summary of Simulation Data for 40 % Car1 - Model Scenario S2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
80	66.4	36.9	61.6	2.22	1.75	21.1
100	57	33.1	49.6	2.71	2.12	20.1
120	56.3	35.2	72	3.37	3.15	18
140	46.9	32.2	60.3	3.9	3.39	16.9
160	39.5	29.8	35.9	4.26	3.6	16
180	40.9	25.6	32.1	4.56	3.88	16.2
200	37.4	25.4	29.6	4.98	4.2	15.3

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
80	49.5	19.6	49.4	0.7	0.54	7.26
100	37.7	15.8	37.8	0.79	0.59	6.54
120	40.6	18	55.7	1.02	0.6	4.88
140	31.2	15.2	48.8	1.11	0.9	3.94
160	23.5	13.1	24.7	1.17	0.89	3.15
180	25.1	8.79	21.2	1.3	0.92	3.5
200	21.4	8.42	19.3	1.41	1	2.74

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
80	147	53.6	5.95	4.13	2.18	69.1
100	107	37.7	5.28	3.43	0.13	57.7
120	120	51.7	3.23	2.1	0.2	89.6
140	80.6	36.3	3.13	2	0.08	66.6
160	60.9	30.4	2.5	1.58	0.03	31.9
180	62.6	13.4	2	1.4	0.08	25.7
200	51.6	10.2	1.13	0.73	0	22.3

Simulation Data for 80 ft Diameter at 50 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	41	35.8	40.3	2.2	1.7	21.5
2	73.1	32.1	36.6	2.2	1.8	19.6
3	71.9	36.3	79.2	2.3	1.8	22
4	48.7	42.5	43.5	2.2	1.7	22.1
5	60.2	34.6	40.4	2.2	1.8	22.1
6	45.7	33.4	34.4	2.2	1.7	20.1
7	73.1	32.1	36.6	2.2	1.8	19.6
8	71.7	39.6	142	2.3	1.8	20.9
9	49.5	32.4	41.1	2.1	1.7	20.4
10	59.2	38.4	40.6	2.1	1.7	20.8
Average	59.4	35.7	53.5	2.2	1.75	20.9

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	24.1	18.3	28.3	0.7	0.6	7.9
2	56.1	14.7	24.8	0.8	0.6	5.9
3	55	19	67.3	0.9	0.7	8.5
4	31.6	25.3	31.6	0.8	0.6	8.5
5	43.3	17.2	28.4	0.8	0.6	8.5
6	28.7	16.1	22.7	0.7	0.5	6.6
7	46.1	18.9	22.1	0.7	0.5	6.1
8	54.7	22.3	130	0.8	0.7	7.3
9	32.5	15.1	29.3	0.7	0.5	6.9
10	42.3	20.9	28.9	0.7	0.5	7.3
Average	41.4	18.8	41.3	0.76	0.58	7.35

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	51.3	49.8	7.25	0	2.25	35.3
2	178	24.5	3.5	0.25	2.25	30.3
3	165	55	8.75	0.5	2.75	82.8
4	78.3	93.5	6.75	6.75	2	42.3
5	127	38.5	7	7	2.25	32
6	70	29.8	5.25	5.25	2.25	25.5
7	138	48.8	4.25	4.25	1.75	25.8
8	152	92.5	5.75	5.75	2.5	225
9	88	29	5.75	5.75	1.75	32.3
10	119	46.3	6.25	6.25	1.75	37.8
Average	117	50.8	6.05	4.18	2.15	56.9

Simulation Data for 100 ft Diameter at 50 % Car1 - Model Scenario S2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	36.4	35	32.8	2.7	2.1	20.4
2	43.5	32.2	24.5	2.8	2.1	21.4
3	68.6	31.7	56.5	2.8	2.2	19.2
4	46.2	30.4	35.7	2.7	2.2	20.9
5	52.1	34.5	32.1	2.8	2.2	20.6
6	40.5	30.9	26.7	2.7	2.1	18.2
7	43.5	32.2	24.5	2.8	2.1	21.4
8	49.3	33.5	70.9	2.8	2.3	19
9	44.8	31.5	22.6	2.6	2	17.9
10	39.5	31.4	34.7	2.7	2.1	18.8
Average	46.4	32.3	36.1	2.74	2.14	19.8

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	19.6	17.6	21	0.8	0.6	7
2	26.6	14.9	12.9	0.9	0.7	7.9
3	51.9	14.6	44.8	1	0.7	6
4	29.3	13.3	24.1	0.9	0.7	7.5
5	35.3	17.3	20.3	0.9	0.7	7.3
6	23.7	13.8	15.2	0.9	0.6	4.9
7	32.6	15.4	25.2	0.9	0.6	4.6
8	32.3	16.3	59.3	0.9	0.8	5.7
9	28	14.2	11.1	0.8	0.6	4.7
10	22.8	14.1	23.2	0.9	0.6	5.5
Average	30.2	15.2	25.7	0.89	0.66	6.11

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	40.8	55.3	5.25	0	0	28.3
2	67	31.5	6.75	0.25	0.25	16.3
3	159	25.3	5	0.25	0.25	58.8
4	72.5	29	5.75	5.75	0	35
5	101	53.3	6.25	6.25	0.75	25.8
6	55	23	3.5	3.5	0.5	18.5
7	84.8	34.3	2.75	2.75	0	36
8	82.8	45.3	4	4	0.25	96.5
9	74.8	31	3	3	0	11.3
10	54	24.8	4	4	0	32
Average	79.1	35.3	4.63	2.98	0.2	35.8

Simulation Data for 120 ft Diameter at 50 % Car1 - Model Scenario S2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	34.3	38.8	25.1	3.5	0	19.6
2	56	31.4	28.3	3.4	0	17.2
3	83	31.2	61.8	3.6	0	17.3
4	39.4	35.1	49.2	3.4	0	17.7
5	54	41.8	67.6	3.5	0	19.3
6	44.2	32	23	3.5	0	16.8
7	56	31.4	28.3	3.4	0	17.2
8	49.8	35.4	80.2	3.4	0	18.9
9	49.1	30.5	26.9	3.3	0	17.1
10	41.6	36.5	43.1	3.4	0	17.1
Average	50.7	34.4	43.4	3.44	0	17.8

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	18	21.7	13.7	1.2	0	6.5
2	39.4	14.3	17.2	1.1	0	4
3	66.7	14.3	50.5	1.3	0	4.3
4	22.8	18.3	38.1	1.1	0	4.7
5	37.6	24.7	56.3	1.2	0	6.2
6	27.8	15.1	12	1.2	0	3.8
7	45.3	15.4	16.7	1.2	0	3.7
8	33.2	18.5	69	1.2	0	5.9
9	32.6	13.5	15.9	1.1	0	4.2
10	25.3	19.5	32.1	1.1	0	4.1
Average	34.9	17.5	32.2	1.17	0	4.74

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	37.5	68	5.5	0	0	18.5
2	113	32.8	1.5	0.25	0	25.3
3	218	19.8	2.5	0	0.25	70
4	53.5	61	2.5	2.5	0	61
5	109	98.5	5	5	0.5	83
6	70.3	26.8	1.75	1.75	0.25	14.8
7	126	37	1.75	1.75	0.25	23
8	86	57	5	5	0.25	119
9	92.3	22.8	2.25	2.25	0	19.8
10	62	53.5	2.25	2.25	0.25	48.8
Average	96.7	47.7	3	2.08	0.18	48.3

Simulation Data for 140 ft Diameter at 50 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	33.2	33.7	37.7	3.9	3.3	17.3
2	56.2	28.4	41.8	3.8	3.3	16.5
3	76.6	27.2	53	3.9	3.4	16
4	38.9	32	46.3	4	3.4	17.5
5	45.5	31.3	32.2	3.9	3.4	16.9
6	42.5	30.4	29.8	4	3.3	16.1
7	56.2	28.4	41.8	3.8	3.3	16.5
8	51.4	30.7	67.4	3.9	3.4	17.2
9	42.5	30.4	31.7	3.8	3.2	15.8
10	36.7	28.7	47.9	3.8	3.3	16.4
Average	48	30.1	43	3.88	3.33	16.6

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	17	17	26.7	1.2	0.9	4.4
2	39.9	11.6	31	1.1	0.9	3.5
3	60.5	10.7	42.1	1.3	1	3.3
4	22.5	15.5	35.4	1.3	1	4.6
5	29.2	14.6	21.2	1.2	1	4.1
6	26.3	13.9	19.1	1.3	0.9	3.4
7	39.2	13.3	22.8	1.3	1	2.8
8	35.1	14.1	56.4	1.2	1	4.4
9	26.2	13.6	20.8	1.1	0.8	3.1
10	20.6	12	37.1	1.2	1	3.7
Average	31.7	13.6	31.3	1.22	0.95	3.73

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	33	47	3.25	0	0	33
2	114	21	1.75	0	0.25	42
3	189	16	2	0	0	49.3
4	52.3	33.3	3	3	0	49.8
5	76.5	39.5	3.25	3.25	0.25	24
6	61.3	25.3	2.25	2.25	0	20.8
7	105	27.5	1.25	1.25	0	28
8	89	30.8	2.75	2.75	0	83.8
9	69.3	30.3	1.75	1.75	0	21.8
10	45.3	18	2.5	2.5	0.25	49.3
Average	83.4	28.9	2.38	1.68	0.08	40.2

Simulation Data for 160 ft Diameter at 50 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	31.4	28	29.3	4.3	3.5	16.3
2	39.8	27.6	30.6	4.2	3.6	16.1
3	44.6	26.3	44.6	4.2	3.6	15.2
4	33.5	28.9	34.1	4.3	3.7	16.2
5	39.3	29.8	25.4	4.2	3.6	16.1
6	33.6	25.4	23.9	4.3	3.6	14.6
7	39.8	27.6	30.6	4.2	3.6	16.1
8	37.9	28.2	49.8	4.3	3.7	16.1
9	39.2	27.1	23.7	4	3.4	15.6
10	33.3	28.4	32.9	4.1	3.5	15.8
Average	37.2	27.7	32.5	4.21	3.58	15.8

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	15.4	11.4	18.4	1.2	0.9	3.7
2	23.6	11	19.9	1.2	0.9	3.3
3	28.6	9.8	33.8	1.3	1	2.7
4	17.4	12.5	23.3	1.4	1	3.5
5	23.2	13.2	14.6	1.2	1	3.5
6	17.5	8.9	13.3	1.3	1	2
7	21.6	9.3	17.9	1.2	1	2.9
8	21.7	11.6	38.9	1.4	1.1	3.5
9	23.1	10.6	13.1	1.1	0.8	3.1
10	17.3	11.8	22.2	1.1	0.9	3.2
Average	20.9	11	21.5	1.24	0.96	3.14

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	31	17.8	3	0	0	23.5
2	58.3	18.5	2.5	0	0	25.3
3	80.8	16.3	2	0	0	40.3
4	38.8	24.3	3.25	3.25	0	32.3
5	61.3	24.3	2.5	2.5	0.25	15.8
6	40.3	11.5	1.5	1.5	0	14.5
7	51	10	1.5	1.5	0	22
8	52	24.5	3	3	0	56.5
9	61.8	20	2.5	2.5	0	13.3
10	39.3	19.5	3	3	0	29
Average	51.4	18.7	2.48	1.73	0.03	27.2

Simulation Data for 180 ft Diameter at 50 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	31	26.3	26.5	4.6	3.8	16.3
2	36.1	25	24.8	4.6	3.8	15.9
3	47.7	23.1	42.9	4.7	4	15.9
4	35.9	24.9	34.3	4.6	4	16.6
5	33.1	26.1	35	4.5	3.8	16.5
6	35.8	23.4	25.6	4.7	3.8	15.1
7	36.1	25	24.8	4.6	3.8	15.9
8	35.4	25.9	41.9	4.7	4.1	15.9
9	36.7	24	23.4	4.4	3.7	15.1
10	32.9	25.2	27.6	4.5	3.8	16.3
Average	36.1	24.9	30.7	4.59	3.86	16

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	15	9.8	15.7	1.4	1	3.7
2	19.8	8.5	14.2	1.4	1	3.2
3	31.6	6.7	32.2	1.6	1.1	3.5
4	19.7	8.6	23.7	1.5	1.1	4
5	17	9.6	24.3	1.3	1	3.9
6	19.8	7	15.1	1.5	1	2.6
7	22.2	7.8	14.1	1.4	1.1	3
8	19.2	9.5	31.3	1.5	1.2	3.3
9	20.6	7.5	12.9	1.3	0.9	2.6
10	16.9	8.7	17.1	1.4	1	3.9
Average	20.2	8.37	20.1	1.43	1.04	3.37

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	27.3	19.5	1.75	0	0	18
2	44	8.25	1.25	0	0.25	17.3
3	87.5	4.25	1.75	0	0.5	37
4	41.5	15.5	2	2	0	32
5	39	15	2.5	2.5	0	28
6	42.8	6.5	1.25	1.25	0	16
7	49.5	5.25	1.25	1.25	0.5	15
8	41.8	15.5	1.75	1.75	0.5	42
9	50.8	8	0.75	0.75	0	12.3
10	38	11.8	2.5	2.5	0	21
Average	46.2	11	1.68	1.2	0.18	23.9

Simulation Data for 200 ft Diameter at 50 % Car1 - Model Scenario S2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	30.5	25.4	26.5	5.1	4.2	14.9
2	35.3	24.4	20.9	4.9	4.2	14.7
3	39.3	22.9	25.9	4.9	4.2	15.4
4	27.7	24.1	27.2	5	4.3	15.7
5	30.5	25.3	30.3	4.9	4.2	15.2
6	35.1	23.9	25.8	5.1	4.2	14.8
7	35.3	24.4	20.9	4.9	4.2	14.7
8	35.3	25.8	31.4	4.9	4.2	15.5
9	37.4	25	20.2	5	4.1	14
10	31.1	24.4	26.4	4.8	4.1	14.9
Average	33.8	24.6	25.6	4.95	4.19	15

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	14.7	8.9	16	1.5	1.1	2.5
2	19.3	8	10.6	1.4	1.1	2.2
3	23.4	6.6	15.4	1.5	1.1	3.2
4	11.7	7.8	16.8	1.6	1.2	3.3
5	14.5	8.8	19.8	1.5	1.1	2.8
6	19.2	7.5	15.5	1.6	1.1	2.4
7	20.1	8.9	20.3	1.5	1.1	2.4
8	19.2	9.4	21	1.4	1.1	3.1
9	21.4	8.5	10	1.5	0.9	1.7
10	15.3	8	16.1	1.4	1	2.5
Average	17.9	8.24	16.2	1.49	1.08	2.61

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	26.8	12.5	0.75	0	0	18
2	42.8	11.3	1	0	0	11.5
3	59.3	3.5	1.25	0	0	15
4	20.3	8.25	1.5	1.5	0	20.5
5	30.8	15.8	1.25	1.25	0	21.8
6	41	5.5	0.75	0.75	0	16.3
7	42.8	6.25	0.75	0.75	0	24.8
8	42.8	17	1.25	1.25	0	26.3
9	53	9	0.25	0.25	0	8.5
10	32	7.5	1	1	0	18.3
Average	39.1	9.65	0.98	0.68	0	18.1

Summary of Simulation Data for 50 % Car1 - Model Scenario S2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
80	59.4	35.7	53.5	2.2	1.75	20.9
100	46.4	32.3	36.1	2.74	2.14	19.8
120	50.7	34.4	43.4	3.44	3.15	17.8
140	48	30.1	43	3.88	3.33	16.6
160	37.2	27.7	32.5	4.21	3.58	15.8
180	36.1	24.9	30.7	4.59	3.86	16
200	33.8	24.6	25.6	4.95	4.19	15
Average						

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
80	41.4	18.8	41.3	0.76	0.58	7.35
100	30.2	15.2	25.7	0.89	0.66	6.11
120	34.9	17.5	32.2	1.17	0.6	4.74
140	31.7	13.6	31.3	1.22	0.95	3.73
160	20.9	11	21.5	1.24	0.96	3.14
180	20.2	8.37	20.1	1.43	1.04	3.37
200	17.9	8.24	16.2	1.49	1.08	2.61
Average						

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
80	117	50.8	6.05	4.18	2.15	56.9
100	79.1	35.3	4.63	2.98	0.2	35.8
120	96.7	47.7	3	2.08	0.18	48.3
140	83.4	28.9	2.38	1.68	0.08	40.2
160	51.4	18.7	2.48	1.73	0.03	27.2
180	46.2	11	1.68	1.2	0.18	23.9
200	39.1	9.65	0.98	0.68	0	18.1
Average						

APPENDIX 4: RESULTS FOR S3 SIMULATION SCENARIO

Simulation Data for 0 % Volume Increase at 0 %Car1 - Model Scenario S3

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	29.7	39.8	33	3.9	3.3	20.9
2	40.7	26.1	56.8	3.7	3.4	16.8
3	53.3	30.7	38.5	3.9	3.5	19.8
4	30.1	25.7	22.2	3.8	3.3	20.6
5	34.4	42.1	34.1	3.9	3.4	18.4
6	28.8	26.8	25.8	3.6	3.2	20.4
7	40.7	26.1	56.8	3.7	3.4	16.8
8	38.1	25.6	36.7	3.9	3.6	17.2
9	43	23.5	40.6	3.6	3.1	16.9
10	34.2	23.2	33	3.6	3.2	15.8
Average	37.3	29	37.8	3.76	3.34	18.4

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	44.1	28.2	186	0.6	0.5	4.6
2	49	23	125	0.6	0.5	4
3	122	24.9	202	0.6	0.6	5
4	52.8	27.4	157	0.6	0.5	5.3
5	114	19.3	165	0.6	0.5	7.8
6	84.4	18.9	97.2	0.7	0.6	5.7
7	65.1	37	123	0.7	0.5	5.4
8	99.7	26.2	162	0.6	0.5	5.5
9	97.5	24.2	103	0.7	0.5	4.4
10	62.9	31.9	121	0.7	0.6	5.1
Average	79.2	26.1	144	0.64	0.53	5.28

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	111	108	2.75	0	0	349
2	159	83.5	2.5	0	0	226
3	478	105	3.5	0	0	268
4	146	142	3.75	3.75	0	253
5	447	68.3	7	7	0	272
6	265	53.3	4	4	0	160
7	197	194	3.25	3.25	0	181
8	360	134	3.75	3.75	0	325
9	373	73.5	3.25	3.25	0	144
10	197	152	3.75	3.75	0	207
Average	273	111	3.75	2.88	0	238

Simulation Data for 5 % Volume Increase at 0 % Car1 - Model Scenario S3

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	28	39.9	29.1	3.7	3.3	20.9
2	40.4	32	67.7	3.8	3.5	17.5
3	71.6	28.7	37.1	4.1	3.6	18.8
4	45.3	30	32.6	4	3.4	17.7
5	35.2	44.1	23.9	4.2	3.7	17.2
6	31	30.5	33	3.6	3.2	18.1
7	40.4	32	67.7	3.8	3.5	17.5
8	46.7	27.2	32.6	3.7	3.5	19.8
9	32.9	32.9	87.2	3.7	3.2	19
10	35.8	25.2	41.5	3.6	3.2	16.5
Average	40.7	32.3	45.2	3.82	3.41	18.3

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	101	38.1	229	0.6	0.5	7.4
2	94.2	24.6	307	0.6	0.5	4.7
3	210	46.1	203	0.7	0.6	4.9
4	119	41	308	0.6	0.6	5.2
5	197	28.8	159	0.6	0.5	5
6	173	14.5	156	0.6	0.6	4.8
7	154	48.9	140	0.7	0.6	4.4
8	154	35.8	226	0.7	0.6	4.2
9	176	24.9	144	0.7	0.6	4.5
10	111	29.6	253	0.7	0.5	5.8
Average	149	33.2	212	0.65	0.56	5.09

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	315	202	7.5	0	0	467
2	329	108	2.75	0	0	653
3	967	355	3.5	0	0	300
4	403	239	4.5	4.5	0	678
5	1051	116	3.25	3.25	0	286
6	714	38.5	3	3	0	283
7	638	341	3	3	0	228
8	632	261	2.25	2.25	0	473
9	740	77.5	3.25	3.25	0.25	241
10	441	138	4.5	4.5	0	500
Average	623	188	3.75	2.38	0.03	411

Simulation Data for 10 % Volume Increase at 0 % Car1 - Model Scenario S3

Travel Time

Sim No	EB	SB	NB	Pt1	Pt2	WB
	Link No					
1	39.2	49.6	35.9	3.9	3.3	20.2
2	46.7	33.9	58	3.9	3.4	17.7
3	66.1	32.5	36.8	3.9	3.4	22.4
4	30.6	42.8	34.1	4.2	3.6	18.7
5	47	46.3	35.3	4	3.4	21.2
6	28.9	47.2	26.7	3.6	3.1	20.2
7	46.7	33.9	58	3.9	3.4	17.7
8	52.4	33.2	41.7	3.7	3.4	21
9	42.4	30.5	86.4	3.7	3.2	18.2
10	48.8	27	59.8	3.5	3.2	19.9
Average	44.9	37.7	47.3	3.83	3.34	19.7

Delay

Sim No	EB	SB	NB	Pt1	Pt2	WB
	Link No					
1	150	56.1	269	0.6	0.5	9.3
2	184	33.2	346	0.7	0.6	5.9
3	238	37.3	346	0.6	0.5	5.6
4	214	38.3	298	0.6	0.5	6.2
5	226	37.4	251	0.7	0.6	8
6	227	21.8	270	0.6	0.6	5.1
7	215	44.9	290	0.7	0.5	5.3
8	140	59.8	330	0.7	0.6	3.9
9	200	47.4	189	0.7	0.5	5.2
10	172	53.3	214	0.7	0.6	5.6
Average	197	43	280	0.66	0.55	6.01

Queue Length

Sim No	EB	SB	WB	Pt1	Pt2	NB
	Link No					
1	535	443	11.8	0	0	551
2	843	196	4.25	0	0	737
3	1178	247	4.5	0	0	620
4	894	223	5	5	0	677
5	1290	217	7.25	7.25	0	497
6	1106	67.3	3.75	3.75	0	513
7	1153	312	4	4	0	556
8	612	614	2.5	2.5	0	708
9	1042	397	4	4	0	354
10	835	481	4.5	4.5	0	440
Average	948	320	5.15	3.1	0	565

Simulation Data for 15 % Volume Increase at 0 % Car1 - Model Scenario S3

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	37.6	54	66.3	3.9	3.3	18.3
2	70.6	33.5	90.1	3.9	3.3	18.3
3	92.2	31.8	57.7	4	3.5	22
4	26	53	35	4.3	3.6	19.2
5	47.4	50.6	42.1	3.8	3.4	22
6	45.2	40.7	35.5	3.7	3.2	19.9
7	70.6	33.5	90.1	3.9	3.3	18.3
8	64.5	32.7	45.1	3.7	3.5	21
9	41.6	28.9	156	3.8	3.3	23
10	68.7	27.1	90.6	3.7	3.4	16.7
Average	56.4	38.6	70.9	3.87	3.38	19.9

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	103	66.5	338	0.7	0.6	5.9
2	233	46.8	314	0.6	0.5	5
3	245	63.6	265	0.7	0.6	5.5
4	242	46	326	0.6	0.5	4.3
5	235	61.4	229	0.6	0.5	5.5
6	245	47.3	241	0.7	0.5	5.5
7	227	61	267	0.7	0.6	5.6
8	180	60.5	364	0.7	0.5	5
9	197	67.3	218	0.7	0.6	6.1
10	187	64.8	229	0.7	0.6	5.2
Average	209	58.5	279	0.67	0.55	5.36

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	387	630	5	0	0	753
2	1269	355	3.25	0	0	761
3	1330	606	5	0	0	490
4	1137	356	3.25	3.25	0	751
5	1363	727	4.75	4.75	0	468
6	1205	344	4	4	0	490
7	1098	612	4.75	4.75	0	507
8	837	718	3.25	3.25	0	785
9	1135	743	5.25	5.25	0	442
10	899	664	4	4	0	530
Average	1066	575	4.25	2.93	0	598

Simulation Data for 20 % Volume Increase at 0 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	48.4	51.2	50.3	4	3.4	23.4
2	45.7	52	74.8	4.1	3.6	17.2
3	121	39.6	25.8	4	3.5	20.5
4	33.1	56.8	37.7	3.8	3.3	20.4
5	62.5	64.9	38.5	4.2	3.6	17.6
6	48	35.9	62.9	3.7	3.2	19.1
7	45.7	52	74.8	4.1	3.6	17.2
8	64.8	34.3	56	4	3.6	19.5
9	47	45.8	79.1	3.7	3.2	20.1
10	84	30.8	66.6	3.8	3.3	21.2
Average	60	46.3	56.7	3.94	3.43	19.6

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	174	72.3	290	0.6	0.5	7.6
2	260	56	342	0.6	0.5	4.8
3	254	68.9	294	0.7	0.6	6
4	251	64.9	327	0.7	0.6	4.6
5	255	58.1	300	0.7	0.6	7.2
6	243	57.9	325	0.6	0.5	5.8
7	213	71.3	333	0.7	0.6	5.2
8	218	59.9	344	0.7	0.5	5.1
9	233	72.3	172	0.7	0.5	5.4
10	206	65.7	243	0.7	0.6	5.1
Average	231	64.7	297	0.67	0.55	5.68

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	781	796	7.25	0	0	696
2	1371	534	3.25	0	0	810
3	1413	814	5.5	0	0	557
4	1200	740	3.25	3.25	0	750
5	1449	614	7.5	7.5	0	630
6	1239	609	4.5	4.5	0	728
7	1187	870	4.5	4.5	0	733
8	1004	658	4	4	0	790
9	1292	796	4.5	4.5	0	352
10	1028	747	4.5	4.5	0	560
Average	1196	717	4.88	3.28	0	661

Simulation Data for 25 % Volume Increase at 0 % Car1 - Model Scenario S3

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	52.7	50.7	51.7	3.8	3.3	21
2	112	44	83.1	3.9	3.4	18.1
3	126	41.7	54.7	4	3.4	25.1
4	24.5	77.3	35.1	4	3.4	21.5
5	45.5	46.5	60.1	3.8	3.3	19.3
6	30.5	67	29.8	3.7	3.2	18.6
7	112	44	83.1	3.9	3.4	18.1
8	61.6	29.6	73.9	4.1	3.7	21.9
9	52.9	40.9	163	3.6	3.2	18.6
10	101	35.4	77.9	3.7	3.3	22.6
Average	71.9	47.7	71.2	3.85	3.36	20.5

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	195	77.4	312	0.7	0.5	8.4
2	283	52.5	350	0.6	0.5	5.2
3	256	68.3	313	0.6	0.5	5.5
4	229	72	320	0.7	0.5	5.5
5	266	59.7	314	0.6	0.5	8.5
6	245	67.7	277	0.7	0.6	5.2
7	229	72.7	282	0.7	0.6	5.7
8	245	62.3	348	0.7	0.6	5
9	235	72.7	293	0.7	0.6	7.3
10	207	73.1	235	0.7	0.6	7.7
Average	239	67.8	304	0.67	0.55	6.4

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	951	818	9.25	0	0.25	816
2	1512	515	4	0	0	880
3	1431	813	5	0	0	631
4	1158	875	4.75	4.75	0	754
5	1492	700	9.25	9.25	0	649
6	1324	741	3.5	3.5	0	658
7	1314	844	4.25	4.25	0	634
8	1308	734	3.25	3.25	0.25	815
9	1345	825	7	7	0	610
10	1037	846	8.25	8.25	0	550
Average	1287	771	5.85	4.03	0.05	700

Simulation Data for 30 % Volume Increase at 0 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	33.3	89.4	41.7	4	3.5	19.7
2	106	50.1	87.1	3.9	3.6	20.3
3	88.3	61	61	4	3.4	20.6
4	26.3	70.1	49.6	4.1	3.5	19.6
5	67.6	55.6	35.5	4	3.3	20.5
6	49.7	54.3	94.3	3.6	3.2	20.1
7	106	50.1	87.1	3.9	3.6	20.3
8	85.9	29.2	92.2	3.9	3.7	18
9	74.5	44.5	147	3.7	3.2	16.5
10	138	37.3	98.3	3.7	3.3	21
Average	77.6	54.2	79.4	3.88	3.43	19.7

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	163	87.6	296	0.7	0.5	9.1
2	271	63.6	360	0.7	0.5	5.7
3	237	77.4	280	0.7	0.5	4.5
4	227	77.4	318	0.7	0.6	8.4
5	252	71.7	242	0.7	0.5	8
6	256	69.5	295	0.6	0.5	6.1
7	242	73.4	322	0.7	0.6	5.2
8	222	70.2	352	0.6	0.5	4.9
9	215	75.6	279	0.7	0.6	7.1
10	245	72.2	291	0.7	0.6	6.2
Average	233	73.9	303	0.68	0.54	6.52

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	855	950	11	0	0	813
2	1529	788	4.25	0	0	840
3	1472	924	3.5	0	0	596
4	1237	936	9.25	9.25	0	785
5	1525	855	7.75	7.75	0	579
6	1386	818	5	5	0	759
7	1384	872	3.75	3.75	0	760
8	1267	750	3.5	3.5	0	840
9	1406	1000	7.75	7.75	0	591
10	1307	900	5.25	5.25	0	689
Average	1337	879	6.1	4.23	0	725

Simulation Data for 35 % Volume Increase at 0 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	48.1	76.6	71.6	4.1	3.5	21.4
2	70.7	70.3	137	3.8	3.4	19
3	109	59	48.2	3.9	3.4	22.7
4	31.5	72	50.2	4	3.5	23.1
5	80	50.3	91.5	3.8	3.4	18.5
6	65.1	49.6	89.8	3.7	3.2	20.4
7	70.7	70.3	137	3.8	3.4	19
8	77.2	39.3	121	4.2	3.8	20
9	114	47.6	192	3.7	3.2	17.9
10	133	44.5	85.2	3.9	3.3	30.1
Average	80	58	102	3.89	3.41	21.2

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	186	87.5	284	0.6	0.5	9.1
2	271	66.4	357	0.7	0.5	7.3
3	238	78.8	275	0.7	0.5	5.7
4	230	84.7	257	0.7	0.6	9
5	236	77.8	217	0.7	0.6	8.5
6	241	73.4	258	0.7	0.6	8.4
7	195	81.1	345	0.7	0.6	7.3
8	260	63.5	383	0.7	0.6	5.7
9	225	78.8	315	0.7	0.5	8.6
10	236	78.4	258	0.7	0.5	7.2
Average	232	77	295	0.69	0.55	7.68

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1024	954	12.5	0	0	817
2	1531	720	6	0	0	875
3	1501	895	4.5	0	0	637
4	1243	979	10	10	0	738
5	1553	868	8.75	8.75	0	515
6	1404	837	8.5	8.5	0	659
7	1225	868	7	7	0	809
8	1416	777	4.5	4.5	0	889
9	1391	860	9.5	9.5	0	723
10	1308	968	7.75	7.75	0	640
Average	1360	872	7.9	5.6	0	730

Simulation Data for 40 % Volume Increase at 0 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	52.6	75.8	71	4	3.5	25.8
2	74.5	69.6	153	3.9	3.4	20.7
3	108	66.6	36.9	4.2	3.6	29.8
4	29.2	91.5	52.4	4	3.5	22.5
5	66.6	66.4	109	4.1	3.4	19.4
6	80.1	61.2	89.3	3.7	3.2	20.2
7	74.5	69.6	153	3.9	3.4	20.7
8	73.2	46.3	104	4.1	3.6	19.4
9	101	51.9	129	3.7	3.2	20
10	158	43	81.8	3.8	3.4	27.9
Average	81.8	64.2	97.9	3.94	3.42	22.6

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	173	95	222	0.7	0.5	13.9
2	259	73.3	342	0.7	0.5	6.3
3	240	78.8	308	0.6	0.5	5.2
4	206	88.3	284	0.8	0.6	8.1
5	261	72.5	317	0.7	0.6	11.4
6	246	73.2	325	0.6	0.5	6.5
7	218	81.7	320	0.8	0.6	6.9
8	246	77.6	334	0.7	0.5	5.8
9	196	84.6	309	0.7	0.6	8.6
10	206	82.2	273	0.7	0.6	10.3
Average	225	80.7	303	0.7	0.55	8.3

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1140	1022	27.3	0	0	697
2	1570	866	4.75	0	0	897
3	1536	909	4.25	0	0	759
4	1308	983	9.5	9.5	0	823
5	1572	844	15	15	0	758
6	1514	796	5.25	5.25	0	827
7	1470	855	8	8	0	843
8	1479	827	4.5	4.5	0	867
9	1380	959	10	10	0	730
10	1267	902	11.8	11.8	0	700
Average	1423	896	10	6.4	0	790

Simulation Data for 45 % Volume Increase at 0 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	49.5	86.1	76.2	3.8	3.3	22.3
2	83.9	79.9	123	3.9	3.4	19.1
3	81.9	92.6	60.8	4.2	3.7	27.8
4	34.5	85.2	67.4	3.9	3.4	21.8
5	74.9	92.7	49.7	3.9	3.4	22.4
6	46.9	93.1	82.2	3.8	3.3	19.6
7	83.9	79.9	123	3.9	3.4	19.1
8	90.2	42.6	83.2	4.3	3.6	24.8
9	91.3	58.7	134	3.7	3.2	19.7
10	120	54.1	102	3.9	3.4	28.5
Average	75.7	76.5	90	3.93	3.41	22.5

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	184	94.2	325	0.7	0.5	9
2	261	68.1	355	0.7	0.5	6.4
3	241	75.6	323	0.6	0.5	6.8
4	214	91.2	271	0.7	0.6	6.1
5	236	77.4	308	0.7	0.5	9
6	236	73.8	322	0.7	0.5	8.5
7	223	84.2	350	0.7	0.6	5.5
8	224	85.5	331	0.7	0.6	9.1
9	210	90.6	284	0.7	0.6	9.9
10	205	88.9	308	0.7	0.5	9.8
Average	223	83	318	0.69	0.54	8.01

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1220	1054	12	0	0	882
2	1567	810	6.5	0	0	901
3	1465	923	7.25	0	0	764
4	1360	1054	5.25	5.25	0	821
5	1582	925	9.75	9.75	0	781
6	1469	827	10.5	10.5	0	835
7	1504	1002	4.5	4.5	0	869
8	1477	902	10.8	10.8	0	885
9	1508	957	13	13	0	729
10	1353	957	10.5	10.5	0	792
Average	1450	941	9	6.43	0	826

Simulation Data for 50 % Volume Increase at 0 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	45.3	111	63.2	3.8	3.3	24.4
2	67.6	83.2	141	4.1	3.7	19.9
3	106	89.7	41.4	3.9	3.5	32.5
4	32.3	99.4	59.6	4.1	3.6	24.5
5	55.9	102	75.4	4	3.4	23.7
6	42.3	90.1	137	3.8	3.4	18.2
7	67.6	83.2	141	4.1	3.7	19.9
8	96.7	43.5	118	4	3.4	21
9	77.3	71	186	3.7	3.2	22.1
10	163	64.4	103	3.7	3.4	28.5
Average	75.4	83.8	106	3.92	3.46	23.5

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	165	98.7	298	0.8	0.6	14.1
2	242	75.9	322	0.7	0.5	7.4
3	225	81.4	292	0.7	0.5	7.6
4	200	95.4	270	0.7	0.6	7.6
5	247	79.9	265	0.7	0.6	10.6
6	215	84.8	285	0.7	0.6	10.5
7	221	90.8	268	0.7	0.6	8.4
8	251	79.3	319	0.7	0.5	9.7
9	209	93.4	290	0.7	0.6	8.9
10	210	89.6	280	0.7	0.6	11.4
Average	218	86.9	289	0.71	0.57	9.62

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1044	1070	25	0	0	870
2	1560	842	7.5	0	0	892
3	1564	991	8	0	0	730
4	1313	1103	8	8	0	851
5	1571	899	11.8	11.8	0	724
6	1447	942	13.3	13.3	0	867
7	1542	1006	10	10	0	742
8	1520	878	11.5	11.5	0	894
9	1459	1063	10.8	10.8	0	743
10	1380	988	18.5	18.5	0	780
Average	1440	978	12.4	8.38	0	809

Summary of Simulation Data for 0 % Car1 - Model Scenario S3

Travel Time

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
0	37.3	29	37.8	3.76	3.34	18.4
5	40.7	32.3	45.2	3.82	3.41	18.3
10	44.9	37.7	47.3	3.83	3.34	19.7
15	56.4	38.6	70.9	3.87	3.38	19.9
20	60	46.3	56.7	3.94	3.43	19.6
25	71.9	47.7	71.2	3.85	3.36	20.5
30	77.6	54.2	79.4	3.88	3.43	19.7
35	80	58	102	3.89	3.41	21.2
40	81.8	64.2	97.9	3.94	3.42	22.6
45	75.7	76.5	90	3.93	3.41	22.5
50	75.4	83.8	106	3.92	3.46	23.5
Average						

Delay

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
0	79.2	26.1	144	0.64	0.53	5.28
5	149	33.2	212	0.65	0.56	5.09
10	197	43	280	0.66	0.55	6.01
15	209	58.5	279	0.67	0.55	5.36
20	231	64.7	297	0.67	0.55	5.68
25	239	67.8	304	0.67	0.55	6.4
30	233	73.9	303	0.68	0.54	6.52
35	232	77	295	0.69	0.55	7.68
40	225	80.7	303	0.7	0.55	8.3
45	223	83	318	0.69	0.54	8.01
50	218	86.9	289	0.71	0.57	9.62
Average						

Queue Length

	Link No					
Average	EB	SB	WB	Pt1	Pt2	NB
0	273	111	3.75	2.88	0	238
5	623	188	3.75	2.38	0.03	411
10	948	320	5.15	3.1	0	565
15	1066	575	4.25	2.93	0	598
20	1196	717	4.88	3.28	0	661
25	1287	771	5.85	4.03	0.05	700
30	1337	879	6.1	4.23	0	725
35	1360	872	7.9	5.6	0	730
40	1423	896	10	6.4	0	790
45	1450	941	9	6.43	0	826
50	1440	978	12.4	8.38	0	809
Average						

Simulation Data for 0 % Volume Increase at 10 % Car1 - Model Scenario S3

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	25.5	47	20.1	3.8	3.2	16.6
2	30.9	29.1	39.5	3.7	3.2	17.9
3	26.3	33.7	28.8	3.7	3.4	23.1
4	26.6	29.1	25.2	3.9	3.5	19
5	32.1	28	22.7	3.8	3.3	20.8
6	29.8	27.4	33.6	3.5	3.1	20.9
7	30.9	29.1	39.5	3.7	3.2	17.9
8	29.6	22.9	35.7	3.5	3.2	20.4
9	40.7	27	36.4	3.7	3.4	18.2
10	52	29.4	29.1	3.8	3.6	14.8
Average	32.4	30.3	31.1	3.71	3.31	19

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	26.7	36.7	56.5	0.7	0.6	6.4
2	42.4	22.9	120	0.7	0.6	4.1
3	135	22.6	96.4	0.7	0.6	6
4	36	22.1	160	0.6	0.6	5.3
5	50.1	23.6	212	0.7	0.6	6.7
6	45.8	17.9	53.8	0.8	0.6	5
7	93.1	30.7	88.3	0.9	0.7	5.6
8	52.1	32.3	156	0.7	0.6	5
9	53.2	20.7	58.8	0.8	0.6	4.1
10	48	27.3	124	0.8	0.6	5.2
Average	58.2	25.7	113	0.74	0.61	5.34

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	141	299	4	0	0	53
2	82	47	2	0	0	94
3	873	55	3	0	0	44
4	105	31	3	3	0	316
5	84	22	2	2	0	659
6	253	42	1	1	0	181
7	241	89	6	6	0	301
8	154	52	3	3	0	658
9	124	25	1	1	0	279
10	184	27	2	2	0	365
Average	224	68.9	2.7	1.8	0	295

Simulation Data for 5 % Volume Increase at 10 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	28.9	58.2	17.9	4.1	3.3	19
2	45.8	28.2	38.7	3.8	3.2	18.6
3	46.3	30.1	47.8	4.2	3.7	20
4	29.3	32.2	23.5	4	3.7	17
5	38	30.9	22.5	3.7	3.3	20.3
6	25.5	31.6	37.4	3.6	3.1	18.1
7	45.8	28.2	38.7	3.8	3.2	18.6
8	25.9	23.3	56.1	3.6	3.2	22.4
9	35.2	31.5	31.2	3.8	3.4	17.8
10	51.7	26	60.7	3.9	3.5	15.1
Average	37.2	32	37.5	3.85	3.36	18.7

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	56.2	49.2	128	0.9	0.7	6.8
2	88.8	28	250	0.8	0.7	4.9
3	194	22.2	212	0.8	0.6	4.9
4	110	38.4	219	0.8	0.7	6.1
5	188	29.7	145	0.8	0.6	8.5
6	67.9	26.2	130	0.8	0.6	6.3
7	140	34.4	104	0.8	0.7	5.3
8	144	26.6	197	0.8	0.6	6.3
9	163	43.4	106	0.9	0.7	4.9
10	117	33.2	243	0.8	0.7	5.6
Average	127	33.1	173	0.82	0.66	5.96

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	617	561	1	0	0	182
2	263	101	4	0	0	700
3	1511	30	4	0	0	260
4	743	38	1	1	0	692
5	1303	33	16	16	0	367
6	502	49	3	3	0	538
7	738	30	5	5	0	479
8	948	76	5	5	0	781
9	944	64	3	3	0	620
10	735	42	8	8	0	853
Average	830	102	5	4.1	0	547

Simulation Data for 10 % Volume Increase at 10 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	25.7	56.1	40.9	3.9	3.3	18.8
2	33.4	35.5	52.5	4	3.3	18.7
3	79.5	29.6	34	4	3.4	19.6
4	37.2	27.4	37.5	4	3.7	16.9
5	34.1	31.1	34.3	3.8	3.3	16.1
6	33.4	32.7	36	3.6	3.1	21.3
7	33.4	35.5	52.5	4	3.3	18.7
8	40.1	27.2	47.4	3.7	3.3	17.2
9	49.8	27.9	48	3.7	3.3	19.2
10	64.4	28.5	38.2	3.9	3.5	16
Average	43.1	33.2	42.1	3.86	3.35	18.3

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	106	52	238	0.8	0.7	6.8
2	178	27.9	288	0.8	0.6	4.8
3	241	23.7	274	0.7	0.6	5.6
4	146	40.7	267	0.7	0.6	5
5	212	51.5	141	0.8	0.6	8.5
6	156	38.1	202	0.8	0.7	6
7	169	58.8	180	0.9	0.8	4.9
8	173	38.8	239	0.8	0.6	5.9
9	183	44.7	138	0.8	0.6	4.7
10	169	46.7	209	0.8	0.7	6
Average	173	42.3	218	0.79	0.65	5.82

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	745	718	2	0	0	697
2	943	102	4	0	0	894
3	1684	35	2	0	0	679
4	973	40	3	3	0	807
5	1503	344	4	4	0	468
6	1099	158	5	5	0	738
7	1287	281	2	2	0	696
8	1548	63	6	6	0	873
9	1511	97	2	2	0	684
10	1348	87	1	1	0	817
Average	1264	193	3.1	2.3	0	735

Simulation Data for 15 % Volume Increase at 10 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	29.2	67.4	30	3.9	3.4	18.6
2	36.3	56.3	38.9	4	3.3	17.4
3	80.2	35.3	36.7	3.9	3.4	23.3
4	34.1	32.9	37.9	4	3.8	17.4
5	45.5	39.5	32.1	3.8	3.3	19.4
6	38.8	30.5	37.8	3.7	3.2	20.2
7	36.3	56.3	38.9	4	3.3	17.4
8	48.8	29.2	40.2	4	3.5	17.6
9	59.7	29.3	74.6	3.9	3.4	18.5
10	88.5	36.7	42.7	4.1	3.7	16
Average	49.7	41.3	41	3.93	3.43	18.6

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	134	58.3	318	0.8	0.7	5.1
2	228	34.8	320	0.8	0.6	5.7
3	259	57.7	128	0.7	0.6	5.4
4	235	37.7	334	0.8	0.6	4.7
5	232	59.8	199	0.8	0.6	6
6	218	56.2	219	0.8	0.7	6
7	179	63.4	183	1	0.7	6.2
8	172	53.2	330	0.9	0.7	5
9	204	64.7	148	0.9	0.6	4
10	178	67.3	239	0.8	0.7	6.6
Average	204	55.3	242	0.83	0.65	5.47

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1054	753	2	0	0	929
2	1595	304	9	0	0	958
3	1678	491	2	0	0	381
4	1563	166	2	2	0	951
5	1683	398	2	2	0	766
6	1684	561	2	2	0	785
7	1510	570	6	6	0	757
8	1672	561	1	1	0	960
9	1684	539	3	3	0	711
10	1510	863	6	6	0	909
Average	1563	521	3.5	2.2	0	811

Simulation Data for 20 % Volume Increase at 10 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	39.5	54.8	22.3	4.1	3.5	26.3
2	49	60.9	53.6	3.8	3.2	16.6
3	69.7	49.7	60.5	4.3	3.6	21.5
4	38.4	34.2	50.9	4.2	3.6	16.3
5	61.1	33.7	22.5	4.1	3.4	17.7
6	32.9	51.1	39.5	3.7	3.2	18.8
7	49	60.9	53.6	3.8	3.2	16.6
8	53.5	30.7	94	4	3.6	19.2
9	58.9	32.2	171	3.7	3.4	17.4
10	81.9	37.5	74.3	3.9	3.6	18.1
Average	53.4	44.6	64.3	3.96	3.43	18.9

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	95.6	76.7	262	0.9	0.7	8.1
2	241	49.4	313	0.9	0.7	5.6
3	254	60.3	302	0.8	0.6	4.8
4	206	63	344	0.8	0.6	5.5
5	219	66.9	216	0.9	0.7	7.2
6	215	68.7	249	0.9	0.6	5.9
7	192	68.6	284	0.9	0.7	5.6
8	200	61.5	317	0.9	0.6	5.6
9	226	63.9	279	0.8	0.7	6.2
10	203	64.4	223	0.8	0.6	5.3
Average	205	64.3	279	0.86	0.65	5.98

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	961	803	9	0	0	892
2	1682	782	5	0	0	965
3	1684	418	3	0	0	763
4	1446	645	2	2	0	958
5	1685	466	2	2	0	808
6	1660	916	7	7	0	855
7	1681	749	2	2	0	916
8	1686	866	4	4	0	938
9	1686	881	5	5	1	915
10	1678	480	2	2	0	801
Average	1585	701	4.1	2.4	0.1	881

Simulation Data for 25 % Volume Increase at 10 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	45.3	57.7	44.4	3.9	3.4	21.7
2	75.5	41.4	80.7	3.8	3.2	18.8
3	90.4	47.8	36.7	4.3	3.6	23.7
4	36.7	50.3	52.4	4.1	3.7	17.8
5	54.5	44.9	47.1	3.7	3.3	21.3
6	39.3	59.5	34.9	3.7	3.2	21.4
7	75.5	41.4	80.7	3.8	3.2	18.8
8	68.9	30.8	83.4	3.9	3.4	19.3
9	77.9	44.8	128	3.9	3.6	18.4
10	117	36.8	69.6	3.8	3.3	20.8
Average	68.1	45.5	65.8	3.89	3.39	20.2

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	188	76.2	277	0.8	0.7	7.6
2	257	54.3	351	0.8	0.6	6.1
3	252	63.3	288	0.8	0.6	6.2
4	227	62.8	370	0.8	0.6	6.1
5	239	63.7	247	0.8	0.6	8.9
6	228	70.1	245	0.8	0.6	6.7
7	192	76.4	281	1	0.8	6.5
8	206	62.9	302	0.8	0.6	6.8
9	199	71.4	192	0.8	0.6	6.6
10	201	72.5	226	0.9	0.7	7.5
Average	219	67.4	278	0.83	0.64	6.9

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1532	972	4	0	0	950
2	1683	618	5	0	0	963
3	1685	676	3	0	0	791
4	1687	728	2	2	0	959
5	1686	445	2	2	0	948
6	1685	840	6	6	0	956
7	1661	747	8	8	0	958
8	1665	668	7	7	0	951
9	1683	948	24	24	0	907
10	1687	680	5	5	0	875
Average	1665	732	6.6	5.4	0	926

Simulation Data for 30 % Volume Increase at 10 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	28.9	77.8	51.8	4	3.3	19.3
2	46.8	69.6	55	3.8	3.4	17.4
3	119	37.2	50.9	4.4	3.7	26.6
4	36.5	65.1	60.6	4	3.6	19.4
5	69.6	50.5	42	3.9	3.5	19.8
6	48.2	38.4	91.3	3.7	3.2	20.1
7	46.8	69.6	55	3.8	3.4	17.4
8	81.7	33.1	116	4.2	3.6	21.7
9	55.2	54.1	147	3.7	3.3	17.4
10	121	35.3	106	3.8	3.4	23
Average	65.3	53.1	77.6	3.93	3.44	20.2

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	187	75.8	289	0.8	0.6	7.3
2	258	62.1	308	0.9	0.6	4.9
3	246	74.4	306	0.9	0.7	4.9
4	247	69.1	341	0.7	0.5	6.7
5	224	74.9	224	0.8	0.6	9.8
6	206	74.7	264	0.9	0.7	7.6
7	224	72.7	268	0.9	0.7	7.6
8	235	65.4	341	0.9	0.7	6.3
9	216	70.5	245	0.9	0.7	6.4
10	204	71.1	301	0.9	0.7	7.3
Average	225	71.1	289	0.86	0.65	6.88

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1621	779	4	0	0	964
2	1685	557	4	0	0	960
3	1680	893	3	0	0	896
4	1685	923	7	7	0	963
5	1684	737	2	2	0	824
6	1686	582	7	7	0	910
7	1664	880	7	7	0	942
8	1684	1004	3	3	0	959
9	1684	861	4	4	0	953
10	1688	666	5	5	0	959
Average	1676	788	4.6	3.5	0	933

Simulation Data for 35 %Volume Increase at 10 % Car1 - Model Scenario S3

Travel Time

Sim No	EB	SB	NB	Pt1	Pt2	WB
	Link No					
1	34.7	85	49.5	4.1	3.3	20
2	36.7	87.1	72.4	3.9	3.5	18.8
3	118	49.6	57.4	4	3.5	18.6
4	31.1	77.9	49.3	4.1	3.7	19
5	65.3	77.7	27.2	3.9	3.6	19.6
6	65.8	48.2	82.7	3.7	3.2	18.6
7	36.7	87.1	72.4	3.9	3.5	18.8
8	61.7	33.9	139	4.1	3.6	17.3
9	79.2	57.1	88.8	3.8	3.4	17.6
10	117	38.3	115	3.8	3.4	24.1
Average	64.7	64.2	75.4	3.93	3.47	19.2

Delay

Sim No	EB	SB	NB	Pt1	Pt2	WB
	Link No					
1	176	85.2	275	0.8	0.6	8.7
2	227	70	333	0.9	0.7	7.1
3	264	70.4	322	0.8	0.6	6.8
4	223	71.1	338	0.8	0.6	6.4
5	218	83.4	162	0.9	0.7	12.6
6	225	73.8	278	0.9	0.7	6.8
7	224	77.4	292	0.9	0.8	6.7
8	242	70.8	318	0.9	0.7	6.6
9	209	78.8	169	1	0.7	8.9
10	195	81.6	261	0.9	0.7	8.5
Average	220	76.3	275	0.88	0.68	7.91

Queue Length

Sim No	EB	SB	WB	Pt1	Pt2	NB
	Link No					
1	1615	964	3	0	0	959
2	1682	723	2	0	0	963
3	1687	710	6	0	0	928
4	1679	850	4	4	0	960
5	1686	610	3	3	0	844
6	1683	484	7	7	0	960
7	1683	1080	3	3	1	958
8	1684	1012	3	3	0	958
9	1684	948	8	8	0	878
10	1684	753	9	9	0	960
Average	1677	813	4.8	3.7	0.1	937

Simulation Data for 40 % Volume Increase at 10 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	49.5	79	70.7	4.3	3.5	18.4
2	88	56	152	4	3.4	17.8
3	113	64	41.4	4.1	3.5	24.3
4	42.9	70.9	57	4.1	3.7	17.6
5	108	51.8	63.9	3.8	3.4	17.6
6	60.3	51.2	93.4	3.8	3.3	20.1
7	88	56	152	4	3.4	17.8
8	97.5	36.4	130	4.1	3.6	18.2
9	67.9	71.9	138	3.8	3.4	19.8
10	116	61.6	101	4.1	3.5	22.6
Average	83.1	59.9	100	4.01	3.47	19.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	189	85	299	0.8	0.6	8
2	273	63.1	335	0.8	0.7	6.8
3	242	78.1	270	0.8	0.6	6.8
4	225	81.3	298	0.8	0.6	10.6
5	199	85.8	186	0.9	0.7	9.9
6	241	72.1	307	0.8	0.7	6.7
7	231	78.5	314	1	0.7	6.5
8	244	71.1	335	0.9	0.7	5.7
9	202	82.3	285	0.9	0.7	7.3
10	185	83.4	265	1	0.7	8.6
Average	223	78.1	289	0.87	0.67	7.69

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1680	903	3	0	0	958
2	1688	785	2	3	0	962
3	1684	768	6	0	0	907
4	1683	902	12	12	0	957
5	1678	623	9	9	0	873
6	1688	607	4	4	0	961
7	1686	700	2	2	0	957
8	1682	840	5	5	0	954
9	1687	815	7	7	0	957
10	1677	891	16	16	0	957
Average	1683	783	6.6	5.8	0	944

Simulation Data for 45 % Volume Increase at 10 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	38.6	94.9	44.5	4.1	3.5	24.5
2	96.4	72.5	102	3.8	3.3	18.9
3	108	70.4	47.5	4.2	3.6	22.4
4	40	94.3	53.6	4.1	3.7	16.7
5	130	49.4	120	3.8	3.4	28.7
6	67	56.7	107	3.7	3.3	17.2
7	96.4	72.5	102	3.8	3.3	18.9
8	121	35.2	143	4	3.5	21.6
9	91.8	69.4	94.5	3.9	3.4	23.3
10	120	73.1	99.3	3.8	3.4	24.4
Average	90.9	68.8	91.4	3.92	3.44	21.7

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	166	91.2	263	0.9	0.7	10.8
2	166	91.2	263	0.9	0.7	10.8
3	251	75.7	263	0.8	0.6	8.5
4	219	83.3	306	0.9	0.6	8.3
5	207	87.4	247	0.9	0.8	11.3
6	224	77.3	302	0.8	0.7	8.4
7	227	86.7	258	1	0.8	6.2
8	218	78	305	0.8	0.6	8.6
9	206	86.5	228	0.8	0.7	8.1
10	178	85.7	286	0.9	0.7	9.5
Average	206	84.3	272	0.87	0.69	9.05

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1684	957	14	0	0	962
2	1680	921	2	0	0	957
3	1685	646	4	0	0	943
4	1687	871	14	14	0	961
5	1679	778	9	9	0	962
6	1686	893	1	1	0	962
7	1684	760	3	3	1	959
8	1681	1027	9	9	0	961
9	1685	817	21	21	0	930
10	1682	964	12	12	0	956
Average	1683	863	8.9	6.9	0.1	955

Summary of Simulation Data for 10 % Car1 - Model Scenario S3

Travel Time

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
0	32.4	30.3	31.1	3.71	3.31	19
5	37.2	32	37.5	3.85	3.36	18.7
10	43.1	33.2	42.1	3.86	3.35	18.3
15	49.7	41.3	41	3.93	3.43	18.6
20	53.4	44.6	64.3	3.96	3.43	18.9
25	68.1	45.5	65.8	3.89	3.39	20.2
30	65.3	53.1	77.6	3.93	3.44	20.2
35	64.7	64.2	75.4	3.93	3.47	19.2
40	83.1	59.9	100	4.01	3.47	19.4
45	90.9	68.8	91.4	3.92	3.44	21.7
50	0	0	0	0	0	0
Average						

Delay

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
0	58.2	25.7	113	0.74	0.61	5.34
5	127	33.1	173	0.82	0.66	5.96
10	173	42.3	218	0.79	0.65	5.82
15	204	55.3	242	0.83	0.65	5.47
20	205	64.3	279	0.86	0.65	5.98
25	219	67.4	278	0.83	0.64	6.9
30	225	71.1	289	0.86	0.65	6.88
35	220	76.3	275	0.88	0.68	7.91
40	223	78.1	289	0.87	0.67	7.69
45	206	84.3	272	0.87	0.69	9.05
50	0	0	0	0	0	0
Average						

Queue Length

	Link No					
Average	EB	SB	WB	Pt1	Pt2	NB
0	224	68.9	2.7	1.8	0	295
5	830	102	5	4.1	0	547
10	1264	193	3.1	2.3	0	735
15	1563	521	3.5	2.2	0	811
20	1585	701	4.1	2.4	0.1	881
25	1665	732	6.6	5.4	0	926
30	1676	788	4.6	3.5	0	933
35	1677	813	4.8	3.7	0.1	937
40	1683	783	6.6	5.8	0	944
45	1683	863	8.9	6.9	0.1	955
50	0	0	0	0	0	0
Average						

Simulation Data for 0 % Volume Increase at 20 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	28.7	35.2	24.2	3.7	3.3	19.4
2	38.3	29.7	35.5	3.6	3.3	19
3	58.5	23.4	26.5	3.8	3.6	19.2
4	28.7	26.1	20.8	3.7	3.1	16.4
5	31.1	29	17.1	3.7	3.3	18
6	26.7	25.9	19.3	3.6	3.2	17.2
7	38.3	29.7	35.5	3.6	3.3	19
8	34.6	22.6	32.2	3.8	3.3	20.8
9	36.4	24.3	41.7	3.8	3.4	19.8
10	42	28.4	22.6	4	3.7	15.6
Average	36.3	27.4	27.5	3.73	3.35	18.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	36.3	32.3	47.1	1	0.8	7
2	39.7	16.8	72.7	0.9	0.7	5.1
3	94.5	21.8	93.1	1	0.8	5.3
4	46.3	26.5	99.1	0.9	0.8	5.4
5	55.6	20.4	124	0.9	0.7	5.2
6	31.5	16.5	38.2	0.8	0.7	4.7
7	65.6	20.7	67	0.9	0.8	5.9
8	63.5	20.9	102	0.9	0.7	5.6
9	44.3	21.6	45.7	0.8	0.6	3.1
10	42.2	23.1	126	0.9	0.8	4.7
Average	52	22.1	81.5	0.9	0.74	5.2

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	89.5	156	6.25	0.25	0	67
2	116	43.3	2.75	0	0	123
3	359	80.8	4	0	0	116
4	125	150	4	4	0	155
5	176	79	3.75	3.75	0	198
6	80.8	34	2.75	2.75	0	49
7	211	62.8	4.25	4.25	0.25	92.5
8	184	87	3.75	3.75	0.25	159
9	129	55	1.75	1.75	0	58.3
10	121	85	3.5	3.5	0	193
Average	159	83.2	3.68	2.4	0.05	121

Simulation Data for 5 % Volume Increase at 20 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	34.7	39.4	23.9	3.7	3.4	23.1
2	34.6	26.8	40.5	3.7	3.3	17.5
3	48.3	27.2	33.6	4.1	3.5	17.5
4	31	32.3	23.8	3.7	3.1	16.1
5	26.8	30.1	22.4	3.8	3.1	19.5
6	29	32.2	28.9	3.7	3.4	17.3
7	34.6	26.8	40.5	3.7	3.3	17.5
8	34.5	27.5	32.9	3.7	3.3	17.4
9	46.8	24.7	76	3.8	3.4	17.3
10	45.7	25.9	41.1	4.2	3.6	16.5
Average	36.6	29.3	36.4	3.81	3.34	18

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	59.6	45.8	72.7	0.9	0.7	8.6
2	85.2	25.7	157	1	0.8	4.9
3	185	26.7	100	1	0.8	5.2
4	129	34.5	207	1.1	0.8	4.6
5	111	28.6	213	0.9	0.7	5.4
6	78.7	21.4	101	1	0.8	4.6
7	122	25.3	116	1.1	0.9	4.6
8	116	26	205	0.9	0.7	5.5
9	76.5	37.4	94.2	1	0.8	4.7
10	82.5	29.1	188	1.1	0.9	6.1
Average	105	30.1	145	1	0.79	5.42

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	197	356	9.5	0	0	116
2	306	90.3	2.75	0.25	0	326
3	869	103	4.25	0	0	132
4	480	295	2.75	2.75	0.5	414
5	461	134	3.5	3.5	0	400
6	261	59.8	3.25	3.25	0.25	191
7	487	86	3	3	0	175
8	466	126	3.25	3.25	0	417
9	287	187	2.75	2.75	0	139
10	298	117	4.75	4.75	0.5	377
Average	411	155	3.98	2.35	0.13	269

Simulation Data for 10 % Volume Increase at 20 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	38	32.3	35.5	3.8	3.3	24.8
2	43.1	39.1	32.9	3.8	3.3	18.2
3	60.5	32.7	18.8	4	3.5	19
4	32.4	36.9	26.2	3.5	3	17.4
5	28.4	32.4	21	3.7	3.1	18.9
6	43.5	39.6	38.5	3.7	3.4	19.7
7	43.1	39.1	32.9	3.8	3.3	18.2
8	32.5	24.1	79.5	3.6	3.3	20.6
9	63	28.5	74.8	3.9	3.5	21.5
10	58	26.4	53.6	3.8	3.5	19.7
Average	44.3	33.1	41.4	3.76	3.32	19.8

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	107	45.1	181	0.9	0.8	5.6
2	151	23.4	295	0.9	0.7	6.3
3	223	34.1	159	1	0.8	5
4	159	39.9	282	1	0.9	4.7
5	187	30.1	172	0.9	0.7	5.5
6	144	26.7	205	0.9	0.8	5.2
7	155	38.2	193	1	0.8	5.8
8	153	37.3	186	1	0.8	6.2
9	175	52	129	1	0.7	5.7
10	158	36.2	220	1	0.8	5.3
Average	161	36.3	202	0.96	0.78	5.53

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	365	334	3.75	0	0	386
2	649	94.5	4.5	0	0	694
3	1204	175	3.25	0	0	227
4	599	309	3.25	3.25	0.25	681
5	1053	172	4	4	0.25	357
6	579	105	3.25	3.25	0	373
7	716	243	4.25	4.25	0	351
8	669	273	4.75	4.75	0	404
9	865	459	4.75	4.75	0	255
10	689	225	3.5	3.5	0.25	448
Average	739	239	3.93	2.78	0.08	418

Simulation Data for 15 % Volume Increase at 20 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	33.6	46.3	45.8	3.8	3.5	21.8
2	39.1	38	41.5	3.9	3.4	21.9
3	69.4	29.7	30	3.9	3.5	18.2
4	34	31.9	29.2	3.6	3.2	18.6
5	33.1	34.3	19.4	3.8	3.2	19.2
6	34.9	41.8	28	3.9	3.4	24.8
7	39.1	38	41.5	3.9	3.4	21.9
8	45.3	28.4	38.5	3.7	3.2	18.9
9	83.2	34.1	72	3.7	3.7	16.5
10	75.6	28.7	69.2	4	3.6	18
Average	48.7	35.1	41.5	3.82	3.41	20

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	130	54.9	287	0.9	0.8	6.8
2	214	32.2	317	1	0.8	6.2
3	244	55.6	254	1	0.7	5.3
4	181	47.6	318	1	0.8	6.4
5	217	56.2	160	1	0.8	10.4
6	181	57.5	279	1	0.9	4.1
7	200	56	222	1.1	0.9	4.2
8	158	60.7	262	1	0.8	5.2
9	201	66.9	142	1	0.8	5.3
10	182	55.7	210	1	0.9	6
Average	191	54.3	245	1	0.82	5.99

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	471	538	6.5	0	0.25	673
2	978	208	3.75	0.25	0	721
3	1229	574	4	0.25	0	417
4	759	395	4.75	4.75	0.25	772
5	1359	584	11.8	11.8	0.25	323
6	884	533	2.5	2.5	0.25	585
7	979	531	3	3	0.25	434
8	758	700	2.75	2.75	0	584
9	1116	851	4.25	4.25	0	286
10	841	360	4.75	4.75	0	459
Average	937	527	4.8	3.43	0.13	525

Simulation Data for 20 % Volume Increase at 20 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	48.7	41.7	39.5	3.8	3.3	20.5
2	46.9	50.5	39.6	4	3.6	17.7
3	98.4	31.6	27.3	3.8	3.2	22.8
4	37.1	40	46.6	3.7	3.2	16.9
5	38.1	36.7	66.9	3.8	3.3	20.5
6	50.2	38.6	45.8	3.7	3.2	20.3
7	46.9	50.5	39.6	4	3.6	17.7
8	44.8	27.1	68	3.9	3.3	22.4
9	95.5	39.6	69.2	3.7	3.6	18.3
10	96	36.1	50.7	4	3.5	16.4
Average	60.3	39.2	49.3	3.84	3.38	19.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	97.8	70.3	260	1	0.7	7.2
2	238	41.9	306	1	0.8	5.8
3	229	63.9	287	1	0.7	3.9
4	183	63	309	1	0.8	5.5
5	237	55.9	285	1	0.7	7.4
6	222	55.5	245	0.9	0.8	5.9
7	186	64.9	263	1	0.7	4.8
8	144	57.6	308	0.9	0.7	6.2
9	220	73	143	1	0.8	4.4
10	179	63.4	231	1	0.8	6.5
Average	194	60.9	264	0.98	0.75	5.76

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	399	744	6	0	0	625
2	1394	302	4.25	0	0	768
3	1269	751	2.25	0	0	539
4	767	748	3.75	3.75	0	747
5	1408	590	7	7	0	599
6	1175	541	4.75	4.75	0.25	563
7	1014	803	3	3	0	577
8	751	635	4.75	4.75	0	774
9	1290	808	3.5	3.5	0	290
10	893	696	6	6	0	519
Average	1036	662	4.53	3.28	0.03	600

Simulation Data for 25 % Volume Increase at 20 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	39.3	66.3	23.9	4	3.6	25.1
2	53.5	50.2	49.1	3.9	3.7	22.7
3	82.9	35.7	24.8	4	3.3	24.2
4	33.8	36.5	50.7	3.7	3.3	17.5
5	45.6	33.7	48.5	3.8	3.3	21.7
6	32.8	39.8	77.6	3.7	3.2	21
7	53.5	50.2	49.1	3.9	3.7	22.7
8	56.9	26.6	147	3.8	3.2	18.6
9	83.1	38.3	143	3.9	3.4	16.7
10	66.2	38.7	86.4	4.2	3.9	17.2
Average	54.8	41.6	70	3.89	3.46	20.7

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	185	74.8	287	1	0.8	6.3
2	266	40	364	1	0.8	5
3	243	66.5	247	1	0.8	5.9
4	232	67	304	1	0.8	5.9
5	234	62.1	238	1.1	0.8	8.7
6	231	60.8	305	1	0.8	7.7
7	213	67.1	285	1.1	0.8	6.5
8	165	59.5	356	1	0.8	8.2
9	221	76.7	181	1.1	0.9	5.9
10	210	66.5	237	1.1	0.8	6.8
Average	220	64.1	280	1.04	0.81	6.69

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	904	841	6.25	0	0	741
2	1486	220	4	0	0	860
3	1407	899	5	0	0	461
4	1136	787	4.75	4.75	0	746
5	1404	687	8.5	8.5	0	532
6	1261	657	6.75	6.75	0	735
7	1255	741	6.5	6.5	0	687
8	909	714	7.5	7.5	0	861
9	1322	1012	5	5	0	406
10	1042	743	6	6	0	597
Average	1213	730	6.03	4.5	0	662

Simulation Data for 30 % Volume Increase at 20 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	46.3	61.4	39.6	3.9	3.5	19.5
2	85	50.7	82.2	4.2	3.5	18.5
3	92.1	43.6	26.3	3.8	3.5	24.6
4	68.8	41.6	53.5	3.7	3.2	18.3
5	52.3	38.4	67.3	3.9	3.3	20.5
6	38.7	50.3	50.3	3.9	3.4	26.3
7	85	50.7	82.2	4.2	3.5	18.5
8	69.5	36	68	4.1	3.4	21.6
9	78.9	42.2	124	3.9	3.5	16.4
10	124	43.5	91.9	4.3	3.8	16.5
Average	74	45.8	68.6	3.99	3.46	20.1

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	117	85.5	274	1	0.8	7.7
2	253	57.8	367	0.9	0.7	6.2
3	254	68	265	0.9	0.7	6.9
4	216	70.3	323	1	0.8	6.3
5	216	69.7	241	1	0.7	8.2
6	207	73.3	235	1	0.8	6
7	227	70.6	200	1.1	0.8	7.2
8	236	57.1	355	0.9	0.7	6.6
9	226	74.4	195	1.1	0.8	6.4
10	227	68.5	277	1	0.9	7.3
Average	218	69.5	273	0.99	0.77	6.88

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	549	1035	8	0	0	759
2	1513	647	4.5	0	0	840
3	1455	794	6.5	0	0	553
4	1180	865	5	5	0	839
5	1517	819	8.75	8.75	0	537
6	1261	811	5.25	5.25	0	567
7	1329	819	6.75	6.75	0.25	481
8	1313	660	6	6	0.25	827
9	1419	917	6.25	6.25	0	474
10	1186	792	7.75	7.75	0	654
Average	1272	816	6.48	4.58	0.05	653

Simulation Data for 35 % Volume Increase at 20 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	43.7	58.2	68.9	3.9	3.5	19.9
2	91.1	59.8	85.6	3.9	3.4	18.3
3	112	37.2	61.8	3.8	3.3	22.6
4	32.7	61.3	51.7	3.7	3.3	21.6
5	61	50.3	53.6	3.9	3.4	20.4
6	35.8	70.3	70.5	3.7	3.4	22.7
7	91.1	59.8	85.6	3.9	3.4	18.3
8	79.7	33	63.5	4.1	3.6	21.4
9	151	41.4	102	4.2	3.8	17.6
10	160	43.2	67.2	4	3.6	21.3
Average	85.8	51.5	71	3.91	3.47	20.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	197	77.4	288	1	0.8	8.4
2	239	62.4	400	1	0.7	6.4
3	236	75.4	211	1	0.8	7.4
4	228	72.5	265	1.1	0.9	6.3
5	224	69.8	266	1	0.7	11.2
6	229	71	298	1	0.8	6.5
7	223	72	299	1.1	0.9	5.7
8	217	66.7	336	1.1	0.8	6
9	217	78.8	171	1	0.8	6
10	220	75.5	246	1.1	0.8	8.3
Average	223	72.2	278	1.04	0.8	7.22

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1095	900	8	0	0	860
2	1563	671	6	0	0	906
3	1502	942	7.75	0	0	448
4	1242	887	5.5	5.5	0	807
5	1534	797	15	15	0	617
6	1426	807	5	5	0	779
7	1415	839	5.5	5.5	0.25	764
8	1296	768	4	4	0.25	867
9	1452	957	4.75	4.75	0.25	418
10	1376	877	8.75	8.75	0	679
Average	1390	844	7.03	4.85	0.08	714

Simulation Data for 40 % Volume Increase at 20 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	51	77	23.6	3.9	3.4	27.1
2	85.7	66.3	91.8	4.3	3.6	19
3	126	38.2	41	3.9	3.4	31.8
4	54.8	51.8	68.3	3.8	3.2	17
5	56.4	68.2	52.8	4.3	3.4	20.5
6	54.3	66.3	64.8	4	3.8	20.7
7	85.7	66.3	91.8	4.3	3.6	19
8	65.1	46.1	74.9	4	3.4	19.2
9	138	57.5	63.1	4.3	3.6	18.3
10	153	44.8	105	3.9	3.5	18.4
Average	86.9	58.3	67.7	4.07	3.49	21.1

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	188	77.7	298	1	0.8	11.3
2	286	58.7	348	1	0.7	6.5
3	237	77.6	266	1	0.8	5.9
4	213	74.3	323	1	0.8	7.9
5	207	74.1	269	1	0.8	11.6
6	224	70.4	281	0.9	0.7	6.9
7	235	72.4	314	1.1	0.8	6.6
8	240	66.8	316	1	0.8	7.3
9	212	82.6	197	1	0.8	8.2
10	234	76.8	268	1	0.8	8.7
Average	228	73.1	288	1	0.78	8.09

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1054	935	16	0	0	831
2	1593	662	5.5	0	0	888
3	1492	956	6.75	0	0	646
4	1273	833	7	7	0	859
5	1555	847	15.5	15.5	0	698
6	1362	836	5.5	5.5	0	739
7	1489	842	5.75	5.75	0	757
8	1425	715	5.75	5.75	0.25	883
9	1516	930	8.5	8.5	0	516
10	1403	873	9	9	0	746
Average	1416	843	8.53	5.7	0.03	756

Simulation Data for 45 % Volume Increase at 20 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	50.9	78.5	71.7	3.9	3.4	21.7
2	107	59.9	132	4.1	3.5	19.7
3	105	55.3	42.8	3.8	3.4	26.2
4	55.3	60.1	62.1	3.6	3.2	22.4
5	71.4	70.1	50	4.5	3.6	19.6
6	65.1	59	126	3.9	3.4	19.2
7	107	59.9	132	4.1	3.5	19.7
8	108	34.7	109	4	3.5	16.2
9	133	65.6	57.1	4.9	4	17.7
10	142	72.2	81.5	4.1	3.8	23.1
Average	94.4	61.5	86.4	4.09	3.53	20.6

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	161	94.8	231	1	0.8	11.3
2	273	62.5	343	1	0.8	7.1
3	247	73.3	229	1	0.8	7.8
4	210	82	287	1.1	0.8	8.5
5	237	72.6	245	0.9	0.7	9.2
6	214	72.8	317	1	0.8	8.4
7	222	77.5	303	1	0.8	8.2
8	220	69.6	339	1	0.7	8.8
9	194	87.1	197	1	0.8	9.2
10	206	84.4	229	1	0.8	11.2
Average	218	77.7	272	1	0.78	8.97

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1025	1044	16	0	0	800
2	1606	654	7	0	0	906
3	1549	893	8.75	0	0	585
4	1325	964	8.75	8.75	0	854
5	1563	848	10	10	0	669
6	1421	875	9.25	9.25	0	823
7	1517	901	9.25	9.25	0	819
8	1412	817	8.75	8.75	0	893
9	1434	986	10.8	10.8	0.25	551
10	1372	999	14.8	14.8	0.25	648
Average	1422	898	10.3	7.15	0.05	755

Simulation Data for 50 % Volume Increase at 20 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	54.2	69.2	101	4	3.6	23.1
2	80.8	84.3	79.6	4.3	3.6	22.6
3	101	72.3	38.1	3.8	3.4	32.6
4	30.6	95.7	49	3.8	3.3	21.6
5	45.6	102	56	3.9	3.3	22.9
6	54.1	95.3	52.2	4	3.4	21.5
7	80.8	84.3	79.6	4.3	3.6	22.6
8	90.6	38.2	174	3.8	3.3	18.1
9	165	42.6	131	4.2	3.4	20.3
10	116	88.9	61.5	4.3	3.6	22.4
Average	81.9	77.3	82.1	4.04	3.45	22.8

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	188	92.8	267	0.9	0.8	11.5
2	251	66.3	355	1	0.7	6.9
3	238	78.6	272	1	0.7	7.1
4	216	83.7	260	1.1	0.9	9.4
5	216	79.6	246	1	0.8	9.7
6	223	75.6	263	0.9	0.8	8
7	224	81.2	297	1	0.8	7.9
8	244	71.9	324	1	0.8	6.4
9	222	79.6	277	1	0.8	7.6
10	186	90.4	266	1	0.8	9.9
Average	221	80	283	0.99	0.79	8.44

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1181	1005	18	0	0	873
2	1556	717	6.5	0.25	0.25	880
3	1576	867	7.25	0	0	681
4	1336	935	12.8	12.8	0.25	867
5	1587	890	12.5	12.5	0	676
6	1466	887	8	8	0	742
7	1516	904	8.5	8.5	0	814
8	1557	889	5.25	5.25	0.25	900
9	1491	953	8.25	8.25	0	706
10	1325	965	14.3	14.3	0	735
Average	1459	901	10.1	6.98	0.08	787

Summary of Simulation Data for 20 % Car1 - Model Scenario S3

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
0	36.3	27.4	27.5	3.73	3.35	18.4
5	36.6	29.3	36.4	3.81	3.34	18
10	44.3	33.1	41.4	3.76	3.32	19.8
15	48.7	35.1	41.5	3.82	3.41	20
20	60.3	39.2	49.3	3.84	3.38	19.4
25	54.8	41.6	70	3.89	3.46	20.7
30	74	45.8	68.6	3.99	3.46	20.1
35	85.8	51.5	71	3.91	3.47	20.4
40	86.9	58.3	67.7	4.07	3.49	21.1
45	94.4	61.5	86.4	4.09	3.53	20.6
50	81.9	77.3	82.1	4.04	3.45	22.8
Average						

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
0	52	22.1	81.5	0.9	0.74	5.2
5	105	30.1	145	1	0.79	5.42
10	161	36.3	202	0.96	0.78	5.53
15	191	54.3	245	1	0.82	5.99
20	194	60.9	264	0.98	0.75	5.76
25	220	64.1	280	1.04	0.81	6.69
30	218	69.5	273	0.99	0.77	6.88
35	223	72.2	278	1.04	0.8	7.22
40	228	73.1	288	1	0.78	8.09
45	218	77.7	272	1	0.78	8.97
50	221	80	283	0.99	0.79	8.44
Average						

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
0	159	83.2	3.68	2.4	0.05	121
5	411	155	3.98	2.35	0.13	269
10	739	239	3.93	2.78	0.08	418
15	937	527	4.8	3.43	0.13	525
20	1036	662	4.53	3.28	0.03	600
25	1213	730	6.03	4.5	0	662
30	1272	816	6.48	4.58	0.05	653
35	1390	844	7.03	4.85	0.08	714
40	1416	843	8.53	5.7	0.03	756
45	1422	898	10.3	7.15	0.05	755
50	1459	901	10.1	6.98	0.08	787
Average						

Simulation Data for 0 % Volume Increase at 30 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	32.1	37.4	18.4	3.7	3.2	19.2
2	31.8	34.6	20.4	4.2	3.5	22
3	30.3	29.8	25.9	3.8	3.2	18.6
4	25.5	24	15.1	3.4	3	15.8
5	27.1	29.5	16.7	4.5	3.3	17.7
6	25.4	26.4	22.3	3.9	3.5	16.8
7	31.8	34.6	20.4	4.2	3.5	22
8	25.6	24.6	24.2	3.7	3.1	22.9
9	25.9	24.9	25.3	3.7	3.1	16.7
10	28.3	28.1	41	3.8	3	19.3
Average	28.4	29.4	23	3.89	3.24	19.1

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	28.7	23.5	55.7	1.1	0.8	3.5
2	35.9	18.1	39.6	1	0.8	4.1
3	78.9	17.7	88.6	1.2	0.9	5.8
4	33	19.2	67.7	1.1	0.9	5.4
5	50	28.5	84.7	1.2	0.9	6.8
6	33.8	13.2	33.2	1	0.8	4.4
7	64.3	17.4	43.4	1.1	0.9	4.5
8	51.9	20.3	117	1.1	0.9	4.4
9	56.3	18.4	56.7	1.1	0.9	3.6
10	29.9	23	65.4	1	0.8	6.2
Average	46.3	19.9	65.2	1.09	0.86	4.87

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	66.8	89.5	1.5	0	0	81
2	93.3	56.3	2	0	0	57.5
3	271	56.5	5	0.25	0.5	114
4	83.3	69.5	3.25	3.25	0.5	101
5	149	132	5	5	0.25	117
6	87.3	23.8	2.5	2.5	0	42.5
7	217	35	2.5	2.5	0.25	57.3
8	148	78.3	3.25	3.25	0	187
9	177	54.8	2.25	2.25	0	69.8
10	79	81.8	6	6	0	96.5
Average	137	67.7	3.33	2.5	0.15	92.4

Simulation Data for 5 % Volume Increase at 30 % Car1 - Model Scenario S3

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	37.2	28.4	37.4	3.8	3.3	20.2
2	24.3	34.4	31.9	4	3.6	19.5
3	61.8	24.3	26.7	3.6	3.3	21.3
4	23	24.6	22.3	3.5	3	16.5
5	26.9	33.3	23	4	3.1	17.5
6	25.8	42.3	21.1	4.2	3.2	15.1
7	24.3	34.4	31.9	4	3.6	19.5
8	29.5	27.8	40.5	3.8	3.3	19.8
9	37.7	24.1	29.7	3.9	3.5	16.5
10	39.4	28.3	37.8	3.7	3.4	15.5
Average	33	30.2	30.2	3.85	3.33	18.1

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	48	32.9	85.9	1.1	0.9	5.2
2	74.4	21.8	135	1.1	0.9	5
3	190	22.6	74.7	1.2	0.9	4.1
4	57.7	30.4	147	1.1	0.9	4.5
5	145	26.4	109	1.1	0.9	5.8
6	62.2	18.2	96.7	1.1	0.9	6.3
7	75.6	21.5	62.6	1	0.9	6.1
8	122	22.9	119	1.2	1	6.3
9	133	24.4	41.8	1.2	0.9	4.5
10	54	28.1	88.4	1.1	0.9	6.2
Average	96.1	24.9	96	1.12	0.91	5.4

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	132	170	4	0	0	131
2	276	62.3	3.25	0	0.5	272
3	906	65.3	3	0.5	0.75	102
4	167	133	2.75	2.75	0	247
5	660	108	4.5	4.5	0.25	168
6	196	55	5.25	5.25	0	174
7	251	81.3	4.5	4.5	0	96.8
8	481	97	5.25	5.25	0.5	204
9	536	73.8	3	3	0	56
10	175	141	5.25	5.25	0	140
Average	378	98.6	4.08	3.1	0.2	159

Simulation Data for 10 % Volume Increase at 30 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	28.8	54.1	26.6	4.1	3.5	20.7
2	51.1	32.5	43.6	4.2	3.6	17.2
3	47.8	29.6	35.2	3.9	3.4	19.3
4	26.3	31	16.7	3.7	3.2	15.1
5	31.1	29.9	26.5	3.9	3.2	16
6	26	46.1	20.3	3.9	3.2	16.7
7	51.1	32.5	43.6	4.2	3.6	17.2
8	38.4	31.9	43.6	3.9	3.3	19.1
9	49.1	26.2	39	3.7	3.3	17.5
10	41.3	32.3	27.8	3.9	3.3	14.8
Average	39.1	34.6	32.3	3.94	3.36	17.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	142	36.3	190	1.2	0.9	5.8
2	95.1	27.5	254	1.1	0.8	4.9
3	208	28.7	153	1.2	0.9	5.1
4	146	28.6	255	1.1	0.9	5.9
5	199	40.1	93.9	1.2	0.9	7.4
6	141	47.9	115	1.2	0.9	6.3
7	131	30.1	152	1	0.8	6.2
8	167	23.6	200	1.2	1	4.7
9	216	31	100	1.2	0.9	4.9
10	130	34.2	180	1.2	0.9	5.4
Average	157	32.8	169	1.16	0.89	5.66

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	517	216	4.5	0	0.75	373
2	368	112	3.25	0	0	573
3	1176	136	3.5	0	0	241
4	562	142	4.75	4.75	0.25	572
5	1081	256	6.75	6.75	0	147
6	577	301	5.25	5.25	0.25	231
7	550	150	5	5	0	283
8	707	85.3	3.25	3.25	0.25	438
9	1121	138	3.5	3.5	0	163
10	558	164	4.25	4.25	0	369
Average	722	170	4.4	3.28	0.15	339

Simulation Data for 15 % Volume Increase at 30 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	43.3	41.9	24.1	4	3.5	20.8
2	43.3	54.2	38.4	4	3.5	17.5
3	58.2	30.1	23	4	3.5	19.7
4	26.4	29.8	23.4	3.9	3.4	17.8
5	36.3	41.7	24.7	4.1	3.5	16.4
6	32.9	32	31.7	3.8	3.3	16.7
7	43.3	54.2	38.4	4	3.5	17.5
8	31.8	28.1	45	3.9	3.3	22
9	39.3	31.3	67.2	3.9	3.7	19.1
10	36.9	32	61	4.1	3.5	16.4
Average	39.2	37.5	37.7	3.97	3.47	18.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	161	57.5	251	1.3	0.9	5.9
2	199	31	305	1.2	0.9	4
3	248	48.1	119	1.2	0.8	6.1
4	208	36	238	1.2	0.9	4.3
5	202	60.5	117	1.3	1	4.9
6	206	43.5	125	1.2	0.9	5.3
7	169	46.5	235	1.2	0.9	6.3
8	173	38.5	241	1.1	0.9	4.9
9	197	63.8	81	1.3	1	5.5
10	183	49.8	188	1.1	0.9	7.3
Average	194	47.5	190	1.21	0.91	5.45

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	635	487	4	0.5	0	559
2	891	133	1.75	0.25	0.25	693
3	1351	424	5	0	0	192
4	986	217	2.25	2.25	0	562
5	1123	650	3.25	3.25	0.25	243
6	1045	274	4	4	0	274
7	874	365	5	5	0.5	496
8	859	275	3.75	3.75	0	596
9	1148	654	4.75	4.75	0.25	139
10	894	468	7.25	7.25	0.25	419
Average	980	395	4.1	3.1	0.15	417

Simulation Data for 20 % Volume Increase at 30 % Car1 - Model Scenario S3

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	32.7	71	20	4	3.5	21.2
2	76.9	36.5	71.3	4.4	3.9	17.5
3	80.4	34.1	39.3	3.6	3.2	21.9
4	29.8	34.2	27.1	3.9	3.4	17.4
5	42.8	37.5	28.1	4.3	3.5	17.3
6	33.6	49.2	23.6	3.9	3.4	16.8
7	76.9	36.5	71.3	4.4	3.9	17.5
8	26.5	29.8	65.6	4	3.4	19
9	50.2	33.2	96.9	3.8	3.4	17.1
10	63.8	33.4	84.6	4.4	3.7	17.3
Average	51.4	39.5	52.8	4.07	3.53	18.3

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	165	63.2	216	1.1	0.9	6.5
2	234	40.9	268	1.1	0.9	5.8
3	266	59.8	179	1.3	0.9	6.2
4	215	66.9	260	1.3	1	8.6
5	224	62.7	147	1.3	1	5.8
6	189	71.2	114	1.4	1	6.3
7	182	62.5	179	1.2	0.9	4.9
8	199	52.3	337	1.2	0.9	4.2
9	199	71.8	143	1.3	1	5.6
10	191	63.1	230	1.2	0.9	5.8
Average	206	61.4	207	1.24	0.94	5.97

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	730	677	5	0	0	535
2	1358	293	3.75	0	0	680
3	1383	670	5.25	0	0.5	308
4	1060	780	8.5	8.5	0.25	652
5	1344	740	4.5	4.5	0	304
6	1044	854	4.75	4.75	0.75	270
7	1052	727	2.75	2.75	0.25	395
8	992	498	2.5	2.5	0	821
9	1190	847	4.5	4.5	0.75	297
10	938	700	4.75	4.75	0	534
Average	1109	679	4.63	3.23	0.25	479

Simulation Data for 25 % Volume Increase at 30 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	27.3	70.2	32	4.1	3.6	25.4
2	92.8	45.5	59.1	4	3.5	16.5
3	96.4	25.5	42	3.7	3.1	26.3
4	42.4	36.7	43.5	3.8	3.1	17.6
5	48.9	32.7	43.7	4.3	3.7	16.3
6	53.5	48	40.1	3.9	3.4	18
7	92.8	45.5	59.1	4	3.5	16.5
8	49	37.9	50.3	4.2	3.6	24.5
9	47.3	44.4	156	3.9	3.6	16.1
10	80.6	34.1	77.5	4.3	3.6	17.2
Average	63.1	42.1	60.3	4.02	3.47	19.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	186	70.5	254	1.3	1	9.3
2	258	43.3	344	1.1	0.9	5.9
3	255	63.3	200	1.3	1	7.1
4	226	64.9	285	1.2	0.9	7.3
5	234	59.5	184	1.1	0.9	5.9
6	221	66.2	133	1.3	1	7.2
7	162	66.1	251	1.1	0.9	7.3
8	203	59.9	310	1.3	1	4.2
9	225	70.7	209	1.2	1	7.5
10	162	69	223	1.2	0.8	5.6
Average	213	63.3	239	1.21	0.94	6.73

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	937	678	11.5	0.25	0	718
2	1516	355	4	0.25	0.25	858
3	1495	752	6.75	0	0.5	373
4	1174	754	7.5	7.5	0	748
5	1479	661	4.75	4.75	0.25	416
6	1261	709	6	6	0.25	333
7	930	805	7	7	0	581
8	1087	538	2.5	2.5	0.5	813
9	1338	794	7	7	0.5	475
10	891	756	5.25	5.25	0	561
Average	1211	680	6.23	4.05	0.23	588

Simulation Data for 30 % Volume Increase at 30 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	38.7	64.3	42.3	4.1	3.5	23.7
2	71.3	55.2	80.1	4.2	3.6	17.6
3	85.7	36.4	30.3	3.7	3.2	25.9
4	43.4	51.3	64.9	4	3.3	16.6
5	58.5	43.6	32	4.5	3.4	18.1
6	51.2	60.7	30.5	4.5	3.7	21.1
7	71.3	55.2	80.1	4.2	3.6	17.6
8	99.2	27.7	53.9	3.8	3.4	16.6
9	92	32.3	103	3.8	3.3	15.5
10	93.5	46.8	71.5	4.7	3.9	16.5
Average	70.5	47.4	58.8	4.15	3.49	18.9

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	204	67.8	250	1.1	0.9	9.4
2	246	63.3	278	1.3	0.9	4.9
3	280	64.6	207	1.2	1	5.7
4	230	72.4	262	1.2	1	6.8
5	210	71.6	234	1.1	0.9	8.9
6	213	68.6	186	1.2	0.9	7.9
7	213	63.3	295	1.2	0.9	6.1
8	267	56.7	307	1.2	1	5.8
9	238	72.5	166	1.2	1	6.5
10	197	70.1	199	1.2	0.9	9.9
Average	230	67.1	238	1.19	0.94	7.19

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	989	769	10.3	0	0.25	681
2	1358	640	2.75	0	0	811
3	1489	773	5	0	0.25	411
4	1269	931	4.75	4.75	0	750
5	1407	779	9.75	9.75	0	537
6	1261	753	6.5	6.5	0	468
7	1225	768	5	5	0.5	714
8	1417	587	3.75	3.75	0.25	826
9	1445	943	5.75	5.75	0.25	375
10	1039	777	14.3	14.3	0.25	493
Average	1290	772	6.78	4.98	0.18	606

Simulation Data for 35 % Volume Increase at 30 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	38.6	86.1	21.5	3.8	3.3	19.3
2	68	51.5	82.9	4	3.3	18.5
3	78.2	44.4	46.5	3.9	3.4	27.6
4	47	51	57.9	3.9	3.3	19.1
5	113	37.9	87	3.9	3.4	17.7
6	67.6	57.3	37.7	4.1	3.3	15.8
7	68	51.5	82.9	4	3.3	18.5
8	81	34	62.3	4.1	3.5	18.1
9	109	30.6	145	4	3.4	15.7
10	106	40.1	107	4	3.3	18.3
Average	77.6	48.4	73.1	3.97	3.35	18.9

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	200	75.2	288	1.2	0.9	7.8
2	254	58.9	354	1.2	0.8	5.1
3	245	65.7	296	1.2	0.9	4.9
4	198	75.7	285	1.2	0.8	10.3
5	213	75.8	201	1.2	1	10.8
6	234	70	226	1.3	1.1	7.9
7	220	65.6	302	1.2	0.8	7
8	247	63.7	318	1.3	1	5.7
9	248	69.4	213	1.2	0.9	5.6
10	180	76.6	253	1.3	1	8.8
Average	224	69.7	273	1.23	0.92	7.39

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1028	949	9.75	0	0	800
2	1530	538	3.75	0	0	918
3	1464	782	3.25	0	0.25	675
4	1224	825	12.3	12.3	0.25	826
5	1539	769	13.3	13.3	0	522
6	1349	822	8	8	0.5	607
7	1328	675	6	6	0	742
8	1431	741	5.25	5.25	0	870
9	1495	791	5	5	0.25	531
10	1043	870	8.5	8.5	0.5	714
Average	1343	776	7.5	5.83	0.18	721

Simulation Data for 40 % Volume Increase at 30 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	28.5	85	32.2	4.1	3.4	25.4
2	70.7	59.9	117	4	3.5	16.9
3	86.1	41	41.7	4	3.2	36.5
4	29.5	74.4	38.7	3.9	3.4	16.1
5	94.1	56.3	30.5	4.1	3.6	18.6
6	57.7	82.6	33	4.4	3.5	16.5
7	70.7	59.9	117	4	3.5	16.9
8	79.1	33.2	92	4.2	3.5	19.1
9	115	45.6	62.3	3.8	3.4	20.7
10	121	42.8	98.1	4.1	3.6	20.3
Average	75.3	58.1	66.2	4.06	3.46	20.7

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	198	73.3	282	1.1	0.9	8.8
2	267	60.2	306	1	0.8	5.2
3	229	72.4	222	1.3	0.9	6.3
4	212	73.5	304	1.2	0.9	6.2
5	241	71.6	194	1.1	0.9	8.7
6	211	70.8	224	1.3	1	8
7	212	70.8	262	1.3	1	7.4
8	292	56.3	315	1.2	0.9	6.3
9	246	75.8	163	1.2	1	7.5
10	181	83.3	216	1.2	0.9	9.1
Average	229	70.8	249	1.19	0.92	7.35

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1133	825	10	0	0	800
2	1520	756	3.25	0	0.25	896
3	1528	912	6.25	1	0.25	514
4	1290	878	5.25	5.25	0	812
5	1565	876	8.25	8.25	0.25	527
6	1371	820	7.5	7.5	0	608
7	1391	872	6.75	6.75	0.25	724
8	1499	593	5.25	5.25	0	865
9	1537	951	8.5	8.5	0.5	431
10	1165	887	11.3	11.3	0	620
Average	1400	837	7.23	5.38	0.15	679

Simulation Data for 45 % Volume Increase at 30 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	37.2	98.1	45.6	4	3.4	19.5
2	127	54.6	67.6	3.7	3.4	18.4
3	102	47.2	39.8	3.8	3.2	25.5
4	85.5	51.7	67.9	3.7	3.2	20.3
5	114	40	87.4	4.1	3.6	16.4
6	30.3	126	20.6	4	3.5	17
7	127	54.6	67.6	3.7	3.4	18.4
8	75.4	39.6	75.3	4.1	3.5	19.6
9	109	46.4	80.9	3.9	3.2	19.9
10	77.3	60.3	121	4	3.5	21.7
Average	88.4	61.9	67.4	3.9	3.39	19.7

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	179	83.7	243	1.2	1	10.6
2	287	62.6	306	1.2	0.9	6
3	249	70.1	295	1.2	0.9	6.2
4	231	77.2	279	1.2	1	7.5
5	221	79.6	224	1.2	1	10.3
6	195	76.4	172	1.2	0.9	9.8
7	227	71.3	282	1.2	1	7.8
8	254	71.4	283	1.3	0.9	6.6
9	226	78.9	217	1.2	1	6.1
10	177	80.7	235	1.2	1	9.3
Average	225	75.2	253	1.21	0.96	8.02

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1232	950	15.5	0	0.5	791
2	1607	698	5.25	0	0	917
3	1550	871	6.25	0	0.25	731
4	1467	849	6.5	6.5	0	855
5	1569	902	12.5	12.5	0	632
6	1272	916	11.5	11.5	0.5	490
7	1446	844	8.75	8.75	0.25	743
8	1503	864	5	5	0.25	872
9	1525	906	4.5	4.5	0.25	572
10	1159	962	10.3	10.3	0	702
Average	1433	876	8.6	5.9	0.2	730

Simulation Data for 50 % Volume Increase at 30 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	33.4	94	64.2	4.7	3.8	24.7
2	160	56.3	85	4	3.5	21
3	79.2	68.4	47.5	3.8	3.3	30.4
4	35.4	95.7	41.4	3.8	3.7	22.3
5	82.6	75.4	49	4.4	3.6	18.6
6	41.4	118	21.6	4.2	3.4	16.4
7	160	56.3	85	4	3.5	21
8	56.5	54.6	118	3.9	3.5	19.5
9	113	59.9	63.9	4	3.6	19.2
10	139	47.8	165	4	3.5	18
Average	90	72.6	74	4.08	3.54	21.1

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	178	88.3	266	1.2	0.8	12.6
2	239	71	296	1.1	0.9	6.2
3	229	74.4	276	1.3	1	7.1
4	230	75.1	277	1.2	0.9	9.3
5	212	85.3	213	1.2	1	11.6
6	196	81.9	242	1.2	1	8.8
7	215	78	283	1.3	0.9	8.1
8	249	70.1	341	1.2	0.9	6.2
9	220	82.7	187	1.2	0.9	8.1
10	188	83.6	308	1.1	0.9	13.7
Average	216	79	269	1.2	0.92	9.17

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1194	1024	20.8	0.25	0	812
2	1600	845	5	0	0	878
3	1531	843	8	0	0.25	682
4	1397	874	10.5	10.5	0	826
5	1573	935	15	15	0	648
6	1370	953	10.8	10.8	0.25	735
7	1440	871	8	8	0.25	821
8	1543	809	5.25	5.25	0.25	908
9	1542	1007	8.25	8.25	0	528
10	1297	948	20.8	20.8	0.25	825
Average	1449	911	11.2	7.88	0.13	766

Summary of Simulation Data for 30 % Car1 - Model Scenario S3

Travel Time

Sim No	EB	SB	NB	Pt1	Pt2	WB
	Link No					
0	28.4	29.4	23	3.89	3.24	19.1
5	33	30.2	30.2	3.85	3.33	18.1
10	39.1	34.6	32.3	3.94	3.36	17.4
15	39.2	37.5	37.7	3.97	3.47	18.4
20	51.4	39.5	52.8	4.07	3.53	18.3
25	63.1	42.1	60.3	4.02	3.47	19.4
30	70.5	47.4	58.8	4.15	3.49	18.9
35	77.6	48.4	73.1	3.97	3.35	18.9
40	75.3	58.1	66.2	4.06	3.46	20.7
45	88.4	61.9	67.4	3.9	3.39	19.7
50	90	72.6	74	4.08	3.54	21.1
Average						

Delay

Sim No	EB	SB	NB	Pt1	Pt2	WB
	Link No					
0	46.3	19.9	65.2	1.09	0.86	4.87
5	96.1	24.9	96	1.12	0.91	5.4
10	157	32.8	169	1.16	0.89	5.66
15	194	47.5	190	1.21	0.91	5.45
20	206	61.4	207	1.24	0.94	5.97
25	213	63.3	239	1.21	0.94	6.73
30	230	67.1	238	1.19	0.94	7.19
35	224	69.7	273	1.23	0.92	7.39
40	229	70.8	249	1.19	0.92	7.35
45	225	75.2	253	1.21	0.96	8.02
50	216	79	269	1.2	0.92	9.17
Average						

Queue Length

Sim No	EB	SB	WB	Pt1	Pt2	NB
	Link No					
0	137	67.7	3.33	2.5	0.15	92.4
5	378	98.6	4.08	3.1	0.2	159
10	722	170	4.4	3.28	0.15	339
15	980	395	4.1	3.1	0.15	417
20	1109	679	4.63	3.23	0.25	479
25	1211	680	6.23	4.05	0.23	588
30	1290	772	6.78	4.98	0.18	606
35	1343	776	7.5	5.83	0.18	721
40	1400	837	7.23	5.38	0.15	679
45	1433	876	8.6	5.9	0.2	730
50	1449	911	11.2	7.88	0.13	766
Average						

Simulation Data for 0 % Volume Increase at 40 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	38.3	31.1	19.7	3.9	3.2	19.1
2	29.9	25.3	28.2	3.7	3.1	18.8
3	36.4	26.5	27.1	3.7	3.1	18.8
4	24.8	25.7	23.8	3.5	3	15.1
5	25.5	27	17.1	3.8	3.1	16
6	24.2	30.2	21	4	3.4	15.2
7	29.9	25.3	28.2	3.7	3.1	18.8
8	26	21.8	25.6	3.3	3	19.3
9	30.1	22	36.5	3.6	3.3	15.3
10	30.4	28.9	33	3.9	3.5	13.5
Average	29.6	26.4	26	3.71	3.18	17

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	15.9	19.7	22.4	1.1	0.8	4.9
2	46.8	12.7	40.1	1.1	0.9	3.2
3	48.5	13.9	60.5	1.2	0.9	5.1
4	27.2	13.6	50	1.2	1	4.5
5	37.5	13.7	30.8	1.1	0.8	5.4
6	28.1	12	21.2	1.2	0.9	3.5
7	34.7	14.3	30.7	1.1	0.9	3.9
8	40.4	16.5	68.8	1.2	0.9	4.6
9	56.2	19.7	20.9	1.3	0.9	4.6
10	36.9	16.5	43.2	1.1	0.9	5.8
Average	37.2	15.3	38.9	1.16	0.89	4.55

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	29.8	67.5	3.25	0	0	28.8
2	145	31.3	1.25	0.5	0	60.3
3	147	38.8	3.75	0.25	0.75	73.5
4	63.5	27.5	2.75	2.75	0	75.3
5	113	30.5	3.5	3.5	0.5	39
6	67.3	19.3	2	2	0	25.3
7	92	19.5	2.25	2.25	0	39.8
8	108	33.8	2.75	2.75	0	111
9	193	51.5	3.5	3.5	0	22.5
10	95.3	41.3	4.5	4.5	0	59.8
Average	105	36.1	2.95	2.2	0.13	53.5

Simulation Data for 5 % Volume Increase at40 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	40.3	32.1	27.2	3.9	3.3	20.7
2	29.2	26.4	35.4	3.9	3.2	16.4
3	57.7	22.7	25.9	3.8	3.2	15.5
4	23.7	25.6	20.4	3.7	3.1	16.5
5	28	27.9	21.5	3.7	3.2	19
6	23.5	27.8	20.6	4.1	3.3	15
7	29.2	26.4	35.4	3.9	3.2	16.4
8	24.4	22.6	31.8	3.5	3.1	15.1
9	33.1	26.9	25.4	4.1	3.4	18.4
10	40.4	32.9	30	4.3	3.5	14.4
Average	33	27.1	27.4	3.89	3.25	16.7

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	30.3	34.1	50	1.2	0.9	5.8
2	68.7	19.6	77.7	1.2	1.1	5.7
3	165	19.8	115	1.3	1	6.1
4	44.5	22.8	131	1.4	1	4.6
5	147	25.7	54.4	1.4	1.1	5.2
6	49.5	16.4	63.7	1.3	1.1	4.6
7	94	19.6	76.1	1.3	1.1	4.9
8	120	18.3	175	1.2	1	5
9	66.1	23.3	33.2	1.2	0.9	4.5
10	46.1	29.5	60.2	1.3	1	5.7
Average	83.2	22.9	83.6	1.28	1.02	5.21

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	72.8	186	4.25	0.25	0.5	76
2	241	60.8	4	0	0.75	132
3	744	52.8	5.5	0.25	0.5	158
4	122	87.3	2.5	2.5	0	230
5	670	98.3	3	3	0.5	82.5
6	143	33.3	2.75	2.75	0	106
7	344	52.8	3.75	3.75	0.75	125
8	490	68.8	3.25	3.25	1	380
9	242	62	3.25	3.25	0.25	42
10	138	119	4.5	4.5	0.25	91.5
Average	321	82.1	3.68	2.35	0.45	142

Simulation Data for 10 % Volume Increase at 40 % Car1 - Model Scenario S3

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	24.8	40.6	18.9	3.7	3.1	17.4
2	30.5	27.6	46.4	3.7	3.2	16.2
3	63.1	26.1	28.4	3.8	3.4	19.3
4	30.7	27	27.6	3.5	2.9	16.7
5	31.7	33.8	16.8	3.6	3.2	18.4
6	24.9	28.3	21.4	4	3.2	16.3
7	30.5	27.6	46.4	3.7	3.2	16.2
8	27.9	25.1	41.7	4	3.2	20.1
9	53.9	23.3	26.3	3.8	3.3	15
10	34.2	26	40	4.1	3.4	17.5
Average	35.2	28.5	31.4	3.79	3.21	17.3

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	72	29.1	218	1.3	1	6.5
2	119	28.4	217	1.5	1.1	4.3
3	205	24.3	65.1	1.4	1	5.3
4	72.8	30	195	1.3	1.1	6.6
5	192	22.7	83.4	1.3	1	5.8
6	101	30.1	125	1.5	1.2	4.6
7	157	30.6	111	1.3	0.9	5.3
8	154	28.3	190	1.3	1	3.7
9	168	34.5	111	1.3	1	5.4
10	127	39.3	63.4	1.4	1	6.3
Average	137	29.7	138	1.36	1.03	5.38

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	219	121	5	0.25	0	471
2	472	113	2.25	0.5	1	472
3	1180	87.5	3.75	0.25	0	89.3
4	227	139	4.5	4.5	0.25	395
5	1056	95	4.25	4.25	1	132
6	389	115	2.75	2.75	0.5	244
7	652	168	4	4	0	239
8	684	102	2	2	0	419
9	773	188	4	4	0.25	207
10	530	223	5	5	0.5	104
Average	618	135	3.75	2.75	0.35	277

Simulation Data for 15 % Volume Increase at 40 % Car1 - Model Scenario S3

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	35.7	35.3	39	3.8	3.2	17.3
2	38.7	30.4	72.9	3.6	3.2	13.6
3	59.4	26.3	32.5	3.7	3.2	21.3
4	27.2	32.2	22	3.8	3.5	14.1
5	31.5	34.3	17.3	4	3.2	17.8
6	43.7	28.8	29.2	4.1	3.2	15.8
7	38.7	30.4	72.9	3.6	3.2	13.6
8	33	24.6	48.7	3.7	3.1	17.9
9	53.1	24.1	27.2	3.5	3.2	16.5
10	50.2	39.5	50.9	4.4	3.7	15.4
Average	41.1	30.6	41.3	3.82	3.27	16.3

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	87.4	47.3	238	1.3	1	6.4
2	202	29.3	203	1.3	1	4.7
3	229	38.8	188	1.3	1	5.9
4	165	41.5	237	1.3	1	6
5	212	33.6	177	1.3	1	5.5
6	181	36.4	126	1.5	1.1	5.2
7	184	33.8	206	1.4	1.1	4.6
8	167	38.4	213	1.3	0.9	4.6
9	204	52.4	95.8	1.3	0.9	4.7
10	148	52.9	196	1.3	1	4.7
Average	178	40.4	188	1.33	1	5.23

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	298	415	5.25	0	0.25	535
2	1027	180	3	0.5	0.5	452
3	1274	226	6	0.25	0	298
4	705	278	4.25	4.25	0	590
5	1328	202	4	4	0	363
6	888	163	3.5	3.5	0.5	270
7	846	200	2.75	2.75	0.5	431
8	794	309	2.75	2.75	0.25	523
9	1227	423	3.5	3.5	0	196
10	659	567	3.5	3.5	0	413
Average	904	296	3.85	2.5	0.2	407

Simulation Data for 20 % Volume Increase at 40 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	47.9	47.3	23	4	3.4	19.5
2	49.4	30.8	81.1	3.8	3.4	15.9
3	101	28	37.9	4.1	3.5	22.7
4	29.7	37.1	23.5	3.7	3	16
5	48.4	36.4	53.4	4	3.4	16.6
6	38.2	37.7	24.9	4.5	3.4	17.3
7	49.4	30.8	81.1	3.8	3.4	15.9
8	36.1	25	43.9	3.6	3.1	17.6
9	46.1	32	38.8	3.9	3.6	14.7
10	54.6	34	79.4	4.2	3.5	18.5
Average	50	33.9	48.7	3.96	3.37	17.5

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	158	62.6	221	1.4	1.1	6.8
2	228	33.9	283	1.4	1.1	5.3
3	262	47.6	156	1.3	1	6.3
4	211	53.6	254	1.4	1	6.5
5	230	62.1	116	1.4	1	7.9
6	185	65.4	134	1.6	1.1	5.4
7	172	59.1	183	1.3	1	5.1
8	158	53.8	280	1.4	1.1	5.9
9	244	55.1	146	1.3	1	5.1
10	181	64.4	188	1.5	1.1	4.9
Average	203	55.8	196	1.4	1.05	5.92

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	685	643	6.5	0	0.25	551
2	1325	184	3.25	0.25	0.5	677
3	1411	465	5.25	0.25	0.25	276
4	1039	507	4	4	0	625
5	1395	705	7.75	7.75	0.25	230
6	995	703	3.75	3.75	0.5	311
7	886	645	3.5	3.5	0.25	389
8	752	498	4	4	0.25	668
9	1432	445	4	4	0.25	282
10	887	719	3.25	3.25	0.5	446
Average	1081	551	4.53	3.08	0.3	445

Simulation Data for 25 % Volume Increase at 40 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	57	33.8	31.6	3.8	3.2	18.4
2	49.1	37.3	60.3	4.1	3.3	16.1
3	74.4	33.7	35.6	4	3.3	22.6
4	46.3	31.9	48.4	3.7	3.1	16.9
5	54.2	37.8	25.5	3.6	3.3	18.2
6	31.8	64.3	23.7	4.2	3.5	17.9
7	49.1	37.3	60.3	4.1	3.3	16.1
8	35.1	25.8	124	3.9	3.2	19.2
9	61	27.5	130	3.9	3.2	14
10	72.7	31.5	77.8	4.3	3.7	17.7
Average	53.1	36.1	61.7	3.96	3.31	17.7

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	147	69.6	253	1.4	1.1	6.9
2	263	42.4	281	1.5	1.1	5
3	258	58	267	1.3	1	5.6
4	220	63.6	263	1.6	1.2	6
5	237	65.2	136	1.3	1	5.5
6	230	60.1	143	1.5	1.1	4.9
7	172	70.9	179	1.6	1.2	5.5
8	200	52.9	289	1.4	1.1	5.5
9	221	67.5	157	1.3	1.1	4.8
10	192	65.3	157	1.3	1.1	7.6
Average	214	61.6	212	1.42	1.1	5.73

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	634	801	5.75	0.5	0.25	714
2	1470	238	3.25	1.5	0.5	691
3	1414	624	4.5	0	0	554
4	1150	752	4.25	4.25	0.5	696
5	1406	721	3.5	3.5	0	288
6	1216	627	3.5	3.5	0.25	344
7	1004	855	3.75	3.75	0.75	400
8	1015	488	3.25	3.25	0.25	833
9	1324	877	3.75	3.75	0.5	342
10	963	824	7.5	7.5	0.75	360
Average	1160	681	4.3	3.15	0.38	522

Simulation Data for 30 % Volume Increase at 40 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	39.8	76.5	21.2	3.8	3.3	16.3
2	46.5	53.4	58.6	4.1	3.3	17.7
3	110	38.2	34.3	3.8	3.2	22.9
4	35.9	41.7	36.9	3.8	3.2	17
5	56.2	38.8	26.1	3.9	3.3	17.3
6	39.9	51.8	54.1	4.4	3.8	18.8
7	46.5	53.4	58.6	4.1	3.3	17.7
8	66.7	24.8	84.8	3.7	3.2	20.5
9	67.8	34.3	78.5	3.9	3.5	15.9
10	60	49.2	49.8	4.5	3.8	16.8
Average	56.9	46.2	50.3	4	3.39	18.1

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	162	78	235	1.4	1.1	8.4
2	264	55.6	288	1.3	1	6
3	258	63	246	1.3	1	5.6
4	207	69.2	262	1.5	1.1	7.6
5	246	63.4	163	1.4	1	6.1
6	198	72	129	1.6	1.2	5.5
7	202	70.9	224	1.4	1.1	5.5
8	229	53.8	313	1.4	1.1	4.9
9	218	69.3	166	1.3	1	4.9
10	179	73.5	125	1.4	1.1	6.2
Average	216	66.9	215	1.4	1.07	6.07

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	798	945	7.5	0.25	0.75	655
2	1432	692	4.25	0	0.25	742
3	1523	780	4.5	0	0.5	542
4	1178	792	6.75	6.75	0.5	709
5	1517	688	5.5	5.5	0.75	396
6	1219	712	4	4	0.5	319
7	1232	823	4.25	4.25	0	548
8	1231	543	2.5	2.5	0.25	852
9	1428	807	3.5	3.5	0.5	389
10	988	810	5.75	5.75	0.5	270
Average	1255	759	4.85	3.25	0.45	542

Simulation Data for 35 % Volume Increase at 40 % Car1 - Model Scenario S3

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	51	55.5	34.4	4	3.5	19.3
2	47.5	62.3	89.5	4.3	3.4	19
3	114	34.3	38.3	4.2	3.5	31.6
4	35.2	61.1	30.4	3.7	3.1	16.4
5	60.5	52.1	34.2	4.1	3.4	19.9
6	26.3	79.7	22.8	4.4	3.5	20.4
7	47.5	62.3	89.5	4.3	3.4	19
8	87.3	26.9	109	3.8	3.2	18
9	77.1	36.2	66.6	4.3	3.6	15.6
10	57.2	74.9	52.6	4.7	3.7	16.1
Average	60.4	54.5	56.7	4.18	3.43	19.5

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	153	76.1	266	1.3	1.1	10.6
2	257	60.2	292	1.5	1.1	4.9
3	272	61.9	218	1.3	1	6.8
4	221	72.7	229	1.5	1.1	7.2
5	215	72.7	159	1.3	1.1	6.4
6	202	70.9	135	1.5	1.2	7.3
7	211	67.9	245	1.5	1.1	6.1
8	232	60	290	1.4	1	5
9	220	70.3	163	1.4	1	7.1
10	196	72.1	164	1.3	1.1	6.6
Average	218	68.5	216	1.4	1.08	6.8

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	828	841	12.8	0.75	0	796
2	1465	778	2.75	0.25	0.5	801
3	1522	749	6	0.75	0.5	512
4	1267	856	6.75	6.75	0.25	699
5	1475	815	6.5	6.5	1.25	403
6	1223	886	6.75	6.75	1	384
7	1279	793	6	6	0.25	642
8	1331	660	3.5	3.5	0.5	855
9	1445	857	6.75	6.75	0.25	416
10	1128	855	5.25	5.25	0.25	433
Average	1296	809	6.3	4.33	0.48	594

Simulation Data for 40 % Volume Increase at 40 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	51	73.3	24.6	4.1	3.5	17.9
2	37.2	77.6	104	4.4	3.6	17.6
3	152	36.6	37.3	3.8	3.4	20.3
4	40.5	62.9	46	3.9	3.2	18.1
5	62.3	60.5	64.1	4.7	3.5	20.5
6	26.1	75.9	34.9	4.5	3.4	17.6
7	37.2	77.6	104	4.4	3.6	17.6
8	89.7	25.1	114	3.6	3.1	16.5
9	122	33.7	113	3.9	3.4	15.6
10	78.3	62.2	75.2	4.4	3.8	19.5
Average	69.6	58.5	71.6	4.17	3.45	18.1

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	144	84	217	1.3	1	10.3
2	235	64.9	264	1.6	1	5.1
3	263	64	225	1.4	1.1	6.5
4	227	73.1	256	1.3	1.1	6.4
5	231	71.7	174	1.5	1.1	10
6	185	73.6	153	1.4	1.1	7.7
7	187	76.2	255	1.5	1.1	7.7
8	228	64.7	303	1.4	1	6.9
9	209	81.4	146	1.5	1.1	6.2
10	168	83.7	185	1.6	1.1	10.2
Average	208	73.7	218	1.45	1.07	7.7

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	868	996	15.3	0.25	0	652
2	1424	816	3.5	0.5	0.25	769
3	1577	771	5.25	1	0.25	552
4	1358	849	4.75	4.75	0.25	763
5	1521	783	11.3	11.3	0.75	491
6	1238	855	7.75	7.75	0.5	428
7	1258	879	7.5	7.5	0.5	744
8	1466	753	6.25	6.25	0.25	839
9	1484	941	4.75	4.75	0.5	360
10	1132	883	12	12	0.25	529
Average	1333	853	7.83	5.6	0.35	613

Simulation Data for 45 % Volume Increase at 40 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	26.2	103	16.9	3.7	3.1	23
2	83.6	56.2	88.3	4.3	3.5	18.3
3	127	41.8	37.3	4	3.6	24.3
4	34.5	74.6	41.7	4.2	3.7	17.7
5	73.1	74.3	26.7	4.2	3.3	22.7
6	35.8	91.2	33.4	4.8	3.6	21.5
7	83.6	56.2	88.3	4.3	3.5	18.3
8	106	30.2	77.5	3.8	3.2	17.5
9	116	41.6	61.2	4	3.5	17.4
10	72.2	74.9	96.2	4.2	3.6	19.7
Average	75.8	64.4	56.8	4.15	3.46	20

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	184	74.7	269	1.4	1.1	12
2	260	65.9	295	1.5	1.2	6
3	253	68.3	240	1.3	1	7.7
4	226	71.7	277	1.4	1	6.1
5	223	75.9	212	1.4	1.1	11.9
6	197	77.7	199	1.5	1.2	6.8
7	161	80.7	239	1.4	1.1	9.8
8	210	68.9	295	1.4	1	8.4
9	216	78.9	162	1.4	1	9.1
10	178	86	186	1.5	1.2	10.1
Average	211	74.9	237	1.42	1.09	8.79

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1124	913	19.3	0	1	814
2	1586	801	4.75	1.75	0.75	868
3	1556	807	8.5	0.25	0	644
4	1371	794	4.75	4.75	0.25	822
5	1536	822	15.5	15.5	0.25	613
6	1320	956	5.5	5.5	0.5	598
7	1129	953	11.3	11.3	0.5	711
8	1487	786	8.5	8.5	0	864
9	1547	938	12	12	0.25	462
10	1184	965	11.5	11.5	0.25	524
Average	1384	873	10.2	7.1	0.38	692

Simulation Data for 50 % Volume Increase at 50 % Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	64	62.5	29.8	4.1	3.5	23.5
2	45.5	86.7	107	4.7	3.7	19.2
3	129	53.5	33.2	4.1	3.3	20.8
4	57.7	65.2	64.7	3.8	3.1	23.5
5	98	58.6	63.9	4	3.3	21.1
6	51.6	75.3	69.4	3.9	3.5	18.6
7	45.5	86.7	107	4.7	3.7	19.2
8	120	34.2	115	3.7	3.1	15.7
9	107	51.7	129	4	3.4	16.6
10	111	56	127	4.2	3.4	17.1
Average	82.9	63	84.6	4.12	3.4	19.5

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	181	83	267	1.4	1.1	10.7
2	242	67.6	284	1.4	1.1	6.8
3	261	68.6	266	1.5	1	7.3
4	218	77.9	244	1.4	1.1	6.7
5	206	86.2	150	1.5	1.2	14.8
6	202	77.8	191	1.6	1.2	7.6
7	200	83.1	236	1.5	1.2	8.7
8	229	66.3	302	1.4	1.1	7.6
9	205	79.9	191	1.5	1.1	7.5
10	171	87.4	203	1.5	1.2	11.8
Average	211	77.8	233	1.47	1.13	8.95

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1214	984	14.8	0	0	824
2	1527	827	5.25	0.5	0	849
3	1583	815	8	0.25	0.25	658
4	1369	928	5.5	5.5	0.25	822
5	1599	953	23.3	23.3	0.75	446
6	1365	865	7.75	7.75	0.75	572
7	1394	891	9	9	0.75	740
8	1561	771	7.5	7.5	0	897
9	1567	936	7.5	7.5	0.5	551
10	1181	1023	16	16	0.25	651
Average	1436	899	10.5	7.73	0.35	701

Summary of Simulation Data for 40 % Car1 - Model Scenario S3

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
0	29.6	26.4	26	3.71	3.18	17
5	33	27.1	27.4	3.89	3.25	16.7
10	35.2	28.5	31.4	3.79	3.21	17.3
15	41.1	30.6	41.3	3.82	3.27	16.3
20	50	33.9	48.7	3.96	3.37	17.5
25	53.1	36.1	61.7	3.96	3.31	17.7
30	56.9	46.2	50.3	4	3.39	18.1
35	60.4	54.5	56.7	4.18	3.43	19.5
40	69.6	58.5	71.6	4.17	3.45	18.1
45	75.8	64.4	56.8	4.15	3.46	20
50	82.9	63	84.6	4.12	3.4	19.5
Average						

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
0	37.2	15.3	38.9	1.16	0.89	4.55
5	83.2	22.9	83.6	1.28	1.02	5.21
10	137	29.7	138	1.36	1.03	5.38
15	178	40.4	188	1.33	1	5.23
20	203	55.8	196	1.4	1.05	5.92
25	214	61.6	212	1.42	1.1	5.73
30	216	66.9	215	1.4	1.07	6.07
35	218	68.5	216	1.4	1.08	6.8
40	208	73.7	218	1.45	1.07	7.7
45	211	74.9	237	1.42	1.09	8.79
50	211	77.8	233	1.47	1.13	8.95
Average						

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
0	105	36.1	2.95	2.2	0.13	53.5
5	321	82.1	3.68	2.35	0.45	142
10	618	135	3.75	2.75	0.35	277
15	904	296	3.85	2.5	0.2	407
20	1081	551	4.53	3.08	0.3	445
25	1160	681	4.3	3.15	0.38	522
30	1255	759	4.85	3.25	0.45	542
35	1296	809	6.3	4.33	0.48	594
40	1333	853	7.83	5.6	0.35	613
45	1384	873	10.2	7.1	0.38	692
50	1436	899	10.5	7.73	0.35	701
Average						

Simulation Data for 0 Percent Volume Increase at 50 Percent Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	38.7	33.5	18.2	4.3	3.5	17.7
2	30	29.7	34.3	3.9	3.3	14.9
3	30.1	24.6	25.3	3.6	3.1	18
4	23.5	28.3	19.4	3.4	3.1	15.9
5	25.4	30.2	18.1	4.5	3.6	16.6
6	22.4	26.2	19.7	3.7	3.1	15
7	30	29.7	34.3	3.9	3.3	14.9
8	32.7	20.6	20.7	3.7	3.4	16.1
9	36.2	22.2	29	3.8	3.4	15.5
10	28.2	22.2	17.8	3.5	3	13.5
Average	29.7	26.7	23.7	3.83	3.28	15.8

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	21.8	19.4	28.3	1.3	1	5.5
2	38	11.4	20.7	1.2	1	4.6
3	32.8	12.5	56.9	1.3	1	4.8
4	32.1	13.2	46.2	1.4	1	4.9
5	42	14.9	39.4	1.1	1	5.4
6	28.2	13.3	22.6	1.4	1.1	4
7	30.3	17.7	26	1.2	0.9	5.1
8	24.5	16.9	58.2	1.4	1.1	5.5
9	38.7	13.5	15.8	1.1	0.8	3.7
10	25.3	16.8	39.5	1.3	1	5.2
Average	31.4	15	35.4	1.27	0.99	4.87

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	45.8	53.5	4.25	0.25	0.25	37.8
2	112	13.8	2.75	0	0.25	28.3
3	92.8	26.3	3	0	0	71
4	80.5	18.8	3	3	0	68.5
5	123	36	3.75	3.75	0.75	51
6	70	20.8	2.5	2.5	0.25	26.8
7	79	46.3	3.25	3.25	0	34
8	58.5	42.8	3	3	0.25	95.8
9	110	25.3	1.75	1.75	0.25	17
10	60.3	35.8	3.75	3.75	0	54
Average	83.1	31.9	3.1	2.13	0.2	48.4

Simulation Data for 5 Percent Volume Increase at 50 Percent Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	37.8	29.6	47.6	3.9	3.3	15.9
2	26.8	33.4	36	3.6	3.3	14.9
3	29.2	26.3	35.5	3.7	3.1	22.4
4	23.4	24.4	20.2	3.4	3.1	16.4
5	22.1	33.8	18.8	3.9	3.6	16.5
6	20.8	31.9	16.3	3.7	3.2	14.2
7	26.8	33.4	36	3.6	3.3	14.9
8	26.2	21.2	22.7	3.6	3.3	22.4
9	33.2	24.5	23	4	3.4	16
10	27.9	32.9	26	3.9	3.1	15.7
Average	27.4	29.1	28.2	3.73	3.27	16.9

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	22.6	23.7	44.1	1.4	1.1	5.3
2	48.9	23	68.6	1.4	1.2	5.2
3	90.2	19.8	69.1	1.5	1.1	7.4
4	43.8	25.6	48.3	1.5	1.1	5
5	72.3	34	54.7	1.5	1.1	8
6	42.4	18.2	30.8	1.5	1.1	5.5
7	60.7	17.5	43.2	1.3	1	4.4
8	99.9	17.8	132	1.5	1.1	4.8
9	59.3	18.6	37.5	1.4	1	4.8
10	61.2	23	86.8	1.5	1.2	5.8
Average	60.1	22.1	61.5	1.45	1.1	5.62

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	50.5	73.3	4.25	0.5	0	64.5
2	160	78.8	3.25	0.5	0.5	113
3	332	78.5	7.5	2.5	0.75	92
4	119	90.3	2.75	2.75	0.25	76.3
5	256	209	7.75	7.75	0.5	76.8
6	115	39	3.25	3.25	0.5	40.8
7	192	44.5	2.25	2.25	0.25	63.3
8	363	61.8	2.5	2.5	0.5	255
9	197	43.5	2.75	2.75	0	49
10	203	77.8	4.5	4.5	0.5	135
Average	199	79.6	4.08	2.93	0.38	96.6

Simulation Data for 10 Percent Volume Increase at 50 Percent Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	30.1	36.4	29.9	3.7	3.1	15.4
2	27.6	40.8	27.3	3.7	3.1	20
3	37.5	31	21.2	3.9	3.3	20.8
4	24.1	28.2	19	3.8	3.3	16.1
5	42.8	39.2	25.1	4.7	3.7	16.7
6	19.7	35.3	21.5	4.1	3.4	18.8
7	27.6	40.8	27.3	3.7	3.1	20
8	51.9	21.2	26.5	3.5	3.5	18.5
9	45.9	26.5	19.2	3.8	3.3	17.1
10	32.5	34	37.7	4.1	3.3	15.7
Average	34	33.3	25.5	3.9	3.31	17.9

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	38.4	44.3	57.3	1.5	1.2	5.6
2	100	21.9	66.1	1.6	1.2	5.8
3	177	19.5	86.8	1.6	1.2	5.2
4	57.6	36.2	193	1.5	1.1	4.7
5	160	39	71.1	1.5	1.2	6.2
6	95.9	28	85	1.5	1.2	4.3
7	133	28.7	84.2	1.6	1.1	7.5
8	149	37.8	146	1.6	1.3	5.8
9	90.8	31.4	94.9	1.5	1.1	5.6
10	105	38.7	60.2	1.5	1.1	5.6
Average	111	32.6	94.4	1.54	1.17	5.63

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	101	255	4.25	0.25	0.5	91
2	381	78	4.5	0.75	0.75	117
3	852	46.5	3.5	1.5	0.75	127
4	170	240	3.25	3.25	0.5	439
5	761	238	4.75	4.75	0.75	107
6	344	115	3	3	0.75	169
7	554	124	6.75	6.75	0	145
8	655	226	3.75	3.75	0.75	306
9	371	161	4.5	4.5	0.5	171
10	415	214	4	4	0.5	105
Average	460	170	4.23	3.25	0.58	178

Simulation Data for 15 Percent Volume Increase at 50 Percent Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	37.6	40.1	21	3.6	3.1	18.4
2	53.1	29.2	81	3.6	3.1	17.3
3	63.2	29.7	37.6	4	3.4	20.7
4	24	28	17.1	3.7	3.2	16.1
5	30.9	37.2	24.5	4.3	3.8	15.5
6	22.9	32.3	26	4	3.4	17.1
7	53.1	29.2	81	3.6	3.1	17.3
8	55.6	22.5	30.6	3.6	3.6	18.1
9	71.6	24.2	26	3.3	3	16.5
10	40.2	32.9	34.1	4	3.3	16.9
Average	45.2	30.5	37.9	3.77	3.3	17.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	109	58.7	203	1.6	1.2	5.9
2	214	29.3	222	1.6	1.1	5.9
3	190	39.7	177	1.5	1.1	4.8
4	137	43.9	184	1.7	1.2	6.6
5	189	42.6	110	1.5	1.1	7
6	163	59.4	92.3	1.9	1.4	5.4
7	167	48.6	129	1.6	1.2	5.5
8	137	55.9	169	1.7	1.3	6.3
9	199	37.9	112	1.7	1.1	5.2
10	152	42.8	134	1.5	1.2	5.5
Average	166	45.9	153	1.63	1.19	5.81

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	400	489	4.75	0.5	0.5	494
2	1035	127	4	1	0.25	513
3	1063	292	2.5	0.75	0.75	294
4	535	349	5.75	5.75	0.5	439
5	1119	329	6.25	6.25	0.5	197
6	770	516	4.25	4.25	1	192
7	903	467	4.25	4.25	0.25	259
8	639	602	4.75	4.75	0.5	398
9	1192	223	3.25	3.25	0.25	227
10	632	361	4.25	4.25	1	267
Average	829	375	4.4	3.5	0.55	328

Simulation Data for 20 Percent Volume Increase at 50 Percent Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	33.5	46.3	33	4.2	3.4	16.6
2	50.9	38.3	80.8	3.8	3.1	16.5
3	65.5	32.1	36.3	4.1	3.3	18.6
4	29.3	29.6	22.6	3.7	3.3	17.2
5	53.5	45.6	19.8	4.3	3.9	16.8
6	27	33.1	26.2	4.3	3.7	19.5
7	50.9	38.3	80.8	3.8	3.1	16.5
8	60.2	25.1	48.8	3.8	3.4	19.4
9	75.2	25.8	23.5	3.7	3.3	14.7
10	44.2	36.8	39.3	4.1	3.3	15.9
Average	49	35.1	41.1	3.98	3.38	17.2

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	113	66.4	200	1.7	1.3	7.1
2	215	44.4	266	1.7	1.2	5.7
3	227	57.5	156	1.6	1.1	5.7
4	226	57.5	153	1.7	1.3	5
5	216	54.7	124	1.6	1.2	8.2
6	206	51.7	121	1.5	1.2	6.8
7	186	59.5	203	1.6	1.3	6.1
8	173	58.8	213	1.7	1.3	5.7
9	223	43	157	1.5	1.1	4.7
10	204	60.4	105	1.6	1.2	4.8
Average	199	55.4	170	1.62	1.22	5.98

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	428	653	6.5	1	0.75	488
2	1171	294	4.25	1.5	0.75	701
3	1163	629	5	1	0.25	272
4	1082	575	2.25	2.25	0.75	345
5	1272	523	7.25	7.25	0.75	218
6	1130	365	6.25	6.25	0.75	280
7	976	587	5	5	0.75	422
8	874	596	4.25	4.25	0.5	478
9	1373	283	3	3	0	338
10	1001	636	3	3	0.5	198
Average	1047	514	4.68	3.45	0.58	374

Simulation Data for 25 Percent Volume Increase at 50 Percent Car1 - Model Scenario S3

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	43.4	55.9	35.6	4	3.4	16.6
2	36.3	54.8	49.7	4	3.2	15.7
3	89.5	30.3	30	3.7	3.2	23.6
4	30.7	30.4	47.3	3.6	3.2	19.7
5	44.3	51.6	18.1	4.7	3.6	16.2
6	31.6	37.1	36.7	4.6	3.6	17
7	36.3	54.8	49.7	4	3.2	15.7
8	50.3	22.7	39.9	3.8	3.7	18.9
9	71.2	27.6	40.7	3.8	3.3	16.2
10	37.2	57.1	29.2	4.1	3.2	20.1
Average	47.1	42.2	37.7	4.03	3.36	18

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	147	68.5	213	1.6	1.2	7.8
2	235	55.1	254	1.6	1.2	5.2
3	268	54.2	230	1.6	1.1	4.8
4	224	61.8	252	1.6	1.3	6.2
5	226	57.3	160	1.6	1.1	6.2
6	204	64.2	103	1.5	1.1	6
7	213	64	129	1.7	1.2	6.4
8	210	52.3	303	1.5	1.1	5.8
9	232	62.9	163	1.5	1.1	7.7
10	210	62.5	162	1.5	1.2	7
Average	217	60.3	197	1.57	1.16	6.31

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	735	792	7.5	0.25	0.5	583
2	1371	434	3.5	0.5	1	695
3	1408	529	3.25	0.5	0.25	450
4	1114	773	5.25	5.25	1	713
5	1477	598	4.5	4.5	0.5	346
6	1206	655	5.25	5.25	0.25	264
7	1232	692	6.5	6.5	0.75	267
8	1051	573	3.5	3.5	0.25	726
9	1394	725	9.5	9.5	0.5	375
10	1046	743	6.25	6.25	0.5	379
Average	1203	651	5.5	4.2	0.55	480

Simulation Data for 30 Percent Volume Increase at 50 Percent Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	50.5	70.3	18.5	4.3	3.7	18.6
2	83.9	38.4	65.7	4.1	3.3	17.4
3	95.8	32.2	26.1	3.8	3.3	24.1
4	33.1	37.7	32.6	4.2	3.4	18.8
5	57.9	60.8	37.8	5	4	16.8
6	34.8	58.1	21.7	4.5	3.5	18.1
7	83.9	38.4	65.7	4.1	3.3	17.4
8	61	26.9	52.9	4	3.4	19.9
9	87.6	30.6	29.6	4	3.2	15
10	77.5	43.5	60.1	4.4	3.7	17.1
Average	66.6	43.7	41.1	4.24	3.48	18.3

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	164	77.6	211	1.8	1.4	9.2
2	248	59	235	1.6	1.2	6
3	228	64.6	192	1.6	1.2	5.6
4	196	68.8	254	1.7	1.3	7.9
5	222	70.3	122	1.5	1.2	9.7
6	213	64.2	93.3	1.6	1.2	7
7	204	64.3	242	1.8	1.3	7
8	250	54.4	245	1.6	1.3	6.9
9	227	69.8	97.6	1.7	1.2	5.1
10	211	67.5	159	1.8	1.3	8.2
Average	216	66.1	185	1.67	1.26	7.26

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	869	906	9.5	1.25	1.5	620
2	1492	552	4	0	1	641
3	1412	677	4	0.25	0.5	400
4	1003	767	8.5	8.5	1	743
5	1449	830	11.5	11.5	0.25	263
6	1267	773	6	6	0.5	267
7	1233	754	6.75	6.75	0.75	669
8	1350	550	4.75	4.75	0.75	674
9	1455	821	4	4	0.75	193
10	1080	690	9.25	9.25	0.75	386
Average	1261	732	6.83	5.23	0.78	485

Simulation Data for 35 Percent Volume Increase at 50 Percent Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	59.8	54.4	24.5	4.3	3.6	18.8
2	56.3	54.1	95.7	4.3	3.4	14.9
3	73.7	53.5	31.3	4.8	3.8	29.5
4	42.2	39.5	61.6	3.9	3.3	18.7
5	41.4	65.7	21.4	4.6	3.7	17.2
6	36.5	43.6	85.2	4.6	3.6	16.5
7	56.3	54.1	95.7	4.3	3.4	14.9
8	68.3	31.7	52.8	3.8	3.5	18.7
9	92.1	37.9	94.6	4.5	3.7	14.7
10	85.5	44.6	92.9	4	3.4	17.6
Average	61.2	47.9	65.6	4.31	3.54	18.2

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	166	80.2	246	1.7	1.3	9.1
2	265	53.6	313	1.5	1.1	5
3	244	65.2	228	1.5	1.1	5.9
4	228	70.2	244	1.6	1.3	6.7
5	220	68.3	145	1.6	1.3	7.8
6	223	63.9	193	1.5	1.2	5.1
7	210	67.3	235	1.7	1.3	5.8
8	237	62	262	1.7	1.3	6
9	249	63.6	195	1.5	1.2	5.9
10	196	69	177	1.6	1.2	7.4
Average	224	66.3	224	1.59	1.23	6.47

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	841	885	9.75	0.25	0.75	726
2	1500	672	3.25	0.25	0.25	854
3	1463	762	5	0.25	1	545
4	1280	784	6	6	0.75	700
5	1539	784	6.75	6.75	1.75	356
6	1323	723	4.25	4.25	0.25	494
7	1303	762	3.75	3.75	0.5	632
8	1368	699	4.25	4.25	1	736
9	1497	659	4.75	4.75	0.5	501
10	1160	804	6.5	6.5	0.5	482
Average	1327	753	5.43	3.7	0.73	603

Simulation Data for 40 Percent Volume Increase at 50 Percent Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	54.6	79.5	25.1	4.5	4	19.1
2	96.2	46.4	110	3.8	3.2	19
3	126	50.7	48.3	4.4	3.7	22.4
4	47.1	54.7	48.5	4.1	3.5	18.1
5	102	54.6	28	4.7	3.8	20.5
6	31.2	64.5	41.2	4.9	3.8	17
7	96.2	46.4	110	3.8	3.2	19
8	83.4	27.6	62.7	4	3.5	16.8
9	116	37.8	132	4.4	3.6	16.5
10	95.1	49	96.1	4.2	3.7	18.5
Average	84.8	51.1	70.1	4.28	3.6	18.7

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	188	74.5	229	1.7	1.3	10.3
2	250	66.5	243	1.6	1.3	5.7
3	232	69.7	190	1.7	1.2	8.4
4	204	73.3	242	1.7	1.3	9
5	225	68.8	189	1.6	1.2	8.9
6	219	69.7	124	1.6	1.2	6.3
7	220	67.5	276	1.6	1.2	7
8	240	63.9	257	1.6	1.3	6.8
9	231	68.7	174	1.6	1.2	6.3
10	187	78.2	189	1.7	1.2	10.4
Average	219	70.1	211	1.64	1.24	7.91

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1146	838	13.3	1	0.5	754
2	1563	761	3.5	0.25	1	792
3	1518	825	9	1	0.5	450
4	1270	798	9.5	9.5	1.25	820
5	1564	774	9.5	9.5	0.5	491
6	1341	861	5.25	5.25	0.5	357
7	1393	723	6	6	0.5	819
8	1420	697	5	5	0.5	749
9	1481	833	5	5	0.75	490
10	1201	868	12.8	12.8	0.75	527
Average	1390	798	7.88	5.53	0.68	625

Simulation Data for 45 Percent Volume Increase at 50 Percent Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	49.6	84.7	21.5	4.3	3.9	18.2
2	79.1	61.5	100	3.9	3.2	21.9
3	121	56	34.2	4.3	3.5	28.2
4	39.7	61.8	46.5	4.2	3.6	24.1
5	48.6	88.6	28.1	4.9	4	18.2
6	43.3	80.9	25.9	4.4	3.4	18
7	79.1	61.5	100	3.9	3.2	21.9
8	85.8	30.6	46.5	4.1	3.5	17.3
9	83.5	61	55.3	4.4	3.7	18.4
10	93.6	63.3	50	4	3.3	22.6
Average	72.4	65	50.9	4.24	3.53	20.9

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	141	90.2	221	1.7	1.3	7.7
2	237	69.4	258	1.7	1.3	8
3	259	67.7	227	1.6	1.3	7.2
4	225	70.7	256	1.7	1.3	6.2
5	205	75.6	228	1.8	1.3	9.2
6	205	76.5	138	1.7	1.4	8.7
7	210	78.2	210	1.8	1.4	7.4
8	235	66.1	283	1.6	1.2	7.1
9	218	72.9	160	1.6	1.2	8
10	184	80.1	148	1.8	1.3	9.3
Average	212	74.7	213	1.7	1.3	7.88

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	883	1038	8.5	0.25	0.25	757
2	1558	802	7	0.75	1	854
3	1540	705	7.25	0.5	1	600
4	1346	789	5.25	5.25	0.5	834
5	1550	799	10.3	10.3	1.25	624
6	1377	907	9.75	9.75	0.75	411
7	1504	889	7.75	7.75	1.5	685
8	1483	747	7	7	0	846
9	1537	879	8.25	8.25	1	477
10	1224	921	11.5	11.5	0.5	428
Average	1400	848	8.25	6.13	0.78	651

Simulation Data for 50 Percent Volume Increase at 50 Percent Car1 - Model Scenario S3

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	56.8	87.4	26.3	4.7	3.9	20
2	98.2	64.2	53.6	4.3	3.4	16.9
3	110	52.2	39.5	3.8	3.2	28.4
4	39.5	59.9	61.9	4.9	3.8	27.1
5	106	83.9	23.4	4.4	3.8	18.1
6	56.2	69	36.9	4.6	3.5	20.4
7	98.2	64.2	53.6	4.3	3.4	16.9
8	108	32.6	104	4	3.5	18
9	115	51.8	68.4	4.6	3.7	17.8
10	127	74.2	54.9	4.2	3.7	20.2
Average	91.4	63.9	52.3	4.38	3.59	20.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	182	84	210	1.8	1.3	9.7
2	232	73.7	236	1.6	1.2	6.2
3	241	72.6	222	1.7	1.3	6.4
4	186	77.8	240	1.8	1.2	9.2
5	215	76.7	198	1.8	1.4	12.7
6	182	79.5	188	1.9	1.4	5.9
7	217	73.9	269	1.7	1.4	7.1
8	226	73.5	275	1.7	1.3	7.2
9	207	78.7	194	1.6	1.2	10.1
10	180	80.2	211	1.8	1.3	10.1
Average	207	77.1	224	1.74	1.3	8.46

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	1118	955	11.5	0.75	0.75	780
2	1564	857	5.25	0.25	0.5	807
3	1528	917	5.25	1.25	1	621
4	1292	916	9.5	9.5	0.25	830
5	1576	940	18.8	18.8	1.5	556
6	1317	885	4.5	4.5	1.5	577
7	1495	897	5.75	5.75	1	847
8	1544	868	7	7	1.25	850
9	1535	961	12	12	0.75	556
10	1221	881	13.8	13.8	0.75	649
Average	1419	908	9.33	7.35	0.93	707

Summary of Simulation Data for 50 Percent Car1 - Model Scenario S3

Travel Time

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
0	29.7	26.7	23.7	3.83	3.28	15.8
5	27.4	29.1	28.2	3.73	3.27	16.9
10	34	33.3	25.5	3.9	3.31	17.9
15	45.2	30.5	37.9	3.77	3.3	17.4
20	49	35.1	41.1	3.98	3.38	17.2
25	47.1	42.2	37.7	4.03	3.36	18
30	66.6	43.7	41.1	4.24	3.48	18.3
35	61.2	47.9	65.6	4.31	3.54	18.2
40	84.8	51.1	70.1	4.28	3.6	18.7
45	72.4	65	50.9	4.24	3.53	20.9
50	91.4	63.9	52.3	4.38	3.59	20.4
Average						

Delay

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
0	31.4	15	35.4	1.27	0.99	4.87
5	60.1	22.1	61.5	1.45	1.1	5.62
10	111	32.6	94.4	1.54	1.17	5.63
15	166	45.9	153	1.63	1.19	5.81
20	199	55.4	170	1.62	1.22	5.98
25	217	60.3	197	1.57	1.16	6.31
30	216	66.1	185	1.67	1.26	7.26
35	224	66.3	224	1.59	1.23	6.47
40	219	70.1	211	1.64	1.24	7.91
45	212	74.7	213	1.7	1.3	7.88
50	207	77.1	224	1.74	1.3	8.46
Average						

Queue Length

	Link No					
Average	EB	SB	WB	Pt1	Pt2	NB
0	83.1	31.9	3.1	2.13	0.2	48.4
5	199	79.6	4.08	2.93	0.38	96.6
10	460	170	4.23	3.25	0.58	178
15	829	375	4.4	3.5	0.55	328
20	1047	514	4.68	3.45	0.58	374
25	1203	651	5.5	4.2	0.55	480
30	1261	732	6.83	5.23	0.78	485
35	1327	753	5.43	3.7	0.73	603
40	1390	798	7.88	5.53	0.68	625
45	1400	848	8.25	6.13	0.78	651
50	1419	908	9.33	7.35	0.93	707
Average						

APPENDIX 5: RESULTS FOR S4-1 SIMULATION SCENARIO

Simulation Data for 0 Percent Volume Increase from WB Approach - Model Scenario S4-1

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	54.8	51.2	85.1	4	3.4	22.8
2	73.8	37	85	3.9	3.4	18.6
3	108	38.7	156	3.9	3.4	19.6
4	53	52.1	91.3	3.8	3.4	19.6
5	83.4	42.9	97	3.9	3.4	22
6	64.3	35.9	70	3.9	3.4	19.6
7	73.8	37	85	3.9	3.4	18.6
8	63.5	36	192	3.8	3.4	20.1
9	72	50.3	63.9	3.9	3.4	17.9
10	62	45.4	123	4	3.5	19.5
Average	70.8	42.7	105	3.9	3.41	19.8

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	36.7	32.5	72.9	0.8	0.6	8.4
2	55.6	18.3	72.9	0.8	0.6	4
3	89.6	20	144	0.8	0.6	5.3
4	34.7	33.5	79.1	0.7	0.6	5.1
5	65.3	24.2	85	0.7	0.7	7.6
6	46.2	17.1	58	0.8	0.6	5.2
7	73.1	24.4	62.9	0.8	0.7	6.9
8	45.4	17.3	180	0.7	0.6	5.7
9	53.9	31.7	52	0.8	0.6	3.6
10	43.9	26.7	111	0.8	0.7	5.1
Average	54.4	24.6	91.7	0.77	0.63	5.69

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	89.8	167	8.5	0	0.25	105
2	183	45.5	2.5	0	0	116
3	327	52.5	4	0	0	178
4	89.5	185	3.5	3.5	0	121
5	221	97.5	6.5	6.5	0	124
6	126	42.5	3.5	3.5	0	82.8
7	224	92.8	6	6	0	87
8	123	50.8	3.75	3.75	0	342
9	175	122	2.25	2.25	0	69.8
10	127	114	3.75	3.75	0	164
Average	169	96.9	4.43	2.93	0.03	139

Simulation Data for 10 Percent Volume Increase from WB Approach - Model Scenario S4-1

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	65.2	57.1	63.5	3.9	3.4	21.2
2	77.8	38.9	128	3.9	3.5	18.6
3	191	39.9	147	3.8	3.4	18.7
4	56	51.8	127	3.8	3.3	19.6
5	103	54.1	121	3.9	3.4	22.7
6	65.8	41.9	82.6	3.9	3.3	19.8
7	77.8	38.9	128	3.9	3.5	18.6
8	104	41.3	201	3.9	3.4	19.2
9	101	57.5	53.8	3.9	3.5	19.9
10	72.9	49.1	117	4	3.5	21
Average	91.4	47.1	117	3.89	3.42	19.9

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	47.2	38.3	51.3	0.8	0.6	6.9
2	59.6	20.2	116	0.8	0.7	4.2
3	173	21.3	135	0.7	0.6	4.4
4	37.8	33.1	115	0.7	0.5	5.2
5	85.1	35.3	109	0.8	0.6	8.3
6	47.8	23.2	70.6	0.8	0.6	5.4
7	78.2	37.4	61.3	0.8	0.7	5.1
8	85.9	22.7	189	0.7	0.6	4.8
9	82.4	38.8	41.8	0.8	0.6	5.5
10	54.9	30.4	105	0.8	0.7	6.5
Average	75.2	30.1	99.4	0.77	0.62	5.63

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	122	216	6.25	0	0	72.3
2	192	55.8	2.5	0	0	217
3	718	66.8	3.25	0	0	171
4	99.3	175	3.5	3.5	0.25	179
5	302	187	7.25	7.25	0	157
6	130	70.3	4.5	4.5	0	104
7	267	187	3.25	3.25	0	87.3
8	292	78.5	2.75	2.75	0	367
9	304	196	4.5	4.5	0	53
10	158	114	6.25	6.25	0	160
Average	258	135	4.4	3.2	0.03	157

Simulation Data for 20 Percent Volume Increase from WB Approach - Model Scenario S4-1

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	60.1	49.8	137	3.9	3.4	23.6
2	71	37.1	165	3.9	3.4	20.5
3	190	53.8	148	3.9	3.4	20.2
4	60.9	56.5	131	3.8	3.4	20.5
5	147	57	99.6	3.9	3.4	21.8
6	64.3	45.2	99.8	3.8	3.3	19.7
7	71	37.1	165	3.9	3.4	20.5
8	119	54.3	167	3.9	3.4	20.3
9	103	55.7	60	3.9	3.4	19.6
10	76.5	52.5	162	3.9	3.5	22.8
Average	96.2	49.9	134	3.88	3.4	21

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	42.1	31	124	0.7	0.6	9.3
2	52.8	18.5	153	0.8	0.6	6.1
3	172	35.2	136	0.8	0.6	5.7
4	42.7	37.9	119	0.7	0.6	6.1
5	129	38.4	87.6	0.8	0.6	7.3
6	46.3	26.4	87.8	0.7	0.6	5.3
7	125	34.3	85.2	0.9	0.7	5.2
8	101	35.7	155	0.8	0.6	5.8
9	84.5	37	48	0.8	0.6	5.2
10	58.4	33.8	150	0.8	0.7	8.4
Average	85.4	32.8	115	0.78	0.62	6.44

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	106	137	12	0	0	190
2	153	51.5	4.5	0	0	281
3	764	156	4.75	0	0.25	170
4	116	210	4.5	4.5	0	193
5	553	170	6.75	6.75	0	130
6	126	120	4.25	4.25	0	127
7	468	132	3.75	3.75	0	134
8	360	216	4.25	4.25	0	292
9	309	192	4	4	0	69.3
10	171	151	9.75	9.75	0	251
Average	312	153	5.85	3.73	0.03	184

Simulation Data for 30 Percent Volume Increase from WB Approach - Model Scenario S4-1

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	66.9	73.1	49	3.9	3.4	24.2
2	83.4	44.2	130	3.9	3.4	21.4
3	166	57	97.4	3.9	3.4	20.1
4	85.9	67.9	101	3.9	3.4	21.1
5	111	68.1	66.3	4	3.4	26.5
6	106	52.6	64	4	3.5	21.4
7	83.4	44.2	130	3.9	3.4	21.4
8	79.6	53.7	191	3.9	3.4	20.3
9	103	59.3	38.6	3.9	3.4	20.5
10	72.3	64.3	158	4	3.5	21.4
Average	95.7	58.4	102	3.93	3.42	21.8

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	48.9	54.4	36.8	0.8	0.6	9.9
2	65.2	25.5	118	0.7	0.6	7.1
3	148	38.4	85.3	0.8	0.6	5.7
4	67.7	49.2	89	0.8	0.6	6.8
5	92.8	49.4	54.2	0.8	0.6	12.1
6	87.9	33.9	52	0.8	0.7	6.9
7	112	68.2	54.7	1	0.8	5.2
8	61.6	35	179	0.8	0.6	6
9	84.7	40.7	26.7	0.8	0.6	6.3
10	54.2	45.6	146	0.8	0.7	7
Average	82.4	44	84.1	0.81	0.64	7.3

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	132	365	14	0	0	50.8
2	219	111	6	0	0	204
3	629	196	4.25	0	0	107
4	193	351	6.5	6.5	0	135
5	332	309	17.8	17.8	0	72.3
6	287	173	7	7	0.25	75.8
7	397	522	3.75	3.75	0	77.5
8	177	166	4.75	4.75	0	352
9	302	236	5.25	5.25	0	34.3
10	155	279	7	7	0	262
Average	282	271	7.63	5.2	0.03	137

Simulation Data for 40 Percent Volume Increase from WB Approach - Model Scenario S4-1

Travel Time

Sim No	Link No					
	EB	SB	NB	Pt1	Pt2	WB
1	52.5	85.7	69.1	3.9	3.4	23.6
2	101	49.8	94.6	4	3.4	22.3
3	186	72.1	151	3.9	3.4	22.7
4	67.9	70.9	130	3.8	3.3	23.1
5	124	67.8	116	3.9	3.5	26.3
6	82.6	52	65.3	3.9	3.4	21.5
7	101	49.8	94.6	4	3.4	22.3
8	99.9	63.9	129	3.8	3.3	22.7
9	124	82.1	66.1	4	3.4	19.6
10	125	78.8	111	4	3.5	22.1
Average	106	67.3	103	3.92	3.4	22.6

Delay

Sim No	Link No					
	EB	SB	NB	Pt1	Pt2	WB
1	34.5	67	56.9	0.8	0.6	9.3
2	83.1	31.1	82.6	0.8	0.7	7.9
3	168	53.5	139	0.8	0.6	8.2
4	49.7	52.3	118	0.7	0.6	8.8
5	106	49.1	104	0.8	0.7	12
6	64.6	33.3	53.3	0.8	0.6	7.1
7	70	83.7	44.4	0.9	0.7	6.5
8	81.9	45.3	117	0.7	0.5	8.3
9	106	63.4	54.2	0.8	0.6	5.2
10	107	60.1	99	0.8	0.6	7.7
Average	87	53.9	86.9	0.79	0.62	8.1

Queue Length

Sim No	Link No					
	EB	SB	WB	Pt1	Pt2	NB
1	87.3	590	13.3	0	0	81.8
2	308	146	7.5	0	0	131
3	706	366	9.25	0	0	176
4	134	377	11	11	0	187
5	422	337	16.5	16.5	0.5	152
6	193	164	6.25	6.25	0.25	73.5
7	229	827	5.75	5.75	0	60.3
8	264	303	8	8	0	210
9	413	461	4	4	0	70.8
10	388	472	8.25	8.25	0	153
Average	315	404	8.98	5.98	0.08	129

Simulation Data for 50 Percent Volume Increase from WB Approach - Model Scenario S4-1

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	54.1	93.9	56.6	4	3.5	23.6
2	88.2	57.4	112	3.9	3.4	21.7
3	194	73.3	70	4	3.4	20.9
4	53.1	102	60	3.9	3.4	23.9
5	97.8	87.5	121	3.9	3.4	22.5
6	70.2	75.9	82.4	3.9	3.4	21
7	88.2	57.4	112	3.9	3.4	21.7
8	102	69.2	172	3.9	3.3	21.9
9	152	80.8	73.8	4	3.5	21.7
10	116	104	104	4	3.5	22.8
Average	102	80.2	96.4	3.94	3.42	22.2

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	36.1	75.1	44.3	0.8	0.7	9.2
2	70	38.6	99.7	0.8	0.6	7.3
3	177	54.8	57.9	0.8	0.6	6.4
4	34.9	83.8	47.8	0.8	0.6	9.6
5	79.8	68.8	109	0.8	0.6	8.1
6	52.2	57.1	70.4	0.8	0.6	6.6
7	111	79	46.1	0.9	0.8	6
8	84.3	50.6	160	0.8	0.6	7.5
9	134	62.2	61.8	0.9	0.7	7.4
10	97.7	85.4	92.1	0.9	0.7	8.4
Average	87.6	65.5	78.9	0.83	0.65	7.65

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	93.3	730	11.3	0	0	64.5
2	232	216	7.5	0.25	0	165
3	778	422	7	0	0	73
4	90	889	12.8	12.8	0	70.8
5	267	697	8.75	8.75	0	164
6	147	436	6.5	6.5	0.25	111
7	388	845	5.5	5.5	0	71.5
8	299	388	8	8	0	293
9	538	586	7	7	0	87.3
10	359	843	10.5	10.5	0	139
Average	319	605	8.48	5.93	0.03	124

Simulation Data for 60 Percent Volume Increase from WB Approach - Model Scenario S4-1

Travel Time

Sim No	EB	SB	NB	Pt1	Pt2	WB
	Link No					
1	71.1	94	65.2	3.9	3.4	25.9
2	120	61.6	93.6	3.9	3.4	23.5
3	201	94.7	138	3.9	3.4	22.6
4	83.2	92.8	87.4	3.9	3.4	22.8
5	140	94	82	4	3.4	24.1
6	97.9	77.2	59.4	3.9	3.4	24.2
7	120	61.6	93.6	3.9	3.4	23.5
8	87.9	93.8	143	3.9	3.4	21.7
9	135	93.6	51.5	4	3.4	22
10	118	114	99.4	4.1	3.6	24.2
Average	118	87.7	91.3	3.94	3.42	23.5

Delay

Sim No	EB	SB	NB	Pt1	Pt2	WB
	Link No					
1	53.1	75.4	53	0.8	0.6	11.6
2	102	43	81.6	0.8	0.6	9
3	183	76.1	126	0.8	0.6	8.2
4	65.1	74.2	75.3	0.8	0.6	8.5
5	122	75.4	70	0.8	0.6	9.6
6	79.9	58.5	47.4	0.8	0.6	9.8
7	103	85.4	52.5	0.9	0.7	7.7
8	69.9	75.2	131	0.7	0.6	7.4
9	117	75	39.6	0.8	0.6	7.8
10	101	94.9	87.4	0.9	0.7	9.8
Average	99.6	73.3	76.4	0.81	0.62	8.94

Queue Length

Sim No	EB	SB	WB	Pt1	Pt2	NB
	Link No					
1	138	717	20.8	0	0	76
2	371	219	10.3	0	0	128
3	772	783	12	0	0	162
4	199	699	9.75	9.75	0	119
5	479	743	12.8	12.8	0	110
6	254	402	12.3	12.3	0	63.8
7	363	900	9.25	9.25	0	75.8
8	213	711	7.5	7.5	0	222
9	484	642	8	8	0	47.5
10	351	946	14	14	0	130
Average	362	676	11.7	7.35	0	113

Simulation Data for 70 Percent Volume Increase from WB Approach - Model Scenario S4-1

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	47.1	113	38.5	4	3.4	22.1
2	118	83.3	90.8	4	3.4	25.7
3	128	98	75.4	3.9	3.4	21.3
4	61.3	108	64.6	3.8	3.4	22.1
5	79.6	103	76.3	4	3.4	22.1
6	84	101	63	3.9	3.4	23.8
7	118	83.3	90.8	4	3.4	25.7
8	44.4	112	124	3.9	3.4	23.1
9	111	115	47.5	4	3.4	24.6
10	95.3	111	121	3.9	3.5	23.7
Average	88.7	103	79.1	3.94	3.41	23.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	29.1	93.9	26.3	0.8	0.6	7.8
2	100	64.7	78.7	0.9	0.6	11.2
3	110	79.4	63.3	0.7	0.6	6.8
4	43.1	89.2	52.5	0.7	0.6	7.7
5	61.5	84.5	64.3	0.8	0.6	7.8
6	66	82.5	51	0.8	0.6	9.4
7	73.6	93.1	22.3	0.9	0.7	8.5
8	26.3	93	112	0.8	0.6	8.7
9	93	95.9	35.6	0.8	0.6	10.2
10	77.2	92.3	109	0.8	0.6	9.3
Average	68	86.9	61.4	0.8	0.61	8.74

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	69.5	889	7.75	0	0	35.5
2	376	522	16.3	0	0	126
3	434	731	8	0	0	80.3
4	118	938	8	8	0	78.5
5	205	852	8	8	0	99.5
6	200	725	12.3	12.3	0	72.3
7	228	975	12.8	12.8	0	28.3
8	64.8	909	10.3	10.3	0	201
9	322	1031	14	14	0	45.5
10	270	950	15	15	0	168
Average	229	852	11.2	8.03	0	93.5

Simulation Data for 80 Percent Volume Increase from WB Approach - Model Scenario S4-1

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	43.6	118	41.8	3.9	3.4	23.9
2	102	100	74.9	3.9	3.4	29.9
3	161	103	42.2	3.9	3.4	22.8
4	53	109	52.3	3.9	3.3	26.5
5	160	106	77.1	3.9	3.4	26.8
6	69.1	112	63.6	3.9	3.4	24
7	102	100	74.9	3.9	3.4	29.9
8	67.7	118	59.9	3.9	3.4	27
9	119	120	46.2	4	3.4	23.8
10	65	116	52.7	4	3.5	26.3
Average	94.1	110	58.6	3.92	3.4	26.1

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	25.5	99.1	29.6	0.8	0.6	9.5
2	83.5	81.4	62.9	0.8	0.6	15.5
3	143	84.3	30	0.8	0.6	8.4
4	34.8	90.8	40.1	0.8	0.6	12.3
5	142	86.9	65	0.8	0.6	12.5
6	51.1	93.2	51.6	0.8	0.6	9.7
7	92.4	96.8	21.7	0.9	0.7	7.9
8	49.7	98.9	47.8	0.8	0.6	12.6
9	101	102	34.3	0.9	0.6	9.5
10	46.9	96.9	40.7	0.8	0.7	11.9
Average	76.9	93	42.4	0.82	0.62	11

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	60.5	920	13.5	0	0	39.3
2	296	672	26.5	0	0	97.8
3	590	863	10.5	0	0	35
4	97.8	914	17.5	17.5	0	58.5
5	555	865	23	23	0	92.3
6	148	884	13.3	13.3	0	73.5
7	319	967	9	9	0	26
8	142	919	19.5	19.5	0	71
9	382	1007	13.5	13.5	0	42.8
10	136	944	19.8	19.8	0	57
Average	272	895	16.6	11.6	0	59.3

Simulation Data for 90 Percent Volume Increase from WB Approach - Model Scenario S4-1

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	36.1	133	38.9	3.9	3.4	27.5
2	71.8	118	57.1	3.9	3.4	28.3
3	140	110	50.2	3.9	3.4	24.1
4	63	111	54.2	3.8	3.3	27
5	119	116	54.3	4	3.5	27.9
6	68.4	116	46.7	3.9	3.3	26.7
7	71.8	118	57.1	3.9	3.4	28.3
8	71.5	124	55.5	4	3.3	30.4
9	69	133	42.1	4	3.4	26.3
10	71.7	123	52.4	3.9	3.4	26.5
Average	78.2	120	50.9	3.92	3.38	27.3

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	18	115	26.7	0.7	0.6	13.2
2	53.5	99.4	45	0.8	0.6	13.9
3	122	91.8	38	0.8	0.6	9.7
4	44.7	92.7	42	0.7	0.5	12.7
5	101	97	42.2	0.8	0.7	13.5
6	50.4	97.3	34.7	0.8	0.6	12.4
7	51.7	110	23.6	0.9	0.7	9.2
8	53.4	106	43.3	0.8	0.6	16.1
9	50.9	114	30.1	0.9	0.6	12.1
10	53.6	104	40.3	0.8	0.6	12.1
Average	59.9	103	36.6	0.8	0.61	12.5

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	37.3	996	27	0	0	35.5
2	168	949	21.8	0	0	66.5
3	468	890	14.8	0	0	44
4	128	889	24.8	24.8	0	62.3
5	373	918	24	24	0	55.5
6	153	963	21	21	0	45.8
7	147	1026	12.8	12.8	0	28.5
8	162	974	33.3	33.3	0	63.5
9	161	1111	19.8	19.8	0	36.5
10	163	1003	21.8	21.8	0	55.5
Average	196	972	22.1	15.7	0	49.4

Simulation Data for 100 Percent Volume Increase from WB Approach - Model Scenario S4-1

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	43.5	137	32.7	3.9	3.3	28.1
2	64.9	124	63.8	3.9	3.4	28.7
3	104	122	52.9	3.9	3.4	25.3
4	59.2	133	45	3.9	3.3	25.6
5	121	125	55.4	3.9	3.5	28.4
6	87.5	124	37.8	3.9	3.3	29.7
7	64.9	124	63.8	3.9	3.4	28.7
8	38.6	139	49.2	3.9	3.3	26.8
9	72.6	135	32.9	4	3.4	26.1
10	52.8	143	44.9	3.9	3.4	26.4
Average	70.9	131	47.8	3.91	3.37	27.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	25.5	118	20.5	0.7	0.5	13.8
2	46.7	105	51.7	0.8	0.6	14.4
3	86.4	104	40.8	0.8	0.6	10.9
4	41	114	32.8	0.8	0.5	11.2
5	103	107	43.3	0.8	0.7	14.1
6	69.5	105	25.8	0.8	0.6	15.3
7	59.6	110	27.6	0.9	0.7	10.7
8	20.4	121	37.1	0.8	0.6	12.3
9	54.5	116	20.9	0.8	0.6	11.7
10	34.7	124	32.8	0.8	0.6	12
Average	54.1	112	33.3	0.8	0.6	12.6

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	60.5	1029	27.8	0	0	26.3
2	132	1011	26.8	0	0	83
3	321	1046	15	0	0	49.8
4	119	984	16	16	0	47.3
5	406	947	30.3	30.3	0.25	57.8
6	231	1070	28	28	0	32
7	179	981	16	16	0	36
8	47.5	1063	22.5	22.5	0	53.8
9	178	1049	19.8	19.8	0	25.5
10	96.8	1102	20.5	20.5	0	43.5
Average	177	1028	22.3	15.3	0.03	45.5

Summary of Simulation Data for Volume Increase from WB Approach - Model Scenario S4-1

Travel Time

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
0	70.8	42.7	105	3.9	3.41	19.8
10	91.4	47.1	117	3.89	3.42	19.9
20	96.2	49.9	134	3.88	3.4	21
30	95.7	58.4	102	3.93	3.42	21.8
40	106	67.3	103	3.92	3.4	22.6
50	102	80.2	96.4	3.94	3.42	22.2
60	118	87.7	91.3	3.94	3.42	23.5
70	88.7	103	79.1	3.94	3.41	23.4
80	94.1	110	58.6	3.92	3.4	26.1
90	78.2	120	50.9	3.92	3.38	27.3
100	70.9	131	47.8	3.91	3.37	27.4
Average						

Delay

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
0	54.4	24.6	91.7	0.77	0.63	5.69
10	75.2	30.1	99.4	0.77	0.62	5.63
20	85.4	32.8	115	0.78	0.62	6.44
30	82.4	44	84.1	0.81	0.64	7.3
40	87	53.9	86.9	0.79	0.62	8.1
50	87.6	65.5	78.9	0.83	0.65	7.65
60	99.6	73.3	76.4	0.81	0.62	8.94
70	68	86.9	61.4	0.8	0.61	8.74
80	76.9	93	42.4	0.82	0.62	11
90	59.9	103	36.6	0.8	0.61	12.5
100	54.1	112	33.3	0.8	0.6	12.6
Average						

Queue Length

	Link No					
Average	EB	SB	WB	Pt1	Pt2	NB
0	169	96.9	4.43	2.93	0.03	139
10	258	135	4.4	3.2	0.03	157
20	312	153	5.85	3.73	0.03	184
30	282	271	7.63	5.2	0.03	137
40	315	404	8.98	5.98	0.08	129
50	319	605	8.48	5.93	0.03	124
60	362	676	11.7	7.35	0	113
70	229	852	11.2	8.03	0	93.5
80	272	895	16.6	11.6	0	59.3
90	196	972	22.1	15.7	0	49.4
100	177	1028	22.3	15.3	0.03	45.5
Average						

APPENDIX 6: RESULTS FOR S4-2 SIMULATION SCENARIO

Simulation Data for 0 Percent Volume Increase from WB Approach - Model Scenario S4-2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	79.4	54.6	67.7	3.9	3.4	21.2
2	78.9	45.7	95.6	3.8	3.3	19.8
3	181	45	90.6	3.8	3.4	19.5
4	68.6	53.1	139	3.8	3.5	19.7
5	157	49.5	60.6	3.9	3.4	20.8
6	63.1	39.1	80.1	3.9	3.4	19.8
7	78.9	45.7	95.6	3.8	3.3	19.8
8	109	54.2	175	3.9	3.4	19.9
9	90.1	51	51.4	3.9	3.4	18.8
10	90.1	51	51.4	3.9	3.4	18.8
Average	99.6	48.9	90.7	3.86	3.39	19.8

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	61.4	35.8	55.4	0.8	0.6	6.9
2	60.7	27	83.5	0.7	0.6	5.3
3	163	26.3	78.5	0.7	0.6	5.1
4	50.4	34.4	127	0.7	0.7	5.4
5	139	30.8	48.5	0.8	0.7	6.3
6	45.1	20.3	68.1	0.8	0.6	5.3
7	115	37.9	105	0.9	0.8	5.2
8	91	35.5	163	0.8	0.6	5.5
9	72	32.3	39.5	0.8	0.6	4.5
10	53.4	40.9	134	0.8	0.7	5.5
Average	85.1	32.1	90.2	0.78	0.65	5.5

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	172	212	6.25	0	0	81
2	204	111	4.25	0	0	135
3	680	108	5.5	0	0	95.8
4	136	199	4	4	0	199
5	602	146	5.75	5.75	0	64.3
6	122	51	4.5	4.5	0	96.5
7	395	196	4	4	0	155
8	297	214	3.75	3.75	0	312
9	239	140	3	3	0	55.5
10	154	235	4.5	4.5	0.25	229
Average	300	161	4.55	2.95	0.03	142

Simulation Data for 10 Percent Volume Increase from WB Approach - Model Scenario S4-2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	87.1	72.7	64.1	3.9	3.4	23.1
2	75.6	36.9	158	3.9	3.5	20.8
3	207	45.6	190	3.9	3.4	19.5
4	76.8	52.2	99.7	3.8	3.4	20.9
5	149	77.4	96.4	4	3.4	19.8
6	64.9	44.8	66.8	3.8	3.4	20.4
7	75.6	36.9	158	3.9	3.5	20.8
8	82.5	56.8	193	3.9	3.4	20.9
9	113	61.5	75.4	4	3.5	18.7
10	86.2	52	126	3.9	3.5	20.3
Average	102	53.7	123	3.9	3.44	20.5

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	69.1	53.9	51.9	0.8	0.6	8.8
2	57.4	18.1	146	0.8	0.7	6.4
3	189	27	178	0.8	0.6	5.1
4	58.6	33.6	87.6	0.7	0.6	6.5
5	131	58.8	84.4	0.8	0.7	5.4
6	46.9	26.1	54.8	0.7	0.6	6.1
7	134	59.2	54.4	0.9	0.7	4.3
8	64.5	38.2	181	0.7	0.6	6.5
9	94.8	42.9	63.4	0.9	0.7	4.4
10	68.2	33.3	114	0.7	0.6	5.9
Average	91.4	39.1	102	0.78	0.64	5.94

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	210	362	11.8	0	0	72
2	182	50.3	5.75	0	0	251
3	821	83.8	4.5	0	0	226
4	162	171	5	5	0	136
5	555	490	4	4	0	132
6	126	107	4.75	4.75	0	77
7	512	385	3.25	3.25	0	83.3
8	185	206	5.75	5.75	0.25	353
9	348	223	3	3	0	86
10	204	169	4.75	4.75	0	177
Average	330	225	5.25	3.05	0.03	159

Simulation Data for 20 Percent Volume Increase from WB Approach - Model Scenario S4-2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	79.6	78.3	65.4	3.9	3.4	23.6
2	112	61.2	132	4	3.5	20
3	217	78.4	119	4	3.4	23
4	95.5	64.6	152	3.8	3.4	20.4
5	213	85.5	68.5	3.9	3.4	22.1
6	113	58.7	57	3.9	3.5	23.2
7	112	61.2	132	4	3.5	20
8	112	69.4	203	3.9	3.4	20.2
9	195	71.9	58.1	4	3.4	20.2
10	184	67.7	201	3.9	3.4	20.5
Average	143	69.7	119	3.93	3.43	21.3

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	61.7	59.5	53.2	0.7	0.6	9.3
2	93.6	42.6	120	0.8	0.7	5.5
3	199	59.8	107	0.9	0.7	8.7
4	77.3	46	139	0.7	0.6	6.1
5	195	66.9	56.4	0.8	0.6	7.7
6	95.1	39.9	44.9	0.8	0.7	8.9
7	132	60.3	57.1	0.9	0.7	8.3
8	93.7	50.8	191	0.8	0.6	5.9
9	177	53.2	46.2	0.8	0.6	6
10	166	49	189	0.8	0.6	6.2
Average	129	52.8	100	0.8	0.64	7.26

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	188	547	12	0	0	76.8
2	321	208	4.75	0	0	206
3	921	426	10.3	0	0	138
4	227	308	5	5	0	227
5	826	533	9.25	9.25	0	80.5
6	317	210	10.8	10.8	0	59.8
7	498	351	9	9	0	81.8
8	309	367	5	5	0	399
9	716	382	5.25	5.25	0	59.3
10	632	419	5.75	5.75	0	342
Average	495	375	7.7	5	0	167

Simulation Data for 30 Percent Volume Increase from WB Approach - Model Scenario S4-2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	80.9	90.3	55.3	3.9	3.4	25.1
2	152	70.3	159	3.9	3.4	21
3	208	95	75.6	4	3.4	22.5
4	71.6	104	119	3.8	3.3	20.5
5	107	94.8	94.6	3.9	3.4	24.8
6	130	71.6	64.9	4	3.4	21.6
7	152	70.3	159	3.9	3.4	21
8	176	68.3	159	4	3.4	22.2
9	214	85.6	53.5	3.9	3.4	21.4
10	148	93.9	115	4	3.4	24.5
Average	144	84.4	105	3.93	3.39	22.5

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	62.9	71.6	43	0.8	0.6	10.8
2	134	51.6	147	0.8	0.6	6.5
3	190	76.4	63.5	0.8	0.6	8
4	53.4	84.9	107	0.7	0.5	6.2
5	89.2	76.1	82.5	0.8	0.6	10.5
6	112	52.9	53	0.8	0.6	7.2
7	153	85.2	30.7	0.9	0.7	6.9
8	158	49.7	147	0.8	0.6	7.7
9	196	66.9	41.6	0.8	0.6	6.9
10	130	75.2	103	0.8	0.6	10.2
Average	128	69.1	81.8	0.8	0.6	8.09

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	182	666	16	0	0	59
2	495	362	6.25	0	0	253
3	810	736	10.8	0	0	81.5
4	146	828	5.75	5.75	0	172
5	328	693	15.5	15.5	0	121
6	414	344	7	7	0	73.3
7	581	915	8.25	8.25	0	40.3
8	581	325	8.5	8.5	0	273
9	902	571	7	7	0	53.3
10	462	763	15.3	15.3	0	160
Average	490	620	10	6.73	0	129

Simulation Data for 40 Percent Volume Increase from WB Approach - Model Scenario S4-2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	147	101	42.6	3.9	3.4	25.5
2	137	93.5	95.9	3.9	3.4	24.5
3	232	103	77.7	4	3.4	23.3
4	103	98	75.3	3.8	3.4	22.1
5	163	112	64.1	3.9	3.4	24.4
6	134	106	61.5	3.9	3.4	24.6
7	137	93.5	95.9	3.9	3.4	24.5
8	151	94.5	95.9	3.9	3.4	28.4
9	213	113	51.1	4	3.4	24.8
10	177	103	139	3.9	3.4	24.6
Average	159	102	79.9	3.91	3.4	24.7

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	129	82.1	30.4	0.8	0.6	11.1
2	118	74.9	83.8	0.8	0.6	10
3	214	84.6	65.6	0.8	0.6	8.8
4	84.9	79.4	63.2	0.7	0.6	7.8
5	145	93.6	52	0.8	0.6	10.1
6	116	87	49.5	0.8	0.6	10.1
7	172	87.5	44.3	1	0.7	7.8
8	133	75.9	83.8	0.8	0.6	14
9	195	94.3	39.1	0.8	0.6	10.4
10	159	83.9	127	0.8	0.6	10.1
Average	147	84.3	63.9	0.81	0.61	10

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	401	826	18	0	0	41
2	415	656	15.5	0	0	135
3	970	823	12	0	0	85.8
4	272	780	8.5	8.5	0	99.5
5	637	880	15	15	0	68.8
6	431	843	13.8	13.8	0	68.3
7	635	806	9.25	9.25	0	65.3
8	495	733	30.5	30.5	0	142
9	818	962	15.5	15.5	0	48.8
10	608	777	13.8	13.8	0	200
Average	568	808	15.2	10.6	0	95.4

Simulation Data for 50 Percent Volume Increase from WB Approach - Model Scenario S4-2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	86.6	115	54.6	4	3.4	34.5
2	170	113	89.1	3.9	3.4	25.7
3	177	121	73.8	3.9	3.4	24.4
4	78	116	53.1	3.8	3.3	23.6
5	192	116	54.2	3.9	3.4	29.6
6	128	116	45.9	3.9	3.4	28.2
7	170	113	89.1	3.9	3.4	25.7
8	119	119	64	3.8	3.3	25.4
9	171	120	45.8	4	3.4	22.8
10	105	130	76.8	4	3.5	25.7
Average	140	118	64.6	3.91	3.39	26.6

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	68.6	96.5	42.3	0.8	0.6	20.2
2	152	94.1	77.1	0.7	0.6	11.3
3	159	103	61.6	0.8	0.6	9.9
4	59.8	97.6	41	0.8	0.5	9.4
5	174	97.6	42.1	0.8	0.6	15.2
6	110	97.7	33.8	0.8	0.6	13.9
7	119	100	52.5	0.9	0.7	9.5
8	101	101	51.9	0.8	0.6	11.1
9	153	102	33.8	0.9	0.6	8.5
10	86.6	112	64.8	0.8	0.7	11.4
Average	118	100	50.1	0.81	0.61	12

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	200	926	60.3	0	0	59.3
2	573	930	15.8	0	0	128
3	633	1001	15.3	0	0	77.8
4	164	956	13	13	0	59.3
5	728	922	34.8	34.8	0	58.5
6	396	981	28	28	0	45.5
7	437	936	12	12	0	86
8	339	887	17	17	0	75.8
9	638	1017	8.75	8.75	0	42
10	332	1042	21.5	21.5	0	98.5
Average	444	960	22.6	13.5	0	73.1

Simulation Data for 60 Percent Volume Increase from WB Approach - Model Scenario S4-2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	78.3	143	36.9	4	3.4	27.5
2	146	131	61.6	3.9	3.4	29.9
3	146	138	37.1	3.9	3.4	28
4	87.5	123	45.4	3.8	3.3	26
5	218	123	51.2	3.9	3.4	25.9
6	126	129	43.8	3.9	3.4	25.3
7	146	131	61.6	3.9	3.4	29.9
8	128	127	41.5	3.9	3.3	25.6
9	206	126	37.4	3.9	3.4	25.1
10	137	132	68.2	4	3.5	28.9
Average	142	130	48.5	3.91	3.39	27.2

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	60.3	124	24.6	0.8	0.6	13.1
2	128	112	49.5	0.8	0.6	15.6
3	128	119	25	0.8	0.6	13.5
4	69.3	105	33.2	0.7	0.5	11.7
5	200	104	39.1	0.8	0.6	11.5
6	108	110	31.8	0.8	0.6	10.8
7	142	110	35.3	0.8	0.6	11.3
8	110	108	29.3	0.8	0.5	11.2
9	188	108	25.4	0.8	0.6	10.8
10	119	113	56.2	0.8	0.7	14.6
Average	125	111	34.9	0.79	0.59	12.4

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	161	1013	23	0	0	32.5
2	488	1039	36.3	0	0	77.5
3	532	1061	25.8	0	0	28.8
4	205	1013	21.3	21.3	0	49.8
5	850	919	19.5	19.5	0	52.3
6	415	1081	16.8	16.8	0	43.5
7	542	979	15.8	15.8	0	48
8	409	972	18	18	0	40.8
9	830	1069	18.5	18.5	0	29.5
10	423	1016	27.8	27.8	0	82.8
Average	485	1016	22.3	13.8	0	48.5

Simulation Data for 70 Percent Volume Increase from WB Approach - Model Scenario S4-2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	115	150	38.8	3.9	3.4	34.1
2	89.6	139	50.6	4	3.5	35.4
3	234	136	53.7	3.9	3.4	26.7
4	82.4	143	42.2	3.9	3.3	31.9
5	191	133	38.8	3.9	3.4	29.3
6	90.7	146	35.9	3.8	3.4	24.8
7	89.6	139	50.6	4	3.5	35.4
8	127	142	67.5	3.9	3.4	28.9
9	209	138	30.4	3.9	3.4	26.8
10	103	147	46.1	4	3.5	30.9
Average	133	141	45.5	3.92	3.42	30.4

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	97.3	131	26.6	0.7	0.6	19.7
2	71.4	120	38.5	0.9	0.6	21
3	217	117	41.6	0.8	0.6	12.3
4	64.2	125	30	0.8	0.6	17.7
5	173	115	26.6	0.8	0.6	15
6	72.7	127	23.9	0.7	0.6	10.5
7	145	123	20.3	0.8	0.7	14.4
8	109	123	55.4	0.8	0.6	14.6
9	191	119	18.4	0.8	0.6	12.5
10	84.6	128	34	0.8	0.6	16.5
Average	123	123	31.5	0.79	0.61	15.4

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	287	1074	65	0	0	35.3
2	247	1077	60.8	0	0	58
3	966	1049	21	0	0	51.3
4	187	1034	43	43	0	44
5	707	1010	29	29	0	34.3
6	235	1128	15.5	15.5	0	30
7	551	1061	29.5	29.5	0	25.3
8	361	1063	34	34	0	84.8
9	843	1113	26	26	0	22.8
10	318	1097	40.5	40.5	0	46.3
Average	470	1070	36.4	21.8	0	43.2

Simulation Data for 80 Percent Volume Increase from WB Approach - Model Scenario S4-2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	68.5	169	32.5	3.9	3.4	37.1
2	123	151	36.6	3.9	3.4	41.1
3	207	149	36	3.8	3.4	31.7
4	96.7	158	39.9	3.9	3.4	32.5
5	232	146	36.3	4	3.5	32.4
6	77.2	160	41.2	3.9	3.4	29.3
7	123	151	36.6	3.9	3.4	41.1
8	67.8	160	43.8	3.9	3.4	31.6
9	193	147	38.7	4	3.4	28.7
10	138	155	40.5	3.9	3.4	29.4
Average	133	155	38.2	3.91	3.41	33.5

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	50.5	150	20.2	0.8	0.6	22.7
2	105	132	24.5	0.8	0.6	26.7
3	190	130	23.8	0.7	0.6	17.3
4	78.5	140	27.7	0.8	0.6	18.3
5	214	127	24.2	0.8	0.7	18.1
6	59.2	141	29.2	0.8	0.6	14.9
7	108	134	16.2	0.8	0.7	15.4
8	49.7	142	31.7	0.8	0.6	17.3
9	175	128	26.7	0.8	0.6	14.4
10	120	136	28.4	0.8	0.6	15
Average	115	136	25.3	0.79	0.62	18

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	136	1127	82.8	0	0	26.3
2	391	1092	106	0	0	33
3	807	1089	40.5	0	0	27.3
4	232	1062	46	46	0	40.5
5	942	1038	48.3	48.3	0.25	30.5
6	170	1137	32.5	32.5	0	37.3
7	374	1089	31.5	31.5	0	18.8
8	139	1093	41.3	41.3	0	46.5
9	776	1137	33.3	33.3	0	33
10	433	1133	32.3	32.3	0	37.8
Average	440	1100	49.4	26.5	0.03	33.1

Simulation Data for 90 Percent Volume Increase from WB Approach - Model Scenario S4-2

Travel Time

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	93.9	173	35.6	4	3.4	39.6
2	90.6	173	29	4	3.5	33.1
3	217	166	32.3	3.9	3.4	36.8
4	80.1	173	37.2	3.8	3.3	36.7
5	187	162	34.9	3.9	3.4	36.7
6	93.9	167	28.8	3.9	3.4	30.6
7	90.6	173	29	4	3.5	33.1
8	64.2	170	38.3	4	3.3	36.8
9	214	158	31.7	3.9	3.4	31.9
10	127	167	30.5	4	3.5	34.9
Average	126	168	32.7	3.94	3.41	35

Delay

	Link No					
Sim No	EB	SB	NB	Pt1	Pt2	WB
1	76	154	23.3	0.8	0.6	25.3
2	72.5	154	16.9	0.9	0.7	18.7
3	200	148	20.2	0.8	0.6	22.5
4	61.8	155	25	0.7	0.5	22.4
5	169	144	22.7	0.8	0.6	22.4
6	75.9	149	16.7	0.8	0.6	16.3
7	78	162	17	0.8	0.6	18.2
8	46.2	151	26.1	0.8	0.6	22.4
9	196	139	19.8	0.8	0.6	17.6
10	109	148	18.4	0.8	0.6	20.6
Average	108	150	20.6	0.8	0.6	20.6

Queue Length

	Link No					
Sim No	EB	SB	WB	Pt1	Pt2	NB
1	218	1118	87	0	0	30.8
2	231	1151	48.3	0	0	22.5
3	871	1124	77	0	0	23
4	188	1093	62.3	62.3	0	35.3
5	709	1086	77.5	77.5	0	28.3
6	244	1151	33	33	0	19.8
7	237	1122	45	45	0	20.8
8	129	1112	66.5	66.5	0	40.8
9	818	1113	44	44	0	22.8
10	382	1144	53.8	53.8	0	22.5
Average	403	1121	59.4	38.2	0	26.6

Simulation Data for 100 Percent Volume Increase from WB Approach - Model Scenario S4-2

Travel Time

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	67.7	188	29	3.9	3.4	52.4
2	122	182	29.2	3.9	3.5	40.4
3	237	179	32.9	3.9	3.4	40.2
4	89.8	188	29.6	3.8	3.3	34.5
5	241	177	29.5	3.9	3.4	30.6
6	108	180	33.2	3.8	3.4	37.4
7	122	182	29.2	3.9	3.5	40.4
8	105	172	35.1	3.9	3.3	41
9	263	170	27.7	3.9	3.4	30.9
10	88.5	191	36	3.9	3.4	40.5
Average	144	181	31.1	3.88	3.4	38.8

Delay

Sim No	Link No EB	SB	NB	Pt1	Pt2	WB
1	49.7	169	16.8	0.7	0.6	38
2	104	164	17.1	0.8	0.7	26
3	219	160	20.7	0.8	0.6	25.8
4	71.7	170	17.4	0.7	0.5	20.1
5	223	158	17.3	0.8	0.6	16.3
6	89.5	162	21.1	0.7	0.6	23.1
7	114	159	21.5	0.8	0.6	27.8
8	87.3	154	23	0.8	0.6	26.7
9	245	152	15.7	0.8	0.6	16.5
10	70.4	173	23.9	0.8	0.6	26.1
Average	127	162	19.5	0.77	0.6	24.6

Queue Length

Sim No	Link No EB	SB	WB	Pt1	Pt2	NB
1	131	1124	257	0	0	21.5
2	371	1140	82	0	0	22
3	997	1121	90.8	0	0	22.8
4	229	1133	59.5	59.5	0	23
5	949	1104	390	390	6.5	121
6	327	1158	92.8	92.8	0	26
7	411	1117	108	108	0	26.3
8	296	1113	85.3	85.3	0	31.5
9	1180	1151	40	40	0	16.8
10	254	1176	85.5	85.5	0	31.5
Average	514	1134	129	86.1	0.65	34.3

Summary of Simulation Data for Volume Increase from WB Approach - Model Scenario S4-2

Travel Time

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
0	99.6	48.9	90.7	3.86	3.39	19.8
10	102	53.7	123	3.9	3.44	20.5
20	143	69.7	119	3.93	3.43	21.3
30	144	84.4	105	3.93	3.39	22.5
40	159	102	79.9	3.91	3.4	24.7
50	140	118	64.6	3.91	3.39	26.6
60	142	130	48.5	3.91	3.39	27.2
70	133	141	45.5	3.92	3.42	30.4
80	133	155	38.2	3.91	3.41	33.5
90	126	168	32.7	3.94	3.41	35
100	144	181	31.1	3.88	3.4	38.8
Average						

Delay

	Link No					
Average	EB	SB	NB	Pt1	Pt2	WB
0	85.1	32.1	90.2	0.78	0.65	5.5
10	91.4	39.1	102	0.78	0.64	5.94
20	129	52.8	100	0.8	0.64	7.26
30	128	69.1	81.8	0.8	0.6	8.09
40	147	84.3	63.9	0.81	0.61	10
50	118	100	50.1	0.81	0.61	12
60	125	111	34.9	0.79	0.59	12.4
70	123	123	31.5	0.79	0.61	15.4
80	115	136	25.3	0.79	0.62	18
90	108	150	20.6	0.8	0.6	20.6
100	127	162	19.5	0.77	0.6	24.6
Average						

Queue Length

	Link No					
Average	EB	SB	WB	Pt1	Pt2	NB
0	300	161	4.55	2.95	0.03	142
10	330	225	5.25	3.05	0.03	159
20	495	375	7.7	5	0	167
30	490	620	10	6.73	0	129
40	568	808	15.2	10.6	0	95.4
50	444	960	22.6	13.5	0	73.1
60	485	1016	22.3	13.8	0	48.5
70	470	1070	36.4	21.8	0	43.2
80	440	1100	49.4	26.5	0.03	33.1
90	403	1121	59.4	38.2	0	26.6
100	514	1134	129	86.1	0.65	34.3
Average						