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16. Abstract <p>This report summarizes the state-of-the-art and state-of-the-practice in queue length modeling through a literature search and survey of traffic engineering practitioners. The report also describes the selection and evaluation of four alternative software packages for modeling queue length at signalized intersections in New Mexico. Output from the four models (HCS+, SimTraffic, Synchro, and TEAPAC) was compared to maximum observed queues obtained from camera data at selected intersections. Data analysis involved determining both the percent error, and the actual difference, in number of vehicles, between model output and the observed queues. In general, both HCS+ and TEAPAC underestimated queue lengths for those approaches with low v/c ratios and overestimated it for those approaches with high v/c ratios. Synchro, on the other hand, calculated values that were, in most cases, lower than observed queues, with little variation across a range of v/c values. SimTraffic, particularly when calibrated using 95th percentile volumes and simulated for a time period approximately equal to the signal cycle length, most closely matched observed queues. Most simulated values, moreover, were somewhat over-estimated by SimTraffic, a more preferable situation than an under-estimate.</p>			
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PREFACE

The research reported herein documents a survey and analysis of the state-of-the-art and state-of-the-practice of queue length modeling. It describes the selection and application of candidate models applied to New Mexico and the implementation of the research results.

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CHAPTER 1: INTRODUCTION

1.1 Overview

This Final Report for NMDOT Project Number NM09DSN-01, Queue Length Modeling, covers the period from the effective contract execution date of March 24, 2009 through the completion of project activities on January 31, 2011. In conformance with the requirements specified in the Department's "*Information and Instructions for Preparing Proposals in the NMDOT Transportation Program*," (the "*Manual*") and as specified in Contract No. CO5248, the report documents all of the activities described in the Scope of Work, including the survey and analysis of the state-of-the-art and -practice of queue length modeling, the analysis and selection of candidate models applicable to New Mexico, and the implementation of the research results. These activities are detailed in subsequent sections of the report and in the accompanying appendices. The report is also accompanied by a multi-media presentation in electronic form and on CD.

1.2 Background

Queues are formed in traffic streams when demand exceeds the capacity of the facility during some given time period. Excess vehicles are stored upstream of the bottleneck location and vehicles are discharged from the queue at a reduced service rate over an extended time period. Numerous highway system examples of queueing exist including at both signalized and unsignalized intersections, at toll plazas, prior to work zone locations, and at both recurring and non-recurring incident sites. Analytical techniques for studying such processes include both shock wave analysis and more traditional queueing analysis, either deterministic or stochastic (1). The formation of queues is a considerable source of travel time delays; it has been estimated that, under extreme conditions, delays caused by queueing can account for over 90 percent of a motorist's total travel time (2).

Various types of queueing models – ad hoc (rule of thumb) vs. deterministic vs. stochastic - and numerous assumptions relating to vehicle arrivals (uniform vs. random vs. Poisson) have been developed to study the formation and dissipation of traffic queues and to provide estimates of both travel time delay and queue length. Output from these models is essential both in evaluating overall system performance and in addressing design (required left turn bay lengths, number of intersection lanes) and operational (traffic signal timing) issues at intersections.

1.3 Research Objectives

The objectives of this project are to develop a methodology for estimating queue length which is both legally defensible and empirically verifiable. This procedure can then be incorporated into the State's Access Management Manual and used on all projects resulting in both reduced costs and improved safety performance. Data management and implementation plans for the methodology will be developed and training of State personnel in use of the methodology will be provided.

1.4 Report Outline

The remainder of this report describes both published technical guidance and the research literature on queue length modeling in Chapter 2. Chapter 3 summarizes the results of a survey of state DOT and local agency personnel regarding agency policy and practice on queue length modeling. Results of this survey are used in the selection of procedures for applicability in New Mexico as described in Chapter 4.

Chapters 5 and 6 describe the local data collection procedures and the analysis of alternative model applications, respectively. Finally, Chapter 7 presents the conclusions and recommendations of the report. Chapter 7 also discusses the implementation plan and suggested training procedures.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Anecdotal evidence suggests that queue length calculations consistently underestimate actual queue lengths observed in the field. This commonly results in unacceptable congestion as vehicles back up into driveways and adjacent intersections. Significant safety issues may also result when, for example, queues of left-turning vehicles back up into through lanes because of insufficient left turn bay storage.

This chapter will summarize both current technical practice in estimating queue lengths as well as the published research literature comparing various approaches.

2.2 Published Technical Practices

A literature review to identify recent research on queue length models and calculation methods was undertaken utilizing online sources maintained by the Transportation Research Board and the Bureau of Transportation Statistics of the US Department of Transportation as well as the more general on-line search engines such as Google. Reported results range from rule-of-thumb methods mentioned in several state design manuals to determine left-turn lengths (the focus of almost all early literature), to more analytical procedures to estimate queue lengths such as those described in the Highway Capacity Manual and the more recent simulation-based approaches (to be described subsequently).

An early NCHRP Report (3) concerned with driveways being blocked by vehicles queued at signalized intersections developed tabulations of the probability of blockage as a function of adjacent lane volume, red signal phase duration, and distance from the stop bar to the driveway location. Although not directly related to the issue of left turn bay length, these results illustrate the effects of phase lengths on intersection queueing.

C.J. Messer et. al., (4) describe a procedure, later summarized in Appendix I of the Signalized Intersection Chapter of the 1985 Highway Capacity Manual, which provides a method for estimating the storage length of an exclusive left-turn bay as a function of the arriving left turn volume, the signal cycle length (C), and the v/c ratio. The procedure, based on random arrivals and a 5 percent probability of bay overflow, provides a graph to calculate a storage length for a given C and v/c and adjustment factors for a range of other values of C and v/c. Typical values suggest lengths capable of storing 1.5 to 2.0 times the average number of left turn arrivals expected per cycle. Low cycle length maximums (100 seconds) may limit this approach for current intersection timing plans.

The rule-of-thumb suggested above has been referenced in a number of state highway design manuals. Massachusetts, for example, states that “. . . a conservative guideline for determining the storage length of a left-turn lane is 150 percent (1.5 times) of the length of the average number of left-turning vehicles arriving during a single signal cycle in the peak hour” (5). The California Department of Transportation (CALTRANS) suggests that “At signalized

intersections, the storage length may be based on one and one half to two times the average number of vehicles that would store per signal cycle depending on cycle length, signal phasing, and arrival and departure rates,” (6). Finally, the Texas Manual, while applying the same 2.0 rule-of-thumb described above, adjusts the length based on truck percentages – 25 feet per vehicle for less than 5% trucks to 40 feet per vehicle for greater than 15% trucks (7).

National publications also refer to such ad-hoc approaches to queue length estimation. The AASHTO “Green Book” (8), for example, states that “. . . the storage length is a function of the probability of occurrence of events and should usually be based on one and one-half to two times the average number of vehicles that would store per cycle, which is predicated on the design volume. This length will be sufficient to serve heavy surges that occur from time to time.”

A thorough discussion of other “rule-of-thumb” applications may be found in “Left Turn Bays,” prepared for the Oregon Department of Transportation by the Transportation Research Institute at Oregon State University, Corvallis, OR (9). One such method estimates storage length as equal to one foot of length per each vehicle turning left during the peak hour.

In fairness to the above discussion, both Massachusetts and Texas suggest that a more analytical guideline to determine storage length is to employ the procedures in the more recent versions of the HCS software or in simulation models (Synchro/SimTraffic is mentioned in both guides).

Many of the ad-hoc methods described above have their basis in the assumption that the left turn arrivals follow a Poisson distribution, which is used to estimate the statistical probabilities of randomly occurring events. Use of the Poisson equation requires a determination of the average number of left-turn arrivals during a specified time period (such as a signal cycle length). Various probabilities may then be calculated as follows:

$$P(X) = e^{-m} m^X / X!$$

Where: $P(X)$ = probability of exactly X left-turning vehicles,
 m = average number of left-turning vehicles per cycle,
 $X = 0, 1, 2, \dots$,
 e = Napierian base of logarithms (2.71828. . .).

This Poisson-based approach, along with additional modifications, has previously been utilized by the City of Albuquerque and some of its consultants to estimate left-turn storage length requirements (10, 11). These procedures compute the average number of left-turning vehicles per cycle described above, calculate the probability of a specific number of vehicles using the Poisson equation, and select the storage length required when the probability reaches a predetermined percentage (usually 95 percent, meaning that there is only a 5 percent chance that a length exceeding this amount will be required). Reference 11 further refines the calculation based on a percentage of vehicles arriving on the red phase of the cycle. Both procedures will be illustrated in a subsequent section of the report to compare with other models.

The assumption of Poisson arrivals was also utilized in an early simulation model developed by Oppenlander and Oppenlander (12). Median, 85th, and 95th percentile values of storage length as a function of cycle length, lane volume, and effective green are provided in a series of tables.

2.3 Recent Research Literature

More recently, several different methods to calculate and model queue length requirements have become available to the analyst. These procedures include both analytical approaches, such as described in the Highway Capacity Manual (HCM) (13) and the SIGNAL2000/TEAPAC software developed by Strong Concepts (14), and advanced simulation models, such as SimTraffic (15) and CORSIM (16). Model results may be difficult to compare, however, because of different definitions and terminology described in the model output. At least four definitions are used, as described below:

Maximum queue length – the number of vehicles in a queue at the beginning of a green phase,

Average queue length – the average length of a queue based on estimates over some time interval,

Average maximum queue length – the average of maximum queue lengths over a number of cycles,

Maximum back-of-queue – the number of vehicles in the queue, including those that enter the queue after the start of the green phase (17).

The following sections will discuss each procedure, including the definitions and terminology used; a comparison of available procedures will then be made.

2.3.1 HCM Procedure

Appendix G of Chapter 16 of the 2000 Highway Capacity Manual describes a procedure to calculate back-of-queue at signalized intersections. Back-of-queue is defined as the number of vehicles that are queued as a function of the vehicle arrival pattern and any overflow vehicles from a previous signal phase. Average back-of-queue and 70th, 85th, 90th, 95th, and 98th percentile back-of-queue values are computed for an individual lane on a given approach. First term queued vehicles (assuming uniform arrivals, adjusted for progression) and second term queued vehicles (an increment to account for flow randomness and overflow) are summed to calculate the maximum distance (in vehicles) over which the queue extends from the stop line for an average signal cycle length. Percentile back-of-queue values are calculated by applying empirically-developed factors based on signal type (pretimed vs. actuated) to the average value described above. Finally, a queue storage ratio, comparing average queue length to available storage distance is calculated to determine if blockage may occur.

The Queue Length Calculation in the HCM is described as follows (13):

Average back of queue calculation

$$Q = Q_1 + Q_2$$

Q = maximum back of queue on an average signal cycle (veh)

Q_1 = average back of queue assuming uniform arrival and then adjusting for the effects of progression (veh)

Q_2 = incremental term due to randomness and cycle failures (veh)

$$Q_1 = PF_2 * \frac{(v_L C / 3600) \left(\frac{g}{C} \right)}{1 - \min \left(0, X_L \right) * \frac{g}{C}}$$

Q_1 = number of vehicles that arrive during the red phases and during the green phase until the queue has dissipated

PF_2 = adjustment factors for effects of progression

v_L = lane group flow rate lane (veh /h)

C = cycle length (s)

g = effective green time (s)

X_L = ratio of flow rate to capacity

$$PF_2 = \frac{\left(1 - Rp \frac{g}{C} \right) \left(1 - \frac{v_L}{s_L} \right)}{\left(1 - \frac{g}{C} \right) \left[1 - Rp \left(\frac{v_L}{s_L} \right) \right]}$$

PF_2 = adjustment factor for effects of progression

v_L = lane group flow rate lane (veh /h)

s_L = lane group saturation flow rate per lane (veh/h)

C = cycle length (s)

g = effective green time (s)

R_p = platoon ratio $P(C/g)$

$$Q_2 = 0.25c_L T \left[\left(\frac{X_L}{c_L T} - 1 \right) + \sqrt{\left(\frac{X_L}{c_L T} - 1 \right)^2 + \frac{8k_B X_L}{c_L T} + \frac{16k_B Q_{bL}}{c_L T}} \right]$$

Q_2 = average overflow queue (veh)

c_L = lane group capacity per lane

T = length of analysis period (h)

X_L = flow rate to capacity ratio

Q_{bL} = initial queue at start of analysis period (veh)

C = cycle length

k_B = adjustment factor for early arrivals

$$k_B = 0.12 I \left(\frac{s_L g}{3600} \right)^{0.7} \quad \text{for pretimed signals}$$

$$k_B = 0.10 I \left(\frac{s_L g}{3600} \right)^{0.6} \quad \text{for actuated signals}$$

I = upstream metering for platoon arrivals

Percentile back of queue

The percentile back of queue is estimated by applying the percentile back of queue factor to the average back of queue.

$$Q_{\%} = Q f_{B\%}$$

$Q_{\%}$ = percentile back of queue (veh)

Q = average back of queue (veh)

$f_{B\%}$ = percentile back of queue factor

$$f_{B\%} = p_1 + p_2 e^{-Q/p_3}$$

p_1 , p_2 and p_3 values are dependent on the type of signal control and percentile values.

The HCM appendix provides table look-up values and a worksheet to perform back-of-queue calculations; the Highway Capacity Software (HCS+) automates this process. The appendix also suggests that values produced by its procedure may be larger than those produced by other methods, particularly for high degrees of saturation or for high percentile values. It is suggested that this may be due to both other methods only reporting average values and to the non-consideration of overflow values in many of the other procedures.

2.3.2 HCM2000/TEAPAC

TEAPAC Complete, Version 8.0 is the latest release from Strong Concepts of a suite of programs, first developed in 1974, which perform a variety of traffic and transportation analysis and design tasks. Included in the package is HCM2000 (previously SIGNAL2000) which performs the same capacity analysis as the Signalized Intersection module in the HCM and thus, should produce the same results. The developer of the TEAPAC software, however, suggests that different results may, in fact, be obtained, particularly under certain scenarios, such as queue length calculations for a protected-permitted left turn. Thus:

HCS will underestimate the queue length, as follows. The green time used in the calculations is the entire green time for both the protected and permitted phases, as it should be, but the saturation flow rate used is the rate determined for the protected phase only. This causes the queue model to release vehicles during the permitted phase at a rate usually much higher than the saturation flow determined for the permitted phase, thus reducing the maximum extent of the back of queue. Since the queue model is founded on a single period of green display, a more appropriate result would be achieved by calculating the average saturation flow rate during the combined protected-permitted green time and using this in the calculations (this is equivalent in concept to the averaging method for saturation flow determination for the various green portions of a permitted phase in the Appendix). This is the method followed by the SIGNAL2000 program (17).

HCM2000 computes maximum queue length (MQL) according to standard queueing theory also called the 'red time formula'. Maximum queue length is calculated as below:

$$Q_n = 2.0 * q * r / N$$

Q_n = number of vehicles in queue per lane

2.0 = 90th percentile randomness factor (Poisson distribution estimate)

q = arrival rate (vehicles per second) $v/3600$

r = adjusted volume (vph)

N = number of lanes in lane group

For over saturated conditions ($v/c > 1$), the queue length is calculated as follows:

$$Q_n = \left[2.0 * q * r + T * V * (X - 1) \right] * N$$

Qn = number of vehicles in queue per lane

2.0 = 90th percentile randomness factor (Poisson distribution estimate)

q = arrival rate (vehicles per second) $v/3600$

r = adjusted volume (vph)

N = number of lanes in lane group

T = length of analysis period

V = volume during analysis period

X = v/c ratio

2.3.3 Synchro

Synchro (15) is a Windows-based traffic modeling program that is macroscopic, analytical, and deterministic. Its capabilities include optimization of cycle lengths, splits and offsets, actuated signal modeling, time-space diagrams and capacity analysis. Synchro implements the Highway Capacity Manual in calculating maximum back of queue. The queue report shows both the 50th and 95th percentile queues. 50th percentile is the maximum back of queue for a cycle with average arrivals while the 95th percentile queue is calculated by increasing the arrival rate to account for fluctuations in traffic.

Synchro does not consider vehicles delayed for less than 6 seconds to be part of the queue because it assumes they are slowed but not stopped. Also, the queue calculated by Synchro is proportional to the red time.

Synchro's maximum back of queue is calculated as below:

$$Q = \frac{v}{3600} * (R - 6) * \left[1 + \frac{1}{s/v - 1} \right] * \frac{L}{n * fLU}$$

R = Red time

s = Saturation flow rate

v = Arrival rate (vph)

L = Length of vehicles including space between them

n = Number of lanes

fLU = Lane utilization factor

If the volume to capacity ratio (v/c) exceeds 1, the queue length is theoretically infinite. Synchro calculates the queue length as the maximum queue after two cycles. The queue length is calculated as below:

$$Q' = (v * (C - 6) + ((v - s) * g/C) * C) / 3600$$

2.3.4 SimTraffic

SimTraffic, also distributed by Trafficware Corporation (15), is a microscopic traffic simulation tool designed to model, among other situations, signalized intersections. In its latest release, Version 7, it produces a queuing and blocking report which provides information about maximum queue lengths by lane as well as the percentage of time that the upstream end of the lane is blocked. A vehicle is considered queued when it is traveling at less than 10 feet per second.

Typical output from the queuing and blocking report includes the maximum “back of queue” recorded for the entire simulation period and observed for every two minute period. A standard deviation is also calculated as well as a statistical 95th percentile queue. Other output parameters include the storage by distance – the length of the turn bay, and the storage block time – the proportion of time that a lane is queued at the top of the storage. Finally, the queuing penalty is an approximation of how many vehicles are affected by a blocking. It is calculated by the estimated volume of the lane times the percent of time that the lane is blocked.

SimTraffic is described by its developers as follows:

SimTraffic is part of the Synchro plus package for modeling, optimizing and simulating traffic systems. SimTraffic is a microscopic simulation tool which is based on a Synchro data set. Every vehicle in SimTraffic is modeled as distinct object, identified by category which is tracked every 0.1s. Individual vehicles have car following and lane change behavior that varies by driver type.

Stochastic elements of the model include driver behavior characteristics, vehicle characteristics, and traffic characteristics such as turn movements, free flow speed, queue discharge headways and other attributes.

SimTraffic gives average queue length, maximum queue length and 95th percentile queue length for each lane for the analysis period. Average queue is the average of 2 minutes

maximum queue observed. The maximum queue is the longest queue observed for the reporting interval period for any lane. No averaging is done.

The 95th percentile queue is calculated as the average queue plus 1.65 standard deviations. The standard deviation is calculated using sum of squares for each 2 minutes.

A vehicle is considered queued in SimTraffic when stopped at a stop bar, behind a queued vehicle or stops to make a mandatory turn. Vehicles are also considered queued when travelling at less than 3m/s (15).

Other literature published by Trafficware suggests that maximum queues reported by SimTraffic may vary considerably when compared to other models. The reasons for these discrepancies as well as methods to achieve comparable values will be discussed in a subsequent section of this report.

2.3.5 *CORSIM*

CORSIM (CORridor SIMulation) is the simulation component of the Traffic Software Integrated System tool set (TSIS) sponsored by the Federal Highway Administration. Its microscopic network simulation model produces measures of effectiveness for each surface street lane. These measures of effectiveness (MOEs) are described as follows:

CORSIM provides average and maximum queue lengths by lane for the analysis period as well as intermediate periods. The average queue estimated by CORSIM is determined by incrementing a counter for each queued vehicle in each lane for every time step. This is then divided by the total number of seconds in the reporting interval. The average queue length is related to the number of seconds that the queues exist. The maximum estimated by CORSIM is the greatest number of vehicles that are queued at any time during the reporting interval for an individual link. A vehicle in CORSIM is considered to be in the queue when its speed drops below 3 feet per second. (16).

2.3.6 *Queue Length Model Comparisons*

A survey of the literature reveals a number of publications which compare queue length output produced by the several models described above. Mystkowski and Kahn, for example, (18) attempted to explain the methodologies for estimating queue length used in several common models, including earlier versions of TEAPAC, Synchro, and CORSIM. Their analysis also compared program results to actual field data of observed maximum and average maximum queues. Results of their analysis, based on data from seven locations in Colorado, indicated that six of the seven CORSIM estimates were greater than the observed average maximum queue length by anywhere from one to six vehicles. Signal94 produced estimates that were four to twenty-eight percent less than the observed maximum queue at five locations and from ten to fourteen percent greater at the other two locations. The 50th percentile queue estimated by Synchro3 was greater than the observed in six instances, ranging from six to eighty percent while the 95th percentile varied from fourteen percent less to twenty percent more than the observed

maximum queue. The authors also conclude that, contrary to their expectations, the programs overestimated observed queue lengths under low v/c conditions, while more reasonable results were produced under higher v/c ratios.

Viloria, Courage, and Avery (19) report on a study specifically focused on storage requirements for left turn lanes. Their report made no comparisons to observed queue lengths and was only appropriate for unsaturated conditions. Like other reported results, they contend that the use of different queue definitions and different computational approaches have resulted in different results. In comparing several model outputs to the HCM model (which they believe is the most comprehensive treatment model of the queuing process and thus the most analytically defensible), the authors found that the HCM estimates were generally higher than most of the other models. They thus provide a set of “queue conversion factors” (actually a series of best fit regression equations) to translate various model outputs to their HCM2000 equivalent. They further conclude that, particularly when demand approaches capacity, some models are “unduly optimistic” in estimating storage requirements and that a goal of achieving 90 percent confidence in the adequacy of the storage lanes may be hard to achieve.

Another study compares CORSIM and SimTraffic as applied to an Iowa arterial with low to moderate traffic volumes (20, 21). Results showed that, for the five intersections in the study area, the SimTraffic maximum queues were consistently higher than those reported by CORSIM with ranges of 25 to over 200 percent. The 95th percentile queues reported by SimTraffic, in fact, were also larger than the CORSIM maximums. Only the average queue reported in SimTraffic seems to compare with the maximum queue reported by CORSIM; the authors conclude that the CORSIM maximum queue usually represents more of an “average” queue over some simulation time period.

The same authors compared CORSIM and SimTraffic in three case studies for different roadway environments (22, 23). They concluded that SimTraffic performs better at isolated signalized intersections, particularly with pedestrians present and has superior animation capabilities, while CORSIM provides more accurate results for arterial corridor and freeway analysis.

Qi, Yi et al, in “Estimation of Design Lengths of Left-turn Lanes,” (24), evaluate both simulation and analytical based methods for determining left-turn lane queue storage length and deceleration length. This work, sponsored by the Texas Department of Transportation (TxDOT) suggests that limitations and lack of guidelines on existing methods in selecting an appropriate approach for estimating left-turn lane length necessitated the study. Three groups of methods were evaluated for estimating queue length: rule-of-thumb, analytical, and simulation. The study’s goal was to provide an evaluation of the capabilities of analytical and simulation based methods in estimating queue storage length. The conventional rule-of-thumb method used by TxDOT recommended in their Roadway Design Manual (as described previously) is twice the average number of arrivals during one signal cycle.

Four Methods were evaluated in the study:

HCS+ Version 5.1- macroscopic software that translates the capacity analysis methodology of HCM2000 into a computer model. HCS+ analysis yields average delay, level of service, and v/c ratios. It offers a queuing module that can provide the median (50th) and 95th percentile queues for each lane group. For this study, the 95th percentile queue result was used.

Synchro Version 6.0 – a macroscopic traffic model that uses an internal analytical method to estimate queue length. It calculates the median (50th) and 95th percentile queue lengths and indicates queue overflow. The 95th percentile queue was used for the study.

SimTraffic Version 6.0 - imports the network inputs from Synchro and performs a microscopic traffic simulation. It reports the maximum queue, average queue, and 95th percentile queue measures for each lane. Once again, the 95th percentile queue was used for the study.

VISSIM Version 4.20 – A microscopic, time-step and behavior-based simulation model developed to model urban traffic and public transit operations. It provides the user with simulation results consisting of on-screen animation of vehicular movements, traffic signal operation, and detector actuations. Compared to other models, VISSIM provides more flexibility in specifying model outputs. In this study, the 95th percentile queue length was calculated from the original output file of VISSIM.

In order to gather input parameters as well as determine the accuracy of the queue length estimation methods, field data were necessary. Seven signalized intersections with significant left-turn lane overflow or blockage problems were selected. These intersections were located in Houston and Austin, Texas. Three groups of data relating to the intersections were gathered relating to traffic, signal, and geometric conditions:

The traffic flow information was extracted from traffic videos at the intersections and included: through volume, left-turn volume, opposing volume, and maximum queue length and percentage of overflow and blockage for each recorded cycle.

Signal phasing information was obtained through the traffic management centers in Austin and Houston and included signal schedules, cycle length, splits, and left-turn phase type.

Geometric information was collected during the field survey and includes length of existing left-turn lanes, v/c ratios, percentages of cycle failures, percentages of overflows and blockages, and 95th percentile observed queue lengths (QL).

Results of the study listed the 95th percentile queue lengths estimated by each model along with the 95th percentile queue lengths observed in the field for each intersection. SimTraffic resulted in the highest accuracy (85.0%), followed by Synchro (83.9%), then HCS+ (79.6%); the least accurate method was obtained with VISSIM (61.2%). The intersections evaluated did not take

into account the influences of adjacent upstream/downstream intersections. A breakdown of the time taken to code and run each software package was also reported.

Study recommendations stated that VISSIM not be used for estimating left-turn queue lengths because the network coding and model calibration are time consuming and it takes more than a half hour longer than the other methods to model an intersection. VISSIM also has a significantly lower level of accuracy than the others methods studied. The study also recommends that the HCS+ not be used since, even though it takes the least amount of time, it tends to underestimate the left turn queue length, especially when the observed left turn lane is long.

If time is limited, the recommendation from the study is to use Synchro, which has higher accuracy than all the methods except SimTraffic. Time requirements for Synchro are shorter than all the methods with the exception of the HCS+. Finally, if there are no time constraints, SimTraffic should be the first choice, since it is the most accurate and the time-cost factor was in an acceptable range. Also, if the impacts of adjacent intersections must be considered based on engineering judgment, then SimTraffic should be used.

The study conclusions sum up the recommendations listed above, stating that while SimTraffic had the best performance, Synchro is recommended as well because it was nearly as accurate and took less time. VISSIM takes too much time and demonstrates relatively poor performance and thus is not recommended. The HCS+ software is also not recommended since, although it takes the least time and is relatively accurate, it underestimates queue lengths which could potentially cause safety problems.

2.4 Summary of Background Literature

It is clear from an examination of the literature describing both the properties and capabilities of the various methods of calculating queue length that the different definitions and procedures produce widely variable results. This is even more apparent when an examination is made of the studies conducted to compare and contrast the various approaches. Simulation models, in particular, must be carefully calibrated to reproduce actual conditions. Even then, the results may be applicable for specific site traffic and geometric situations. Standard definitions and model equivalents must be developed and applied if New Mexico is to be able to employ model outputs for design and operational decisions.

CHAPTER 3: SURVEY OF CURRENT PRACTICE

3.1 Introduction

In order to determine the current state-of-the-practice in queue length determination, a short survey and accompanying cover letter, shown in Appendix A, was developed by the researchers. After review by the project's Technical Panel, the survey was distributed via email to state DOT traffic engineers, specifically those serving on the Subcommittee on Traffic Engineering of AASHTO's Standing Committee on Highways. The survey was also distributed to one local agency traffic engineer in each state; these individuals were identified using the Institute of Transportation Engineer's (ITE) membership directory. The 100 emails generated an immediate response from a dozen intended recipients whose email addresses were no longer active. In these cases, attempts were made to identify replacement traffic engineers from the state or local level using the ITE directory. In several states, it was not possible to find a local agency traffic engineer.

3.2 Survey Response

The survey was ultimately distributed to the 52 state agency traffic engineers and 44 local agency traffic engineers shown in Appendix B. About four weeks after the distribution of the initial survey, a follow-up survey was resent to those who had not responded; this effort generated some additional responses.

The initial and follow-up surveys generated a total of 35 responses (a 36% response rate). The 22 state respondents (42%) included AR, CA, CO, FL, HI, ID, IL, IN, MD, MS, MT, NE, OH, OR, PA, RI, SC, TX, VA, WA, WV, and WY. The 13 local agency respondents (30%) included Albuquerque, Ann Arbor, MI, Bowling Green KY, Charlotte, NC, Fargo ND, Lafayette LA, Lakewood CO, Las Vegas NV, Overland Park KS, Phoenix, AZ, Pocatello ID, San Jose, CA, and Salt Lake City, UT. The higher responses from western states is probably due to the researcher's familiarity with western traffic engineers. Respondents are shown in *ITALICS* in Appendix B.

The first question asked which tools the agencies used to estimate left turn queue lengths. Many respondents selected multiple tools. The most commonly used tools are listed below, with the number of respondents and (percent of respondents):

25 (71%) *SimTraffic*

23 (66%) *HCM/HCS+*

8 (23%) *CORSIM*

7 (20%) *Other*

6 (17%) *Synchro*

The summary of all responses is shown in Appendix C.

Question 2 asked how confident the respondents were in the results provided by the tool(s) they used. Of the 35 respondents, 31 (89%) reported that they were somewhat confident. Two respondents felt highly confident in the results, while one was not confident at all.

The third question asked how closely the queue length estimates compared with the actual, observed queues. Nearly half (17, 49%) responded that they had not compared estimated lengths to actual lengths. Nine respondents (26%) felt that the estimated lengths were quite close to the actual lengths. Two respondents felt that the tools estimated lengths that were too short, while only a single respondent felt that the tools consistently overestimated queue lengths.

Question 4 asked for the most useful parameter for describing queue length. The respondents were given five choices, but were allowed to make multiple selections. Average maximum queue length over a number of signal cycles was selected by 11 respondents (31%). An identical number reported using a percentile of the queue length, with the most popular being the 95th percentile queue length, selected by nine respondents. Ten survey replies (29%) indicated that the most useful parameter was the maximum queue length at the beginning of the green signal interval. Nine respondents (26%) selected the maximum back of queue, including the vehicles that join during the green interval. The almost equal preference for these four choices makes it difficult to reach a firm conclusion about the most useful parameter for describing queue length. In the absence of a clear preference, the most reasonable choice would be to select the easiest parameter to measure in the field.

The most varied responses came from the fifth question, which asked when the respondents considered that a vehicle has joined the traffic queue. The responses are summarized below:

20 (57%) Don't conduct queue length studies

9 (26%) When a vehicle has slowed to ____ mph

4 (11%) Within ____ feet of stopped vehicle in the queue

3 (9%) Other

The most commonly cited speed was when a vehicle has slowed to 5 mph, while the most commonly cited distance was 40 feet.

Question 6 asked respondents for their preferred treatment for a backed up left-turn lane. Again, respondents were allowed multiple responses. As shown below, the responses were very balanced:

28 (80%) Install dual left-turn lane

27 (77%) Lengthen the protected green interval

25 (71%) Extend the turn lane

9 (26%) Other

The final question asked if the respondents could provide information on any documented queue length studies. One state responded that most of their TIA and EA studies document this type of information. The Texas DOT provided a link to the 2007 study performed for them by Qi et. al. at Texas Southern University and described previously.

CHAPTER 4: MODEL SELECTION

Based on the survey findings, as well as on other considerations, three modeling software packages were identified for additional analysis – the integrated Synchro/SimTraffic package, HCM/HCS+, and HCM2000/TEAPAC. Both Synchro/SimTraffic and the HCM/HCS+ were selected because of their high preference among state and local agencies, while TEAPAC was chosen instead of CORSIM because of CORSIM’s applicability to corridor rather than isolated signalized intersection. TEAPAC was also more familiar to the researchers as they had acquired the package several years ago and had attended training in its applications. A summary of the selected models, their assumptions, and queue calculation estimates is given in Table 1.

TABLE 1 Summary of Traffic Models and Queue Length Estimation

Model	Method/Assumption	Estimated Queue
Synchro (version 7)	Analytical, macroscopic and deterministic model. No initial queue for $v/c < 1$. Considers queue from previous cycle for $v/c > 1$.	50 th % and 95 th % Maximum back of queue.
SimTraffic (version 7)	Microscopic, stochastic model.	Average, Maximum and 95% back of queue.
HCS+ (version 5.4)	Analytical, macroscopic model. No initial queue for $v/c < 1$. Considers queues from previous cycle for $v/c > 1$.	Average, 70%, 85%, 90%, 95% and 98% maximum back of queue.
TEAPAC (version 8.10)	Uniform arrivals on red. No initial queue. Adjustment factor of 2 is used to provide a 90th percentile randomness factor.	Maximum queue.

Model differences are summarized in Table 2 and Figure 1 on the following pages

TABLE 2 Differences Between Models

	Synchro	HCS+	TEAPAC	SimTraffic
Actuated Signals	Internally calculates actuated green time.	User must specify average green time.	User must specify average green time.	Depends on Synchro data.
Queue length calculation	Assumes vehicle is queued when stopped or delayed for more than 6 sec. Does not include vehicles delayed for less than 6 sec.	Queue length includes all vehicles queued until they clear the intersection.	Considers vehicles queued on a red phase.	Assumes vehicle is queued when stopped behind a queued vehicle, stopped to make a mandatory lane change or travels at less than 3m/s.
Progression Factor	Calculates progression factor from arrivals from upstream intersections.	User must specify progression factor.	User must specify progression factor.	Depends on Synchro data.
Vehicle Length	25 ft.	25 ft.	25 ft.	19.5 ft.

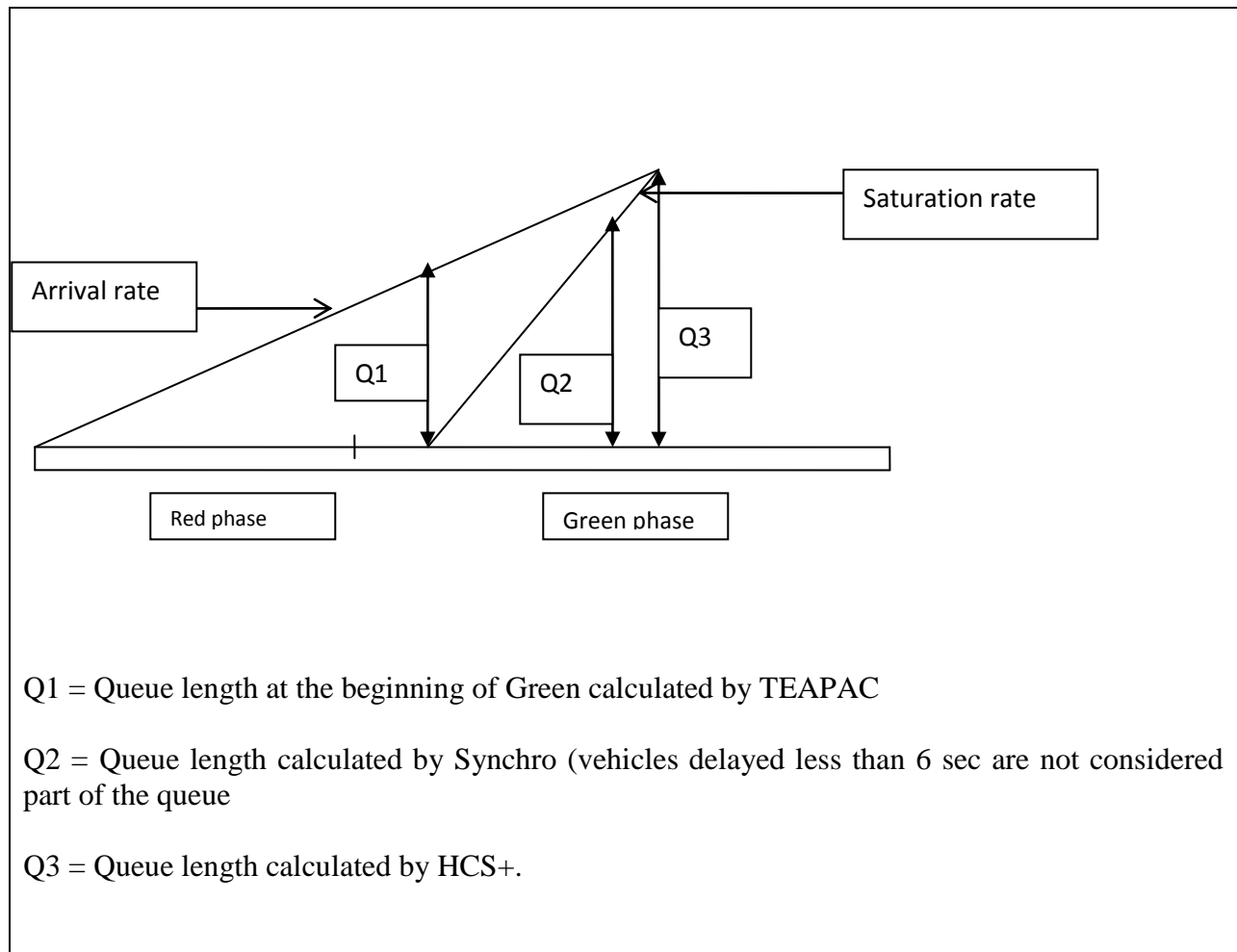


FIGURE 1 Queue Length Comparisons

CHAPTER 5: DATA COLLECTION

5.1 Data Collection Plan

In order to evaluate the selected models in terms of their ability to estimate left turn queue lengths, it was necessary to identify and collect field data at several locations. In addition to observed queue lengths, the data needs included geometric, traffic, and signal timing information at a number signalized intersections.

The initial data collection plan envisioned field studies employing hand-held video cameras on various intersection approaches to collect, for each signal cycle during a specified period, both left-turn queue lengths and total traffic volumes on an approach. Several trial runs demonstrated the numerous problems associated with such a method.

Both the lack of an adequate “depth of field” on the cameras used as well as an inability to locate the camera high enough above the intersection to observe more than a few approaching vehicles seriously limited the effectiveness of this procedure. As an alternative, it was decided to examine locations with existing traffic detection cameras on mast arms or other high mounted locations to collect the required volume and queue data. Traffic data collection thus focused on identifying signalized intersection within the City of Rio Rancho, the only jurisdiction at the time collecting acceptable traffic camera data. (The City of Albuquerque and the NMDOT have subsequently installed traffic cameras at selected locations on their systems.)

In addition to identifying candidate intersections, the data collection plan required consideration of the following:

Geometric Data

- Layout of the intersection,
- Number and type of approach lanes,
- Length of left turn lane(s).

Traffic Data

- Left-turn and through volumes,
- Queue lengths in left turn lane(s),
- Left turn queue carryovers.

Signal Timing Data

- Cycle length,

Cycle splits,

Type of left turn phasing.

protected,

protected/permitted.

The data collection plan also envisioned collecting data at intersections operating under a number of different conditions, such as a range of v/c ratios, and from both single and dual left turn lanes.

5.2 Candidate Intersections

Conversations with Department of Public Works personnel in Rio Rancho led to the identification of four suitable candidate intersections. The locations of the three intersections along NM 528 are identified on the map below and are summarized, along with a fourth location, in Table 3 that follows.

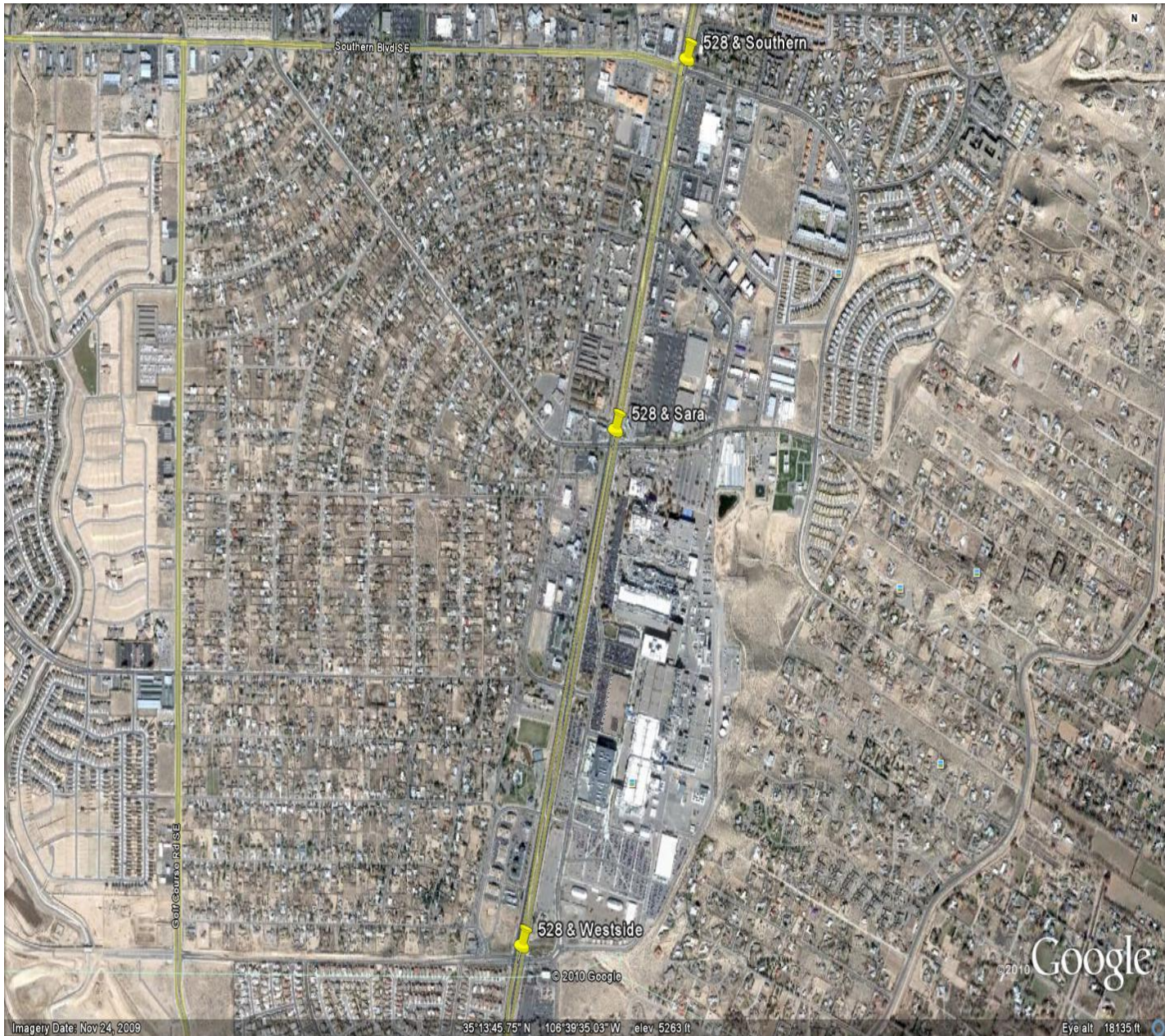


FIGURE 2 Three Candidate Intersections along NM 528

TABLE 3 Candidate Intersections

Intersection	No. of Lanes	LT Phasing	Signal Type	Intersection Layout
NM 528 & Westside	Dual LTs on All Approaches	All Protected Only	Actuated, Coordinated	See Figure 3
	4 Thru, 1 ERT NB & SB		C = 108 sec. (AM)	
	2 Thru, 1ERT EB		C = 126 sec. (PM)	
	1 Thru, 1Thru/RT WB			
NM 528 & Sara	Long Single LT on NB & SB Approaches	All Protected/Permitted	Actuated, Coordinated	See Figure 4
	Single LT EB Approach; Dual LT WB Approach		C = 108 sec. (AM)	
	3 Thru Lanes NB & SB Approaches		C = 126 sec. (PM)	
	1 Thru Lane, EB & WB Approaches			
	Single Free RT on All Approaches			
NM 528 & Southern	Long, Dual LT on NB Approach	All Protected Only	Actuated, Coordinated	See Figure 5
	Shorter, Single LT on SB Approach		C = 108 sec. (AM)	
	Dual LTs, EB & WB Approaches		C = 126 sec. (PM)	
	3 Thru Lanes SB; 2 Thru Lane NB			
	1 Thru Lane EB & WB			
	Single Free RT on All Approaches			
Broadmoor & High Resort	Single LTs on NB, SB, & WB	NB, SB, WB Protected/Permitted No EB Arrow	Actuated	See Figure 6
	No Exclusive LT Lane on EB Approach			
	Single Thru & RT Lanes on NB, SB, & WB Approaches			
	Single LT, Thru, RT on EB Approach			

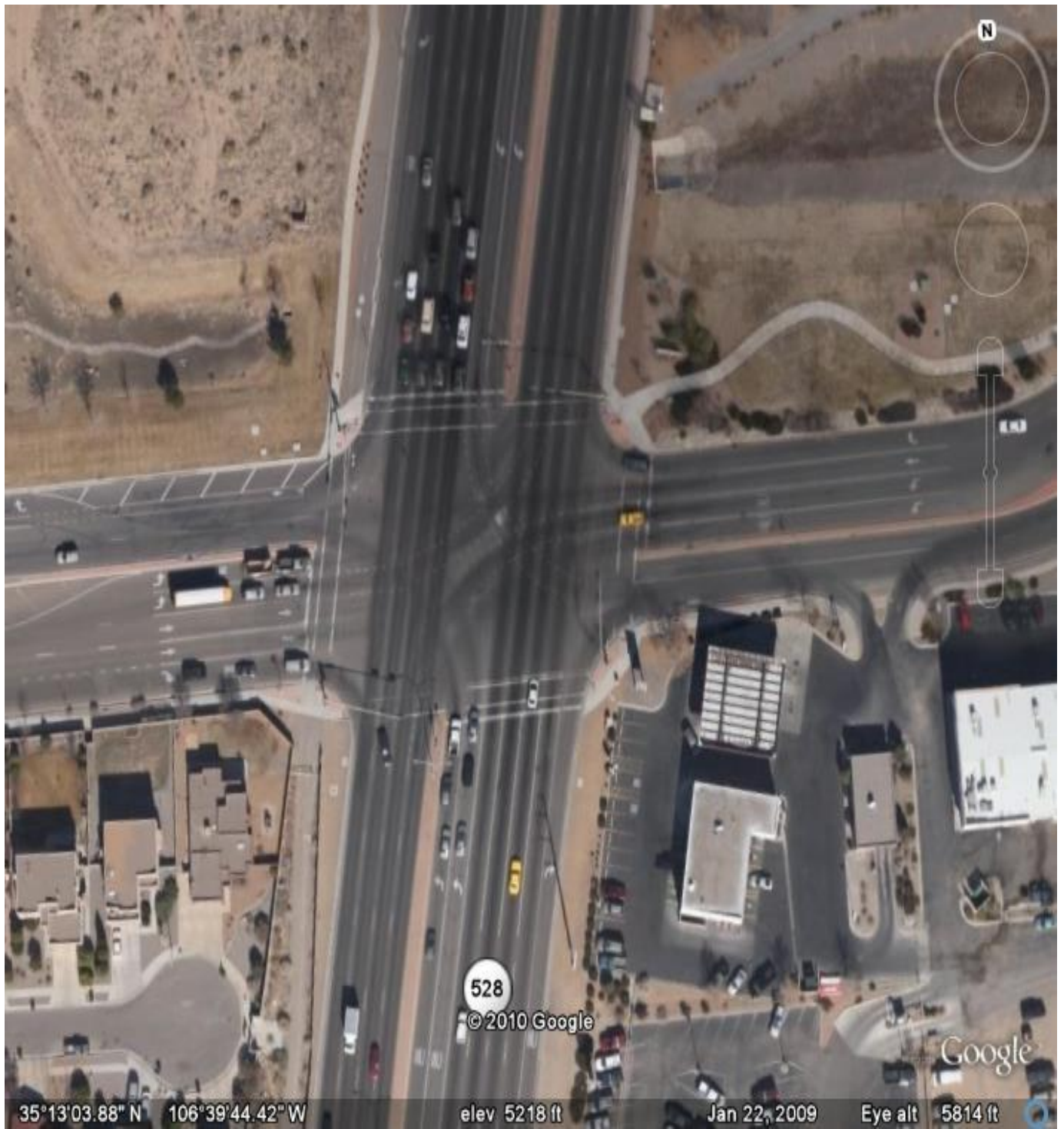


FIGURE 3 NM 528 and Westside Boulevard (E/W)



FIGURE 4 NM 528 (N/S) and Sara Rd.

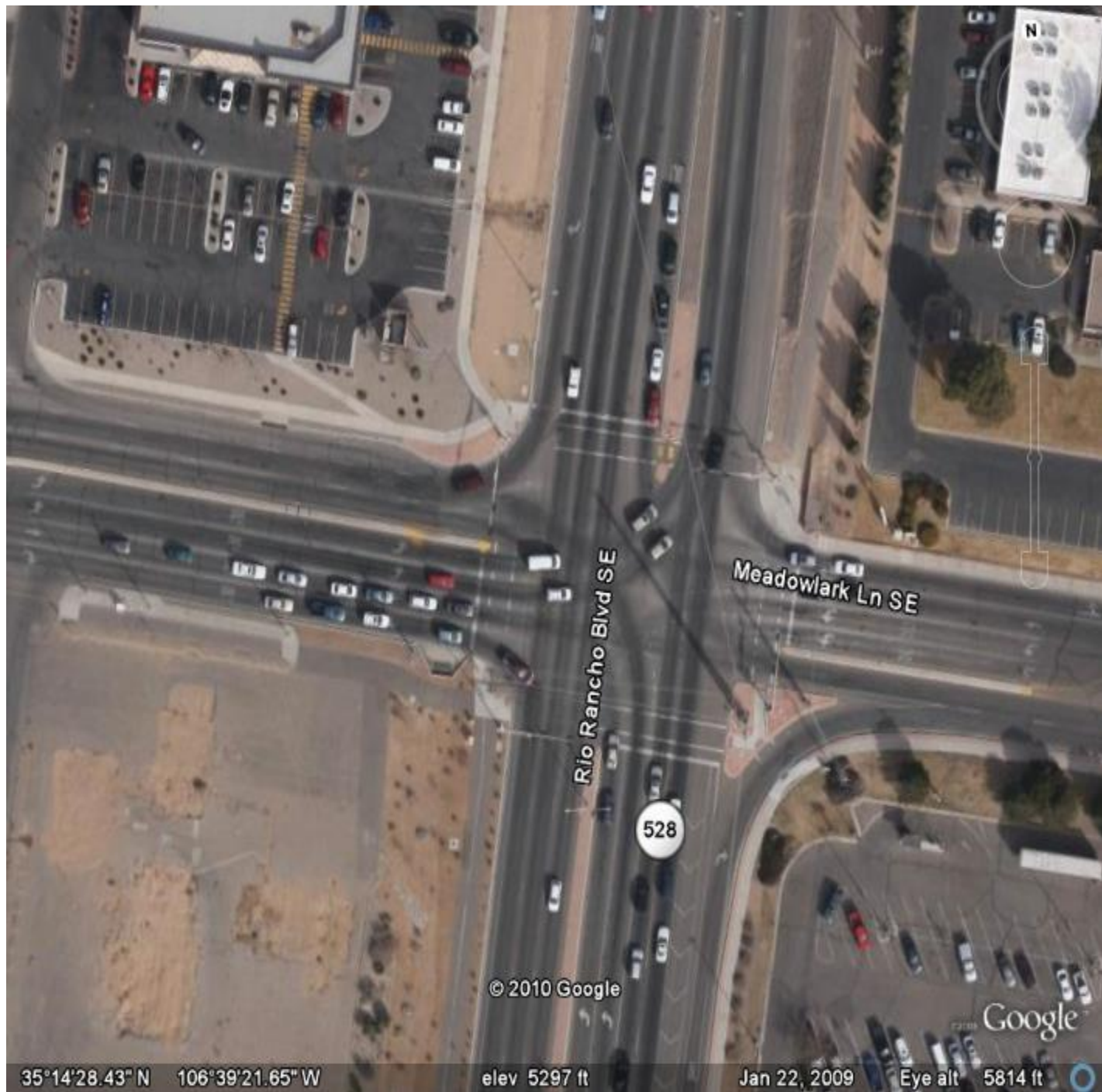


FIGURE 5 NM 528 (N/S) and Southern Blvd./Meadowlark Ln.



FIGURE 6 Broadmoor (N/S) and 7 Falls Dr./High Resort Blvd.

For the three intersections located along NM 528, Synchro-based timing data from 2006 provided by the City of Rio Rancho allowed the determination of initial v/c ratios for both AM and PM peak periods. This allowed the researchers an opportunity to select a range of v/c ratios to analyze, representing both under- and over-saturated conditions. Typical splits for the actuated, non-coordinated intersection at Broadmoor and High Resort were also provided.

5.3 Video Data

Video cameras used for basic intersection detection applications by the City of Rio Rancho were already located on all approaches at each of the selected intersections; most were fixed cameras, but some had pan/tilt/zoom (PTZ) capabilities, allowing a better view of queue lengths. Camera data was acquired by attaching a four-channel digital video recorder to the video-out feed in each intersection’s controller box. A simple plug-in and an identification of the desired time period

allowed simultaneous recording of all four approaches at each selected intersection location. Simply unplugging and moving the recorder to the next intersection allowed the data collection to proceed.

Video data capture took place over a 23 day period in March 2010 at the three intersection locations along NM 528 (the Broadmoor/High Resort intersection will be discussed subsequently) with over 207 hours collected and stored on the recorder. Data were collected during the morning from 6:00 to 10:00 AM and in the afternoon/early evening from 3:00 to 8:00 PM. The video had time stamps and, usually, icons allowed the timing and phasing patterns to be viewed at each location.

Camera limitations at the Broadmoor/High Resort intersection precluded the use of video data at this location. Instead, AM and PM manual turning movement counts, along with AM and PM intersection delay studies on the EB approach were performed. Maximum queues at this location were also observed during this data collection effort.

5.4 Data Reduction

The large amount of video data collected necessitated a detailed examination of only selected approaches at each intersection during a “typical” weekday. Table 4 shows the locations, time periods, and approaches which were viewed to determine maximum queue lengths. Also shown in the table are the v/c ratios for the selected approaches as calculated by Synchro from observed video volume counts. The HCS+ calculations for v/c ratios are similar.

TABLE 4 Video Data

<u>Location</u>	<u>Day/Date</u>	<u>Times</u>	<u>Approaches</u>	<u>v/c</u>
NM528 & Westside	Wed. 3/24/10	7:00-9:00 AM	SB LT	0.32
			WB LT	0.31
	4:00-6:30 PM	WB LT	0.51	
		NB LT	0.73	
NM528 & Sara	Wed. 3/17/10	7:00-9:00 AM	SB LT	0.17
			NB LT	0.82
	4:00-6:30 PM	SB LT	0.23	
		NB LT	1.12	
NM528 & Southern	Wed. 3/3/10	7:00-9:00 AM	EB LT	0.83
			SB LT	0.85
	4:00-6:30 PM	EB LT	1.04	
		SB LT	0.94	

The video data selected for in-depth analysis thus represents a typical weekday (Wednesday), both AM and PM peak periods, and a wide range of v/c ratios, including two approaches where oversaturated conditions exist.

A detailed examination of the video for each of the approaches described in Table 4 involved a time-consuming process of recording and calculating various items: the time stamp for the start of the green for the left turn movement, a count of the number of vehicles in the queue at that time (by lane if the approach had two lanes), the time stamp at the end of the left turn movement (which allowed a calculation of the movement’s effective green), a count of the number of vehicles, if any, remaining in the queue at the end of the effective green (the carryover), a count of the number of vehicles that arrive after the start of the green, and a calculation of the total number of vehicles that are served by the green. This laborious process – sitting in front of a monitor for hours – was made somewhat more tolerable by the playback, fast forward, and rewind features of the recorder. The left turn data was summed at 15 minute intervals to determine the peak hour and peak hour factors were calculated.

For illustration purposes, a portion of one of the spreadsheets for one location is shown in Table 5; complete results for all twelve approaches are described in Appendix D.

TABLE 5 Sample Video Recorder Data Reduction

Location:	NM 528 & Westside							
Date:	3/24/2010							
Approach:	NB Left PM							
Time @ Start of LT G	Number in Queue		Time @ End of LT G	G	Queue @ the end of G (Carryover)		# that arrive after start of G	Total # that pass on G
	Lane 1	Lane 2			Lane 1	Lane 2		
	shldr.	med.			shldr.	med.		
16:01:10	5	8	16:01:44	0:00:34	0	0	3	16
16:03:09	5	10	16:03:42	0:00:33	0	0	4	19
16:05:30	7	9	16:05:56	0:00:26	0	0	1	17
16:07:16	3	6	16:07:39	0:00:23	0	0	1	10
16:09:39	10	9	16:10:07	0:00:28	0	0	0	19
16:11:33	7	10	16:12:04	0:00:31	0	0	0	17
16:13:49	6	9	16:14:19	0:00:30	0	0	2	17
16:15:48	7	9	16:16:13	0:00:25	0	0	0	16

The data in Table 5 may be interpreted as follows: for the afternoon Northbound left turn movement at NM 528 and Westside (a dual left turn), when the green starts at 4:01:10 PM there

are 5 vehicles queued in the shoulder lane and 8 vehicles queued in the median lane. When the turn arrow ends 34 seconds later (at 4:01:44), all 13 vehicles have turned. The additional 3 vehicles that arrive after the start of the green have also successfully turned for a total of 16 left-turning vehicles.

Tables such as the one illustrated above may be used to determine a number of intersection characteristics in addition to the observed maximum queue length. Lane distribution for dual left turns, for example, may be calculated from column 2 and 3 totals and a left turn queue carryover percentage (the percentage of cycles in which the left turn queue cannot be cleared) may be determined by examining columns 6 and 7. Total volume for the left turn movement of interest may also be determined by summing the last column in the table.

5.5 Data Collection Results

The results of the data collection and reduction efforts are summarized in Table 6, which shows the maximum observed queue (MOQ) for each of the 12 movements identified in Table 4. For those approaches with dual left turn lanes, the queue length is for the lane with the longer queue. The table shows, in addition, the queue carryover (the proportion of the total cycles in which the queue does not clear in one cycle and has to be carried over). Current v/c ratios, calculated from observed camera volumes, are also indicated for peak hour.

TABLE 6 Maximum Observed Queues (MOQ)

<u>Intersection</u>	<u>LT Movement /Period</u>	<u>MOQ (vehicles)</u>	<u>% Carryover</u>	<u>Movement Type</u>	<u>Peak Hour v/c</u>
528 & Westside	SB/AM	4#	0	Protected	0.32
	WB/AM	3#	0	Protected	0.31
	WB/PM	5#	0	Protected	0.51
	NB/PM	14#	2.8	Protected	0.73
528 & Sara	SB/AM	2	0	Protected/ Permitted	0.17
	NB/AM	8	1.0	Protected/ Permitted	0.82
	SB/PM	3	0	Protected/ Permitted	0.23
	NB/PM	24	1.3	Protected/ Permitted	1.12
528 & Southern	EB/AM	12#	1.5	Protected	0.83
	SB/AM	15	42.4	Protected	0.85
	EB/PM	13#	18.0	Protected	1.04
	SB/PM	12	11.1	Protected	0.94

Longer of two queues in dual left turn lane.

On both single and dual left turn approaches with low v/c ratios (< 0.35), maximum observed queue lengths range from two to four vehicles. Those approaches with moderate to high v/c ratios ($0.35 < v/c < 0.95$) show a MOQ range of from five to fifteen vehicles. The two oversaturated approaches have maximum observed queues of 13 (in a single lane of a dual left) and 24 (the PM NB movement at 528 and Sara) vehicles.

Not surprisingly, the protected/permitted movements at 528 and Sara have little or no carryover, since any queue not dispersed during the green arrow can usually complete the turn on the green ball. Even the long queue NB during the PM peak is able to disperse during one cycle because of the long NB green ball and the number of available gaps in the SB traffic. The high carryover on the SB AM approach of NM 528 and Southern was apparently due to a disabled vehicle on the approach between 8:30 and 8:45 am.

In general, those locations with low MOQs and/or low/moderate v/c ratios have low percent carryovers. Only those few locations with both high MOQs and protected only phasing have significant carryover percentages.

CHAPTER 6: DATA ANALYSIS

The primary objective of the project is to compare the output of the three selected models described in Chapter 4 (HCM/HCS+, Synchro/SimTraffic, and TEAPAC) to the observed queue lengths described in Chapter 5. This chapter will document the results of these comparisons. In addition, the chapter will compare the two local applications discussed earlier (the Harmon Poisson Procedure and the Harwick Modified Poisson Procedure) in terms of their ability to estimate left turn queue lengths. Finally, the procedures will be applied to a fourth intersection (Broadmoor/High Resort) and compared to observed field data.

The analysis will proceed with an examination of each model's comparison to the observed data. A summary table will then be presented illustrating overall results.

6.1 HCS+ vs. Observed Queues

The comparison of HCS+ queue calculations with the observed queue lengths is given in Table 7. The table shows for each of the twelve intersection approaches studied the observed v/c ratio for the approach from the camera data, the 95th percentile queue length, in vehicles, modeled from the Highway Capacity Software, the Maximum Observed Queue (MOQ), also from camera observations, and the percent error, calculated as $[(95^{\text{th}} \text{ HCS+}) - (\text{MOQ})] / (\text{MOQ}) * 100$. An existing initial queue prior to the start of the analysis period was not assumed.

TABLE 7 95th Percentile Queue Lengths from HCS+ vs. Observed Data

Intersection and Approach	v/c	95 th HCS+	MOQ	% Error	Veh. Diff.
		(vehicles)	(vehicles)		
NM528 & Southern, EB AM	0.83	18	12	+50.0	+6
NM528 & Southern, SB AM	0.85	14	15	-6.7	-1
NM528 & Southern, EB PM	1.04	23	13	+76.9	+10
NM528 & Southern, SB PM	0.94	22	12	+83.3	+10
NM528 & Sara, SB AM	0.17	2	2	0.0	0
NM528 & Sara, NB AM	0.82	9	8	+12.5	+1
NM528 & Sara, SB PM	0.23	2	3	-33.3	-1
NM528 & Sara, NB PM	1.12	34	24#	+41.7	+10
NM528 & Westside, WB AM	0.31	3	3	0.0	0
NM528 & Westside, SB AM	0.32	2	4	-50.0	-2
NM528 & Westside, WB PM	0.51	6	5	+20.0	+1
NM528 & Westside, NB PM	0.73	17	14	+21.4	+3

The actual queue length observed on the video is longer than 24 vehicles, as the storage bay was filled to capacity with overflow. However, the number of vehicles could not be counted beyond 24 because of the poor quality of the video. The NB Left is only a single lane, necessitated by right-of-way restrictions on Sara which allow only one lane leaving the intersection.

An initial analysis of the data in Table 7 indicates that, for lower v/c ratios (0.50 or less), the HCS+ procedure, while providing a good match for two of the four approaches, also underestimates the required queue lengths from anywhere from 33 to 50 percent; the difference in numbers of vehicles, however, amounts to only one or two. For higher v/c ratios, in contrast, (more than 0.50) model results, with only one exception, overestimate the required lengths from anywhere from 12 to over 80 percent. The overestimates range as high as ten vehicles on several highly saturated approaches.

An evaluation of the overall performance of the HCS procedure that has been used by other researchers is to calculate the procedure's "accuracy" as follows: (24)

$$\text{Accuracy} = 1 - \text{Avg. } \{ \text{Abs. Value } ((\text{Est.} - \text{Obs.}) / \text{Obs.}) * 100\% \}$$

This calculation is simply one minus the average of the absolute values of the column 5 data in Table 7. The "accuracy" of the HCS procedure is thus calculated as 67.0%. The results using this procedure may be somewhat misleading, however, both because it makes no distinction between over- and under-estimations, and also because it misrepresents the significance of those approaches that have low queue lengths, both observed and calculated. The NB PM NM528 and Sara approach, for example, is overestimated by 41.7% , or 10 vehicles; the SB PM approach at the same intersection, on the other hand, is underestimated by 33.3 %, but only by one vehicle – a much less serious issue.

6.2 Synchro vs. Observed Queues

The comparison of Synchro queue calculations with the observed queue lengths is given in Table 8. In a manner similar to Table 7 above, Table 8 shows for each of the twelve intersection approaches studied the observed v/c ratio for the approach from the camera data, the 95th percentile queue length, in vehicles, modeled using the Synchro software, the Maximum Observed Queue (MOQ), also from camera observations, and the percent error, again calculated as $[(95^{\text{th}} \text{ Synchro}) - (\text{MOQ})] / (\text{MOQ}) * 100$.

TABLE 8 95th Percentile Queue Lengths from Synchro vs. Observed Data

Intersection and Approach	v/c	95 th Synchro (vehicles)	MOQ (vehicles)	% Error	Veh. Diff.
NM528 & Southern, EB AM	0.83	8	12	-33.3	-4
NM528 & Southern, SB AM	0.85	9	15	-40.0	-6
NM528 & Southern, EB PM	1.04	13	13	0.0	0
NM528 & Southern, SB PM	0.94	13	12	+8.3	+1
NM528 & Sara, SB AM	0.17	1	2	-50.0	-1
NM528 & Sara, NB AM	0.82	7	8	-12.5	-1
NM528 & Sara, SB PM	0.23	1	3	-66.7	-2
NM528 & Sara, NB PM	1.12	30	24#	+25.0	+6
NM528 & Westside, WB AM	0.31	2	3	-33.3	-1
NM528 & Westside, SB AM	0.32	2	4	-50.0	-2
NM528 & Westside, WB PM	0.51	4	5	-20.0	-1
NM528 & Westside, NB PM	0.73	10	14	-28.6	-4

The actual queue length observed on the video is longer than 24 vehicles, as the storage bay was filled to capacity with overflow. However, the number of vehicles could not be counted beyond 24 because of the poor quality of the video. The NB Left is only a single lane, necessitated by right-of-way restrictions on Sara which allow only one lane leaving the intersection.

With only three exceptions, all of the queue lengths estimated by Synchro give values that are lower, by anywhere from 20.0 to 67% compared to the maximum observed queues. In addition, the actual difference in the number of vehicles (estimated vs. observed) in two cases is estimated as six (a 150 foot change in storage length), and in four of the remaining ten cases the difference is two vehicles or more (a difference of 50 feet).

There appears, moreover, to be no consistent pattern related to v/c ratio. Some of the approaches with high ratios, such as those in the PM at NM528 and Southern, show the best results, while others, such as the SB AM at 528 and Southern, show large discrepancies. Those locations with low v/c ratios, as expected, do show smaller differences in vehicle estimates compared to observed values.

6.3 TEAPAC vs. Observed Queues

The comparison of TEAPAC queue calculations with the observed queue lengths is given in Table 9 which shows, for each of the twelve intersection approaches studied, the observed v/c ratio for the approach from the camera data, the 90th percentile queue length (TEAPAC gives the 90th percentile HCS+ queue), in vehicles, modeled using the TEAPAC software, the Maximum Observed Queue (MOQ), also from camera observations, and the percent error, again calculated as $\frac{[(90^{\text{th}} \text{ TEAPAC}) - (\text{MOQ})]}{(\text{MOQ})} * 100$.

TABLE 9 90th Percentile Queue Lengths from TEAPAC vs. Observed Data

Intersection and Approach	v/c	90 th TEAPAC (vehicles)	MOQ (vehicles)	% Error	Veh. Diff.
NM528 & Southern, EB AM	0.83	13	12	+8.3	+1
NM528 & Southern, SB AM	0.85	9	15	-40.0	-6
NM528 & Southern, EB PM	1.04	15	13	+15.4	+2
NM528 & Southern, SB PM	0.94	16	12	+33.3	+4
NM528 & Sara, SB AM	0.17	2	2	0.0	0
NM528 & Sara, NB AM	0.82	8	8	0.0	0
NM528 & Sara, SB PM	0.23	1	3	-66.7	-2
NM528 & Sara, NB PM	1.12	37	24#	+54.2	+13
NM528 & Westside, WB AM	0.31	2	3	-33.3	-1
NM528 & Westside, SB AM	0.32	2	4	-50.0	-2
NM528 & Westside, WB PM	0.51	5	5	0.0	0
NM528 & Westside, NB PM	0.73	15	14	+7.1	+1

The actual queue length observed on the video is longer than 24 vehicles, as the storage bay was filled to capacity with overflow. However, the number of vehicles could not be counted beyond 24 because of the poor quality of the video. The NB Left is only a single lane, necessitated by right-of-way restrictions on Sara which allow only one lane leaving the intersection.

The TEAPAC model results show an almost even split between under- and over-estimation, with four of the approaches underestimated by from 33 to 67 percent while five approaches are over-estimated by anywhere from seven to 54 percent. Three approaches, with relatively low MOQs, compare well. Vehicle differences, however, exceed four in only two of the 12 cases, with one difference of 13 vehicles in the oversaturated NB PM NM528 & Sara approach.

Like the HCS+ results, moreover (which TEAPAC is reputed to emulate), the low v/c approaches (< 0.50) are under-estimated but within one or two vehicles, while most of the high v/c locations are over-estimated. Keep in mind also that the TEAPAC results are 90th percentile HCS+; a truly valid comparison to MOQ would have to add perhaps one vehicle or so to the calculated TEAPAC estimates. This comparison is shown in the next section.

6.4 HCS+ 95th percentile vs. TEAPAC 90th HCM percentile

The HCS+ queue output described in Table 7 calculates 95th percentile queues while the TEAPAC results in Table 9 are supposed to replicate the HCS+ 90th percentile length. Table 10 compares the two results. Surprisingly, the results do not compare very closely, even considering that the HCS+ data represent 95th percentiles and would be expected to be somewhat higher than the 90th percentile estimated by TEAPAC. Most locations, particularly those with high v/c ratios, show vehicle differences of up to eight vehicles.

TABLE 10 95th Percentile Lengths from HCS+ vs. 90th Percentile HCM from TEAPAC

Intersection and Approach	v/c	95 th HCS+	90 th TEAPAC (vehicles)	% Error	Veh. Diff.
NM528 & Southern, EB AM	0.83	18	13	+23.0	+5
NM528 & Southern, SB AM	0.85	14	9	+55.5	+5
NM528 & Southern, EB PM	1.04	23	15	+53.3	+8
NM528 & Southern, SB PM	0.94	22	16	+37.5	+6
NM528 & Sara, SB AM	0.17	2	2	0	0
NM528 & Sara, NB AM	0.82	9	8	+12.5	+1
NM528 & Sara, SB PM	0.23	2	1	+100.0	+1
NM528 & Sara, NB PM	1.12	34	37	-8.1	-3
NM528 & Westside, WB AM	0.31	3	2	+50.0	+1
NM528 & Westside, SB AM	0.32	2	2	0	0
NM528 & Westside, WB PM	0.51	6	5	+20	+1
NM528 & Westside, NB PM	0.73	17	14	+21.4	+3

6.5 SimTraffic vs. Observed Queues

Estimating queue lengths with SimTraffic differs from the procedures used by the previous models in several respects:

- SimTraffic performs microscopic traffic simulation whereas HCS+, Synchro, and TEAPAC perform a macroscopic analysis which is analytically based.
- Synchro and SimTraffic are an integrated software package; SimTraffic imports geometric, traffic, and signal timing parameters directly from Synchro.
- SimTraffic must be calibrated to ensure that the simulation represents real-world conditions.
- SimTraffic must be “seeded” with vehicles to start the simulation and be run multiple times to deal with the randomness of the simulation results.
- Vehicle length in SimTraffic is assumed to be 19.5 feet vs. the 25 foot length assumed for the other models. SimTraffic queue lengths (as measured in distance, not in vehicles) may thus be 25 percent less, all else being equal.
- 95th percentile queues in SimTraffic may be based on various assumptions relating to traffic volume characteristics and simulation time. These different assumptions are reflected in Table 11.

TABLE 11 Various 95th Percentile Queue Lengths from SimTraffic vs. Observed Data vs. Synchro Results

Intersection and Approach	v/c	95 th SimTraffic (1)	95 th SimTraffic (2)	95 th SimTraffic (3)	MOQ	95 th Synchro	“Best” SimTraffic##
		Unadjusted Volumes, 10 min. Sim.	95 th %ile Volumes, 2 min. Sim.	Unadjusted Volumes, 1 hr. Sim.	(vehicles)		
NM528 & Southern, EB AM	0.83	10	12	10	12	8	(2)
NM528 & Southern, SB AM	0.85	10	16	10	15	9	(2)
NM528 & Southern, EB PM	1.04	16	15	16	13	13	(2)
NM528 & Southern, SB PM	0.94	13	14	13	12	13	(1), (3)
NM528 & Sara, SB AM	0.17	3	3	3	2	1	(1), (2), (3)
NM528 & Sara, NB AM	0.82	10	8	8	8	7	(2), (3)
NM528 & Sara, SB PM	0.23	5	5	5	3	1	(1), (2), (3)
NM528 & Sara, NB PM	1.12	34	33	48	24#	30	(2)
NM528 & Westside, WB AM	0.31	3	4	3	3	2	(1), (3)
NM528 & Westside, SB AM	0.32	2	3	2	4	2	(2)
NM528 & Westside, WB PM	0.51	6	6	4	5	4	(1), (2), (3)
NM528 & Westside, NB PM	0.73	12	17	12	14	10	(1), (3)

The actual queue length observed on the video is longer than 24 vehicles, as the storage bay was filled to capacity with overflow. However, the number of vehicles could not be counted beyond 24 because of the poor quality of the video. The NB Left is only a single lane, necessitated by right-of-way restrictions on Sara which allow only one lane leaving the intersection.

The SimTraffic Model assumptions which best replicate MOQ.

Table 11 clearly requires some explanation. Column 3 (95th SimTraffic (1)), represents queue lengths based on volumes unadjusted for the Peak Hour Factor (the default setting in SimTraffic) and for a 10 minute simulation time (also SimTraffic’s default interval).

Column 4 ((95th SimTraffic (2)), was simulated with a 95th percentile traffic volume and a two minute simulation time (approximately representing the AM and PM cycle lengths of 108 seconds and 126 seconds, respectively). The Trafficware Manual (25), suggests this approach to more closely compare SimTraffic and Synchro 95th percentile results.

Column 5 (95th SimTraffic (3)), is yet another approach recommended by Trafficware to observe the 95th percentile queue; that is to simulate for an hour without volume adjustments. With a few exceptions, this approach seems to closely match the 10 minute simulated volumes. Detailed procedures for calibrating the SimTraffic model are described in the Trafficware Users Guide (25).

While the simulations using unadjusted volumes seem more variable when compared to the maximum observed queues, method (2) more closely matches the observed volumes, even when taking into consideration the shorter vehicle lengths assumed by SimTraffic. Nine of the 12

approaches examined with SimTraffic, in fact, are most closely approximately by method (2), as shown in the last column in the table. Two of those that are not are different by only one or two vehicle lengths and only NM528 and Westside shows a difference of more than two vehicles.

6.6 Summary of Model Evaluation

A summary of the model comparisons is shown in Table 12 on the following page. The numbers highlighted in *Italics* illustrate the model result which most closely matches the maximum observed queue. As can be seen in the table, the 95th SimTraffic (2) model most closely matches in four of the 12 approaches examined, resulting in a “score” of 4. Both HCS+ and TEAPAC also match four approaches and thus also score a four. Synchro results most closely match only three of the 12 locations (the numbers add to more than 12 because of several “ties.)

TABLE 12 Model Comparisons (Vehicles)

Intersection and Approach	v/c	Macroscopic	Macroscopic	Macroscopic	Microscopic	
		95 th HCS+	95 th Synchro	90 th TEAPAC	95 th SimTraffic (2)	MOQ
NM528 & Southern, EB AM	0.83	18	8	13	12	12
NM528 & Southern, SB AM	0.85	14	9	9	16	15
NM528 & Southern, EB PM	1.04	23	13	15	15	13
NM528 & Southern, SB PM	0.94	22	13	16	14	12
NM528 & Sara, SB AM	0.17	2	1	2	3	2
NM528 & Sara, NB AM	0.82	9	7	8	8	8
NM528 & Sara, SB PM	0.23	2	1	1	5	3
NM528 & Sara, NB PM	1.12	34	30	37	33	24#
NM528 & Westside, WB AM	0.31	3	2	2	4	3
NM528 & Westside, SB AM	0.32	2	2	2	3	4
NM528 & Westside, WB PM	0.51	6	4	5	6	5
NM528 & Westside, NB PM	0.73	17	10	15	17	14
Score		4	3	4	4	
Accuracy		67.0%	69.3%	74.3%	75.6%	

The actual queue length observed on the video is longer than 24 vehicles, as the storage bay was filled to capacity with overflow. However, the number of vehicles could not be counted beyond 24 because of the poor quality of the video. The NB Left is only a single lane, necessitated by right-of-way restrictions on Sara which allow only one lane leaving the intersection.

The “score” alone, however, fails to clearly distinguish among the models. A second evaluation criterion used to assess the model estimates is the “accuracy” as described previously. While this method may be somewhat biased in that it gives undue weight to approaches with short queue

lengths (in the low single digits) which may be over- or under-estimated by only one or two vehicles, it nevertheless is a measure of the overall usefulness of the model.

Both HCS+ and Synchro have an accuracy of less than 70%, while both TEAPAC and SimTraffic show an accuracy of about 75%. The other two SimTraffic runs not shown in this table (SimTraffic (1) and SimTraffic (3)) have accuracy rates of 71 and 68%, respectively.

A final measure of a model’s ability to replicate observed queues can be illustrated by whether it, on average, tends to over- or under-estimate queue lengths. This is shown in Table 12, which gives, for the 12 approaches modeled, how many were over- or under-estimated.

TABLE 13 Model Comparisons (Over/Under)

Measure	Macroscopic 95 th HCS+	Macroscopic 95 th Synchro	Macroscopic 90 th TEAPAC	Microscopic 95 th SimTraffic (2)
Net Vehicles Estimated (all 12 approaches)	+37	-17	+10	+21
# of Approaches Overestimated	7	2	5	9
# of Approaches Underestimated	3	9	4	1
# of Approaches Exact	2	1	3	2
Average # of Vehicles Over/Under Estimated	+3	-1.4	+0.8	+1.8

The table shows that TEAPAC, for example, was about equally likely to overestimate observed queues as it was to underestimate, with five approaches overestimated, four underestimated, and three estimated exactly. This is also reflected in the low number of net vehicles estimated on all 12 approaches. The SimTraffic model, on the other hand, and, to a greater extent, the HCS+ software, tend to overestimate queue lengths by an average of 1.8 and 3 vehicles, respectively. Finally, Synchro seems to under-estimate on nine of the 12 approaches by an average of 1.4 vehicles. The question thus seems to be, since no model exactly replicates observed queues, is it preferable to overestimate and construct a longer than necessary left turn lane or to underestimate, construct a shorter lane than required, and run the risk of significant backups and blockages. Considering all factors in the table, it is the researchers’ opinion that overestimation is not as critical as underestimation or a model which sometimes does both. Based on these criteria, it appears that the SimTraffic model best reproduces the observed maximum queues.

6.7 Broadmoor/High Resort Application

The models were also applied to a fourth intersection for which camera data was not available. The intersection, shown in Figure 6, of Broadmoor and High Resort (Seven Falls on the EB approach) is signalized with single protected left turn lanes on the NB, SB, and WB approaches, but a shared left/thru lane on the EB approach. There are cameras at the intersection but they were in a fixed position which precluded the collection of any queue length data. Instead, traffic volume and delay counts were conducted on Tuesday, April 20, 2009 from 6:30 to 8:00 AM and

from 2:00 to 3:30 PM (there is a school nearby that influenced the selection of these peak periods). A maximum queue of 12 vehicles was observed in the SB PM Broadmoor approach and is compared to model-predicted queue lengths in Table 14 below.

TABLE 14 Model Results - Broadmoor and High Resort (SB PM)

MOQ	Macroscopic 95 th HCS+	Macroscopic 95 th Synchro	Macroscopic 90 th TEAPAC	Microscopic 95 th SimTraffic (2)
12	11	5	8	11

Both HCS+ and SimTraffic are within one vehicle of the Maximum Observed Queue while both Synchro and TEAPAC underestimate by seven and four vehicles, respectively.

6.8 Other Modeling Considerations

6.8.1 Blockage/Carryover

In addition to the ability of the models to replicate maximum queue lengths, other considerations, such as the model’s ability to estimate through lane blockage by vehicles wishing to turn left, and carryover – the inability of the left turn phase to accommodate all left-turning traffic in one signal cycle – must be considered. The HCS+, for example, calculates a queue storage ratio, the ratio of the queue storage requirements based on the 95th percentile queue to the lane’s actual storage length. Any number over 1.0 indicates an inability to store the required number of vehicles. Similarly, SimTraffic’s queueing and blocking report calculates a queueing penalty- the estimated volume of the lane times the percent of time the lane is blocked.

In examining the observed camera data in Table 6, it can be seen that significant carryover only occurred at those locations with very high v/c ratios and/or protected only left-turn phasing. At AM SB NM 528 and Southern, for example, over 40 percent of the cycles could not accommodate those turning left on the short (13 seconds) protected only phase from a single left turn lane. This is reflected in the queueing penalty assigned by SimTraffic to the movement.

6.8.2 Model Efficiency

A final consideration in the usefulness of the various models to replicate maximum observed queues (MOQ) is the level of effort, in terms of the average execution time (what Qi, et. al. call the “time-cost”) to implement the models. The researchers’ best estimates of this cost for each of the models are as follows:

HCS+

An average of 15 minutes is required for modeling queue lengths using HCS+. The output is obtained immediately after the volume, timing, phasing, geometric, and traffic parameters are coded.

Synchro

Synchro takes an average of 20 minutes for the direct calculation of queue lengths. The required parameters are also volume, timing, phasing, traffic and geometry.

TEAPAC

An average of 15 minutes is required in TEAPAC to model queue lengths. They are calculated directly after the volume, timing, geometric, and traffic parameters are entered.

SimTraffic

The amount of time required for modeling queue lengths in SimTraffic depends on the speed of the PC, the size of the network (just an intersection in this case), the ease of calibration, and the number of simulation runs. On average, it takes an additional 45 minutes (on top of the 20 minutes for coding and input of Synchro data) to model queue lengths by this method.

6.9 Local Technical Practices

In addition to the software packages described above, the researchers examined two local practices for calculation of left turn queue lengths. The first was developed around 1990 by Dave Harmon, then a Traffic Engineer with the City of Albuquerque, and was used for both turn lanes associated with new developments as well as for city-funded projects.

Harmon's procedure is an Excel spreadsheet utilizing a Poisson distribution and an average number of left turns per signal cycle. The user inputs, for each approach, the estimated number of left turns per hour, the signal cycle length, and an assumed vehicle length of 25 feet. The spreadsheet then calculates the average number of left turning vehicles per cycle and the individual and cumulative Poisson terms for 0, 1, 2, vehicles. The procedure stops when the cumulative percentage reaches 100% and the vehicle count associated with the cumulative value closest to the selected percentage (usually 95%) is selected and multiplied by 25 feet to get the desired turn bay length.

The Harwick procedure was developed by Nevin Harwick, a local traffic engineering consultant and was based on an empirical relationship he developed while working in King County, WA. The procedure has been applied locally in Traffic Impact Studies developed for a number of state, local, and private clients.

Harwick modifies the negative exponential relationship used to develop a 95th percentile queue as follows:

The storage length design value for all left turn lanes is the 95th percentile queue. For these analyses, when a left turn movement operates with less than 15% of the signal cycle's green time (represented by the g/C ratio), the analysis assumes that all vehicles arrive at that left turn approach with a red indication. In reality, there is frequently a percentage of vehicles that arrive on the green indication and proceed through the left turn lane without stop delay. If the left turn being analyzed has greater than 15% of the signal cycle green time, the potential for arrival on green increases, and an adjustment for half of that green time is provided in the analysis, reducing the design queue length. This queue adjustment is calculated following generation of the 95th percentile queue length, Q_{95} , using the equation: $Q_{LT} = Q_{95} * [1.00 - (g/C)/2]$ (11).

Both the Harmon and Harwick procedures were compared against the Maximum Observed Queues at the twelve approaches previously described. The results are shown in Table 15.

TABLE 15 Local Practices Comparison (Vehicles)

Intersection and Approach	Harmon	Harwick	MOQ
	Q_{95}	Q_{LT}	
NM528 & Southern, EB AM	18	16	12
NM528 & Southern, SB AM	8	6	15
NM528 & Southern, EB PM	20	20**	13
NM528 & Southern, SB PM	12	11	12
NM528 & Sara, SB AM	3	2	2
NM528 & Sara, NB AM	9	6	8
NM528 & Sara, SB PM	3	2	3
NM528 & Sara, NB PM	26	17	24
NM528 & Westside, WB AM	3	3**	3
NM528 & Westside, SB AM	2	2**	4
NM528 & Westside, WB PM	7	5	5
NM528 & Westside, NB PM	19	17	14

** (g/C) < 15% therefore no reduction per Harwick.

The Harwick figures, as per the Q_{LT} equation, reduce the Q_{95} estimates provided by Harmon, as expected. Both procedures also provide reasonable results for the protected movements at NM 528 and Westside, which, with one exception (NB PM), have relatively low v/c ratios. Similarly, at NM 528 and Sara the comparisons are also reasonable, with the exception of the oversaturated NB PM movement.

The comparisons are not so good at NM 528 and Southern where the protected approaches have relatively high v/c ratios, and, for the SB AM approach in particular, a very high carryover rate

(over 40 percent of the cycles do not clear all queued vehicles). Neither procedure, however, accounts for the effects of an initial queue.

6.10 Data Analysis Summary

Based on an ability to most closely match observed left turn queues (MOQ) at three signalized intersections, SimTraffic seems to perform better than HCS+, Synchro, or TEAPAC. This observation is based on several factors:

SimTraffic most closely matches the MOQ for four of the twelve approaches examined and has the second best match in an additional five instances. Using a scoring of 4,3,2,1 points for closest, second closest, etc. to MOQ, SimTraffic scores 40, while TEAPAC, Synchro, and HCS+ score 37, 36, and 34, respectively.

Using the “accuracy” calculation previously described, SimTraffic has the highest percentage of 75.6%, while the others score at 74.3% (TEAPAC), 69.3% (Synchro) and 67.0% (HCS+).

SimTraffic consistently overestimates observed queues perhaps resulting in initially longer than necessary turn bay lengths. This is preferable, in the researchers’ opinion, to underestimation of lengths which could lead to overflow with its associated safety and operational problems as well as costs associated with possible retrofits.

When applied to a fourth intersection for which camera data were not available, SimTraffic most closely matched the manually observed queue.

A number of cautions must be observed in light of the above statements, however:

All four models produce results which vary, with some obvious exceptions, by in many cases only one or two vehicles, particularly on those approaches with low v/c ratios.

Some of the models perform very poorly on some approaches with high v/c ratios. This seems to be a particular problem on long, single lane left turn approaches.

Different assumptions and the selection of the appropriate calibration parameters can influence the SimTraffic results. The model seems to work best with an adjusted 95th percentile volume and a short simulation time.

The local procedures of Harmon and Harwick, when applied to the observed queues, produce mixed results. The protected/permitted movements at NM 528 and Sara show reasonable results, as do the low v/c approaches at NM 528 and Westside. The highly saturated approaches at NM 528 and Southern, however, are not modeled well by either procedure.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

This final chapter of the report summarizes the activities undertaken by the researchers regarding the main tasks undertaken by the project: the literature review, as documented in both the research literature and the state of the practice; the evaluation and selection of candidate queueing models with application to New Mexico; and data collection and analysis procedures associated with model evaluation; and model application. Several conclusions associated with model selection and application are presented and recommendations for model deployment are given.

The chapter also describes the implementation plan suggested by the researchers, including the dissemination of the research results, a plan for Department training describing model applications, and the development (in a separate submittal) of a multi-media presentation.

7.2 Summary of the Literature

An examination of the technical literature revealed highly variable results in both the capabilities and applications of alternative procedures for queue length estimation. Early approaches, described in many state and national design manuals, suggest rule-of-thumb approaches based on the assumption of Poisson arrivals while more recent analytical and simulation approaches are sometimes difficult to compare because of different definitions and assumptions.

Of the several model comparisons described in the technical literature some suggested mixed results when comparing earlier versions of TEAPAC and Synchro to observed queue lengths; these same studies also observed an overestimation of queue lengths for low v/c conditions with higher v/c ratios producing closer results. This was just the opposite of the authors' expectations.

More recent research which was examined indicated that SimTraffic produced the most "accurate" results, while Synchro and HCS+ produced estimates which were less accurate. This same report also recommended that, while SimTraffic should be used if turnaround time is not an issue, Synchro performs nearly as good and could be used if time constraints exist. Finally, HCS+ is not recommended in this instance since it underestimates queue lengths which could result in safety problems.

7.3 Survey of Current Practice

The survey of current practice, distributed to approximately 100 state and local traffic engineers, indicated a strong preference for either SimTraffic or HCS+ to model queue lengths; significantly smaller percentages indicated a preference for Synchro, TEAPAC or a Poisson-based analysis. Most respondents felt somewhat confident that their preferred method produced reasonable results, but had done few, if any, studies to confirm that suspicion. Preferred treatments for a backed up left turn lane focused on geometric improvements (converting to a

dual lane, subject to right-of-way availability) or signal timing changes such as increasing the time of a protected green interval.

Based on both the literature and state-of-the-practice reviews, the researchers decided to evaluate four software packages for application in New Mexico: SimTraffic, HCS+, Synchro, and, because they already had a copy of the software, TEAPAC.

7.4 Data Collection and Analysis

The initial approach of videotaping existing intersection queues was abandoned, because of height and field-of-view concerns, in favor of identifying intersection locations with existing high-mounted cameras. Three locations in Rio Rancho, all located along NM 528, were selected; both single and dual-lane configurations and protected and protected/permitted operations were represented. A variety of v/c ratios existed, including several over-saturated approaches.

Data were collected with a four-channel video recorder which was plugged directly into the intersection's controller. The recorder was rotated among the three intersections resulting in the collection and storage of over 200 total hours of data. Of these, the AM and PM periods at each of the three intersections were examined for each of two approaches. Only mid-week time periods were selected and different approaches could be examined in the morning and evening periods to reflect the heavier traffic flows. The results, when combined with the time stamps and traffic signal icons on the video, allowed queue lengths for each left turn movement to be counted. Total left turn volumes for each approach could also be estimated and v/c ratios computed. In addition to queueing and volume data, the video was also used, in the case of dual left turn lanes, to determine lane distribution. The proportion of cycles which could not clear all vehicles in the queue (the carryover) could also be estimated from video data.

Data analysis involved comparing the maximum observed queues from the video data to model results obtained from SimTraffic, HCS+, Synchro, and TEAPAC. Both the percent error and the actual difference, in number of vehicles, were calculated for each package.

In general, HCS+ underestimated queue length for those approaches with low v/c ratios and overestimated it for those approaches with high v/c ratios. Its accuracy was calculated as 67.0%. TEAPAC, which is touted to emulate HCS+ results, also both over- and under-estimated observed queues, with low v/c ratios underestimated and high v/c ratios overestimated. Synchro, on the other hand, calculated values that are, in most cases, lower than observed queues, and which showed little variation across a range of v/c ratios.

Finally SimTraffic's method two, based on a two minute simulation time, most closely matched observed queues on four of the twelve approaches with nine approaches overestimated and only one approach underestimated. Since it is the researchers' opinion that it is better to over-, rather than under-estimate, SimTraffic, with an average of only +1.8 vehicles estimated, better replicates maximum observed queues than the other three models examined.

7.5 Recommendations

Based on the models' ability to replicate observed queue lengths, as well as other traffic operations considerations, the following recommendations can be made:

- 1.) SimTraffic simulation method two, based on using 95th percentile volumes and a simulation time of two minutes (closely matching the existing intersection cycle lengths), best replicates the observed left turn lanes at the three New Mexico intersections examined. This recommendation is based on the following:
 - a. SimTraffic has the highest "score" of the four models examined based on a 4, 3, 2, 1 scoring system
 - b. SimTraffic also finishes first of the four models in the "accuracy" calculation described earlier.
 - c. SimTraffic consistently overestimates required queue lengths; this is preferable to the over- and/or the over-/under-estimates associated with the other three models examined.
 - d. When applied to a fourth intersection for which camera data was not available, SimTraffic performed best in replicating the manually-observed queues.
 - e. SimTraffic results will vary if assumptions relating to volume data and simulation inputs are changed.
- 2.) HCS+, TEAPAC, and Synchro all produce comparable results based on "score" while both HCS+ and Synchro produce lower "accuracy" results; of the three remaining models, HCS+ is recommended for use if time constraints preclude the use of the more time-intensive coding and simulation runs associated with SimTraffic.
 - a. HCS+ also over-estimates required queue lengths, with the advantages described in 1c.) above.
 - b. HCS+ also provides the best estimate (tied with SimTraffic) at the non-camera intersection described in 1d.) above.
 - c. HCS+ output is obtained more quickly than output from SimTraffic due to simpler coding and processing time requirements.
- 3.) Local technical practices may be employed for small projects, such as those required for traffic impact analyses associated with small developments. These procedures, based on Poission analysis, produce results comparable to the larger, more elaborate methods employed by the four models.

In addition to the recommendations listed above which are associated with the primary project objective of assessing software which best replicates observed queue lengths, several additional recommendations related to data collection, use, and storage are described below.

- 4.) Data collection at intersections equipped with cameras is a simple process, requiring only a four-channel video recorder with a large amount of internal storage and a video output connection in the intersection's controller.
 - a. The recorder may be set to collect data on all four approaches for any time period.

- b. Cameras equipped with pan/tilt/zoom capabilities are preferable to those with fixed fields of view, since they allow approaches with lengthy queues to be more accurately counted.
 - c. For those locations without cameras, a high observation location is necessary if using a hand-held camera; multiple locations may be necessary to collect data from all intersection approaches.
- 5.) Data analysis of camera video to determine maximum queues, as well as other volume and/or timing data, requires considerable viewing of output, preferably on a large monitor.
- a. The process may be made less onerous through use of the recorder's fast forward and rewind capabilities.
 - b. In order to analyze timing issues, either software with clock timing and icons indicating the intersection's phase changes must be available or the signal head indications on each approach must be visible.
 - c. Camera data may be stored indefinitely on the recorder or transferred via a USB connection to an external storage device.
- 6.) Turning movement data collected at intersections in conjunction with traffic impact analyses or other studies currently is not available or archived at a central location within the DOT.
- a. Traffic personnel at NMDOT's Santa Fe headquarters should be tasked with storing all intersection turning movement studies on state-administered routes, whether collected by DOT personnel, other agencies, or consultants working under state contract.
 - b. Consideration should be given to employing TRADAS, the NMDOT's TRAffic DAta System software for storage of turning movements. Correspondence with Elizer Pena indicates that the Planning Division currently stores the few turning movement counts that they perform every year in a sub-folder in the Petra folder (the Jamar download software).
 - c. Other options for data storage and viewing may include the TIMS and EDMS systems. No further details were obtained from these groups.
 - d. Additional investigation of the data collection and storage needs of the NMDOT are underway in a separate study being conducted by the Civil Engineering Department at UNM. Results are expected in the Fall of 2011.

7.6 Implementation Plan

The Implementation Plan proposed for this project includes suggestions for Department training toward implementing the project's recommendations, a discussion of steps, both taken and proposed, to disseminate the research results, and a description of a multi-media presentation describing the project for non-technical audiences (distributed as a separate document).

7.6.1 Department Training

The researchers propose to train Department personnel in the project's results and recommendations at two venues. Project staff will attend the first scheduled meeting of the Department's District Traffic Engineers in Calendar Year 2011 to brief them and their staffs on the results of the project. If appropriate, project staff will also attend the 2011 Engineering Conference in Las Cruces to train additional NMDOT personnel, as well as other agency personnel and private consultants who may be attending that meeting.

7.6.2 Dissemination of Research Results

Preliminary project results were presented at the Department of Civil Engineering's Graduate Research Seminar by Ms. Gloria Ababio on November 19, 2010. Ms. Ababio, the project's Graduate Research Assistant, will also be using data developed during the project period as part of her thesis for the M.S. degree in Civil Engineering with an emphasis in Transportation. She anticipates completing her degree requirements in the Spring of 2011.

Additional dissemination of the project's results will also be made through submissions of a technical discussion to WesternITE, the Institute of Transportation Engineers (ITE) Western District Newsletter and/or a more technical paper to ITE Journal, the Institute's national publication. A presentation to the New Mexico section of ITE will also be proposed for one of their monthly meetings in the Spring.

7.6.3 Multi-Media Presentation

A multi-media Power Point presentation of the project's results suitable for a non-technical audience has also been prepared and will be submitted as a separate document. After review by the project's Technical Panel, this presentation will be made available on CD for Department use.

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APPENDIX A(1): SURVEY LETTER

July 20, 2009

Name of State Traffic Engineer:

The Department of Civil Engineering at the University of New Mexico, under a contract with the New Mexico Department of Transportation (NMDOT), is attempting to develop defensible and verifiable models to estimate queue lengths at signalized intersections. We'd appreciate it if you could take a couple of minutes to respond to the attached survey form.

We intend to use the results of this survey to select several models/procedures to be compared to empirical queue length observations at selected locations in New Mexico. The procedure(s) will then be incorporated into the State's Access Management Manual and used on all projects, potentially resulting in both reduced costs and improved safety performance.

After you have completed the survey, check the "submit form" in the upper right corner of the form, add the information to the dialog box, and click "send." In the Select Email Client dialog box, click the "Internet Email" box, click OK, and then save the file. Please email your response to jerome@unm.edu, or mail the response and any supplementary materials to Professor Jerome W. Hall, Department of Civil Engineering, MSC01 1070, The University of New Mexico, Albuquerque, NM 87131-0001. If you have any questions, don't hesitate to contact me at 505.277.1418. If there is someone else in your office who is in a better position to respond to this, please forward the survey to them.

Thank you in advance for your help.

Jerome E. Hall, Ph.D., P.E.

Professor

APPENDIX A(2): SURVEY INSTRUMENT

Modeling Left-Turn Queue Lengths

1. Which, if any, of the following tools do you use to estimate future queue lengths in left-turn lanes? Check all that apply.
 - CORSIM
 - Highway Capacity Manual/Highway Capacity Software
 - Poisson analyses
 - SIGNAL2000/TEAPAC
 - SimTraffic
 - Other

2. Considering the technique(s) from question 1 that you use, how confident are you in the results they provide?
 - Highly confident
 - Somewhat confident
 - Not confident at all
 - Other

3. Based on the technique(s) that you use for queue length estimation, how do your estimates compare with actual, observed queue lengths at study locations?
 - Estimates are consistently higher than actual values.
 - Estimates are usually quite close to actual values.
 - Estimates tend to underestimate actual values.
 - Have not compared estimates to actual values.
 - Other

4. Based on your analyses and observations, which of the following is the most useful parameter describing queue length?

- Maximum queue length at the beginning of the green interval.
- Average queue length over some time period.
- Average maximum queue length over a number of signal cycles.
- Maximum back of queue, including vehicles that join during the green interval.
- Percentile queue length
- Other

5. In conducting field studies of queue lengths, when do you consider that a vehicle has joined the end of the queue?

- When a vehicle has approached within _____ ft of a stopped vehicle in the queue.
- When an approaching vehicle has slowed to a speed of _____ mph or ft/s.
- Don't conduct queue length studies.
- Other

6. Assume that you have a single, channelized left-turn lane that consistently backs up and blocks the adjacent through-traffic lane, what would be your preferred treatment? Check all that apply.

- Extend the turn lane length, if possible.
- Lengthen the protected green interval for left-turning traffic, if possible.
- Install a dual left-turn lane, if possible.
- Other

7. Has your agency documented any queue length studies that might be helpful to the researchers on this project?

Yes

No

8. Can you offer any additional guidance to the researchers regarding queue length modeling?

Name of person providing this information:

Agency:

Email:

Phone:

Please return this survey to:

Professor Jerome W. Hall

Department of Civil Engineering

MSC01 1070

University of New Mexico

Albuquerque, NM 87131

Email: jerome@unm.edu

APPENDIX B: TRAFFIC QUEUEING SURVEY

Those shown in ITALICS have responded

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dclements@dot.state.ny.us,
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fluyanda@act.dtop.gov.pr,
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rhull@utah.gov,
mcclando@wsdot.wa.gov,
Tim.S.Kirk@wv.gov,
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lallsbrook@hampton.gov,
chris.fornal@milwaukee.gov,

APPENDIX C: SUMMARY OF TRAFFIC QUEUEING SURVEY RESPONSES

1 Which tools do you use to estimate LT queue lengths?

8 Corsim
23 HCM/HCS
5 Poisson analysis
3 SIGNAL2000/TEAPAC
25 SimTraffic
5 VISSIM
1 SIDRA
6 Synchro
7 Other

2 How confident are you in the results?

2 Highly confident
31 Somewhat confident
1 Not confident at all
1 Other

3 How do your estimates compare with actual, observed queues?

1 Estimates consistently higher than actual
9 Estimates usually quite close
2 Estimates tend to underestimate actual
17 Have not compared estimates to actual
5 Other

4 Which is the most useful parameter describing queue length?

10 Maximum queue length at beginning of green interval
5 Average queue length over some time period
11 Average maximum queue length over a number of signal cycles
9 Maximum back of queue, including vehicles that join during the green
11 _____ Percentile queue length
1 50
1 90
9 95
1 Other

5 When do you consider that a vehicle has joined the queue?

4 Within ____ ft of stopped vehicle in the queue

- 1 20 ft
- 2 40 ft
- 1 50 ft
- 9 When vehicle has slowed to _____
- 1 0 mph
- 1 3 mph
- 5 5 mph
- 1 10 mph
- 1 20-25 mph
- 20 Don't conduct queue length studies
- 3 Other

6 What is your preferred treatment for a backed up LT lane?

- 25 Extend the turn lane
- 27 Lengthen the protected green interval
- 28 Install dual left-turn lane
- 9 Other

- 7 Any documented queue length studies?
- 2 Yes
- 33 No

APPENDIX D: VIDEO RECORDER DATA REDUCTION SPREADSHEETS

	A	B	C	D	E	F	G	H	I
1	Location:	NM 528 & Southern							
2									
3	Date:	3/3/2010							
4									
5	Approach:	EB Left AM							
6									
7									
8	Time @ Start of	Number in Queue		Time @ End of LT Green	Effective green time	Number in Queue at the end of green(Spillover)		Number that arrive after start of Green	Total number that pass on green
9	LT Green								
10		Lane 1	Lane 2			Lane 1	Lane 2		
11		(shoulder)	(median)			(shoulder)	(median)		
12	7:00:09	4	3	7:00:29	0:00:20	0	0	1	8
13	7:01:57	4	2	7:02:16	0:00:19	0	0	0	6
14	7:03:44	4	4	7:04:03	0:00:19	0	0	0	8
15	7:05:33	2	1	7:05:47	0:00:14	0	0	1	4
16	7:07:20	5	6	7:07:46	0:00:26	0	0	0	11
17	7:09:08	4	1	7:09:30	0:00:22	0	0	0	5
18	7:10:58	6	6	7:11:17	0:00:19	0	0	0	12
19	7:12:45	5	5	7:13:05	0:00:20	0	0	0	10
20	7:14:33	3	4	7:14:52	0:00:19	0	0	1	8
21	7:16:21	3	6	7:16:43	0:00:22	0	0	0	9
22	7:18:09	3	2	7:18:32	0:00:23	0	0	0	5
23	7:19:56	2	0	7:20:11	0:00:15	0	0	0	2
24	7:21:44	4	1	7:22:03	0:00:19	0	0	2	7
25	7:23:31	5	6	7:23:55	0:00:24	0	0	2	13
26	7:25:31	2	0	7:25:35	0:00:04	0	0	0	2
27	7:27:08	3	4	7:27:31	0:00:23	0	0	0	7
28	7:29:02	2	1	7:29:19	0:00:17	0	0	0	3
29	7:30:46	1	2	7:31:02	0:00:16	0	0	1	4
30	7:32:32	5	7	7:32:56	0:00:24	0	0	0	12
31	7:34:21	6	8	7:34:46	0:00:25	0	0	0	14
32	7:36:08	4	5	7:36:31	0:00:23	0	0	1	10
33	7:37:57	9	9	7:38:21	0:00:24	0	0	0	18
34	7:39:45	5	6	7:40:09	0:00:24	0	0	0	11
35	7:41:33	2	3	7:41:57	0:00:24	0	0	11	16
36	7:43:21	4	4	7:43:40	0:00:19	0	0	1	9

	A	B	C	D	E	F	G	H	I
37	7:45:07	10	10	7:45:34	0:00:27	0	0	0	20
38	7:47:04	12	10	7:47:29	0:00:25	0	0	0	22
39	7:48:46	7	7	7:49:10	0:00:24	0	0	1	15
40	7:50:33	5	4	7:50:53	0:00:20	0	0	1	10
41	7:52:21	8	8	7:52:44	0:00:23	0	0	0	16
42	7:54:09	4	5	7:54:31	0:00:22	0	0	2	11
43	7:55:56	7	6	7:56:20	0:00:24	0	0	0	13
44	7:57:54	9	10	7:58:17	0:00:23	0	0	0	19
45	7:59:35	4	4	7:59:50	0:00:15	0	0	0	8
46	8:01:23	7	7	8:01:44	0:00:21	0	0	1	15
47	8:03:09	2	3	8:03:28	0:00:19	0	0	1	6
48	8:04:57	3	3	8:05:21	0:00:24	0	0	0	6
49	8:06:45	3	5	8:07:07	0:00:22	0	0	0	8
50	8:08:34	7	5	8:08:56	0:00:22	0	0	0	12
51	8:10:22	4	4	8:10:40	0:00:18	0	0	0	8
52	8:12:10	4	6	8:12:34	0:00:24	0	0	1	11
53	8:13:58	3	2	8:14:31	0:00:33	0	0	4	9
54	8:15:45	7	6	8:16:11	0:00:26	0	0	2	15
55	8:17:34	2	6	8:17:56	0:00:22	0	0	4	12
56	8:19:22	4	3	8:19:39	0:00:17	0	0	0	7
57	8:21:10	4	4	8:21:34	0:00:24	0	0	4	12
58	8:22:58	5	6	8:23:22	0:00:24	0	0	3	14
59	8:24:46	3	3	8:25:03	0:00:17	0	0	0	6
60	8:26:34	5	5	8:26:56	0:00:22	0	0	1	11
61	8:28:21	5	3	8:28:42	0:00:21	0	0	0	8
62	8:30:10	7	7	8:30:34	0:00:24	0	0	0	14
63	8:31:57	6	3	8:32:20	0:00:23	0	0	0	9
64	8:33:46	4	3	8:34:11	0:00:25	0	0	6	13
65	8:35:34	4	3	8:35:58	0:00:24	0	0	1	8
66	8:37:22	7	5	8:37:47	0:00:25	0	0	0	12
67	8:39:11	7	7	8:39:35	0:00:24	0	0	4	18
68	8:40:57	4	3	8:41:22	0:00:25	0	0	1	8
69	8:42:47	9	8	8:43:10	0:00:23	0	0	0	17
70	8:44:34	4	6	8:44:56	0:00:22	0	0	0	10
71	8:46:21	8	9	8:46:46	0:00:25	0	1	0	16
72	8:48:10	8	9	8:48:34	0:00:24	0	0	0	17
73	8:49:57	11	10	8:50:22	0:00:25	0	0	0	21

	A	B	C	D	E	F	G	H	I
74	8:51:45	5	5	8:52:10	0:00:25	0	0	5	15
75	8:53:34	3	2	8:53:57	0:00:23	0	0	6	11
76	8:55:22	8	8	8:55:46	0:00:24	0	0	2	18
77	8:57:10	5	6	8:57:34	0:00:24	0	0	0	11
78	8:58:58	3	4	8:59:17	0:00:19	0	0	0	7
79	Total volume								733

	A	B	C	D	E	F	G	H	I
1	Location:	NM 528 & Southern							
2									
3	Date:	3/3/2010							
4									
5	Approach:	EB Left PM							
6									
7									
8	Time @ Start of	Number in Queue		Time @ End of	Effective green	Number in Queue at the		Number that arrive after	Total number
9	LT Green			LT Green	time	end of green(Spillover)			
10		Lane 1	Lane 2			Lane 1	Lane 2		
11		(shoulder)	(median)			(shoulder)	(median)		
12	16:00:51	6	4	16:01:07	0:00:16	0	0	0	10
13	16:02:57	8	10	16:03:18	0:00:21	1	2	0	15
14	16:05:03	10	6	16:05:25	0:00:22	0	0	0	16
15	16:07:09	6	5	16:07:29	0:00:20	0	0	0	11
16	16:09:20	2	4	16:09:38	0:00:18	0	0	0	6
17	16:11:21	5	5	16:11:42	0:00:21	0	0	0	10
18	16:13:26	8	8	16:13:46	0:00:20	0	0	0	16
19	16:15:38	6	7	16:15:57	0:00:19	0	0	0	13
20	16:17:39	5	6	16:18:00	0:00:21	0	0	0	11
21	16:19:51	6	6	16:20:07	0:00:16	0	0	0	12
22	16:21:51	4	4	16:22:11	0:00:20	0	0	1	9
23	16:23:58	3	5	16:24:19	0:00:21	0	0	0	8
24	16:26:02	5	6	16:26:24	0:00:22	0	0	1	12
25	16:28:10	7	6	16:28:29	0:00:19	0	0	2	15
26	16:30:14	10	12	16:30:37	0:00:23	3	2	0	17
27	16:32:16	9	8	16:32:45	0:00:29	2	1	0	14
28	16:34:27	8	8	16:34:49	0:00:22	0	0	0	16
29	16:36:34	8	6	16:36:53	0:00:19	0	0	1	15
30	16:38:39	7	6	16:39:00	0:00:21	0	0	0	13
31	16:40:45	7	6	16:41:04	0:00:19	0	0	0	13
32	16:42:51	5	4	16:43:12	0:00:21	0	0	1	10
33	16:44:57	7	6	16:45:18	0:00:21	0	0	4	17
34	16:47:03	4	6	16:47:25	0:00:22	0	0	3	13
35	16:49:09	8	8	16:49:31	0:00:22	0	0	0	16
36	16:51:21	9	9	16:51:39	0:00:18	3	1	0	14

	A	B	C	D	E	F	G	H	I
37	16:53:21	9	10	16:53:43	0:00:22	1	0	1	19
38	16:55:27	3	6	16:55:49	0:00:22	0	0	1	10
39	16:57:32	4	5	16:57:55	0:00:23	0	0	3	12
40	16:59:39	7	7	17:00:00	0:00:21	0	0	0	14
41	17:01:45	6	7	17:02:06	0:00:21	0	0	0	13
42	17:03:51	7	7	17:04:13	0:00:22	0	1	3	16
43	17:05:57	7	9	17:06:18	0:00:21	0	0	3	19
44	17:08:03	10	13	17:08:24	0:00:21	2	2	0	19
45	17:10:08	12	10	17:10:30	0:00:22	3	0	0	19
46	17:12:15	9	10	17:12:36	0:00:21	2	1	0	16
47	17:14:21	10	11	17:14:42	0:00:21	1	2	0	18
48	17:16:27	10	12	17:16:49	0:00:22	1	3	0	18
49	17:18:33	8	10	17:18:55	0:00:22	0	1	0	17
50	17:20:39	5	8	17:21:01	0:00:22	0	0	0	13
51	17:22:45	5	7	17:23:06	0:00:21	0	0	0	12
52	17:24:51	4	6	17:25:13	0:00:22	0	0	0	10
53	17:26:57	3	3	17:27:19	0:00:22	0	0	3	9
54	17:29:03	6	5	17:29:25	0:00:22	0	0	0	11
55	17:31:09	5	5	17:31:29	0:00:20	0	0	0	10
56	17:33:15	6	5	17:33:37	0:00:22	0	0	0	11
57	17:35:21	9	10	17:35:41	0:00:20	0	0	0	19
58	17:37:26	5	6	17:37:49	0:00:23	0	0	0	11
59	17:39:33	5	6	17:39:53	0:00:20	0	0	0	11
60	17:41:39	7	8	17:42:00	0:00:21	0	0	0	15
61	17:43:45	7	4	17:44:09	0:00:24	0	0	0	11
62	17:45:51	8	6	17:46:11	0:00:20	0	0	0	14
63	17:47:57	8	7	17:48:19	0:00:22	0	0	0	15
64	17:50:04	6	6	17:50:25	0:00:21	0	0	2	14
65	17:52:09	4	2	17:52:31	0:00:22	0	0	0	6
66	17:54:14	5	7	17:54:36	0:00:22	0	0	0	12
67	17:56:21	4	3	17:56:39	0:00:18	0	0	1	8
68	17:58:27	7	6	17:58:49	0:00:22	0	0	1	14
69	18:00:32	8	9	18:00:55	0:00:23	0	0	0	17
70	18:02:38	8	6	18:03:01	0:00:23	0	0	0	14
71	18:04:45	8	4	18:05:06	0:00:21	0	0	0	12
72	18:06:51	5	6	18:07:10	0:00:19	0	1	0	10
73	18:08:56	9	7	18:09:18	0:00:22	0	0	0	16

	A	B	C	D	E	F	G	H	I
74	18:11:03	5	3	18:11:24	0:00:21	0	0	0	8
75	18:13:09	7	5	18:13:30	0:00:21	0	0	4	16
76	18:15:14	4	4	18:15:35	0:00:21	0	0	0	8
77	18:17:21	5	8	18:17:41	0:00:20	0	0	1	14
78	18:19:21	8	6	18:19:47	0:00:26	0	0	0	14
79	18:21:33	5	6	18:21:54	0:00:21	0	0	0	11
80	18:23:39	3	4	18:24:00	0:00:21	0	0	0	7
81	18:25:45	4	2	18:26:03	0:00:18	0	0	1	7
82	18:27:51	3	2	18:28:12	0:00:21	0	0	2	7
83	18:29:57	6	5	18:30:18	0:00:21	0	0	2	13
84	Total volume								932
85		189	211			18	14	23	
86		201	223						
87	Lane Utilization Factor(fLU)	0.951							

	J	K	L	M
1				
2				
3				
4				
5				
6				
7				
8	15 minute vol	Hourly vol		
9				
10				
11				
12	84	377		
13				
14				
15				
16				
17				
18				
19	80	413		
20				
21				
22				
23				
24				
25				
26	115	423	PHF	0.88
27			flow rate	480
28				
29				
30				
31				
32				
33				
34	98	396		
35				
36				

	J	K	L	M
37				
38				
39				
40				
41	120	398		
42				
43				
44				
45				
46				
47				
48	90			
49				
50				
51				
52				
53				
54				
55	88			
56				
57				
58				
59				
60				
61				
62	100			
63				
64				
65				
66				
67				
68				
69	93	174		
70				
71				
72				
73				

	J	K	L	M
74				
75				
76	81			
77				
78				
79				
80				
81				
82				
83				
84				
85				
86				
87				

	A	B	C	D	E	F	G	H	I
1	Location:	NM 528 & Southern							
2									
3	Date:	3/3/2010							
4									
5	Approach:	SB Left AM							
6									
7									
8	Time @ Start of	Number in Queue		Time @ End of	Effective green	Number in Queue at the		Number that arrive after	Total number
9	LT Green			LT Green	time	end of green(Spillover)			
10		Lane 1	Lane 2			Lane 1	Lane 2		
11		(shoulder)	(median)			(shoulder)	(median)		
12	7:01:40		3	7:01:54	0:00:14		0	0	3
13	7:03:29		4	7:03:42	0:00:13		0	0	4
14	7:05:17		1	7:05:30	0:00:13		0	0	1
15	7:07:05		5	7:07:18	0:00:13		0	0	5
16	7:08:52		2	7:09:06	0:00:14		0	0	2
17	7:10:41		5	7:10:54	0:00:13		0	0	5
18	7:12:29		2	7:12:42	0:00:13		0	0	2
19	7:14:17		2	7:14:30	0:00:13		0	0	2
20	7:16:05		2	7:16:18	0:00:13		0	0	2
21	7:17:53		7	7:18:06	0:00:13		3	0	4
22	7:19:41		7	7:19:54	0:00:13		1	0	6
23	7:21:29		4	7:21:42	0:00:13		0	0	4
24	7:23:17		7	7:23:30	0:00:13		1	0	6
25	7:25:05		6	7:25:18	0:00:13		0	0	6
26	7:26:53		9	7:27:06	0:00:13		1	0	8
27	7:28:46		3	7:28:59	0:00:13		0	0	3
28	7:30:29		2	7:30:42	0:00:13		0	0	2
29	7:32:17		6	7:32:30	0:00:13		0	0	6
30	7:34:05		6	7:34:18	0:00:13		0	0	6
31	7:35:53		5	7:36:06	0:00:13		1	0	4
32	7:37:41		2	7:37:54	0:00:13		0	0	2
33	7:39:29		6	7:39:42	0:00:13		2	0	4
34	7:41:17		6	7:41:30	0:00:13		0	0	6
35	7:43:05		5	7:43:18	0:00:13		0	0	5
36	7:44:53		7	7:45:06	0:00:13		1	0	6

	A	B	C	D	E	F	G	H	I
37	7:46:49		4	7:47:02	0:00:13		0	0	4
38	7:48:31		3	7:48:44	0:00:13		0	4	7
39	7:50:17		1	7:50:30	0:00:13		0	0	1
40	7:52:05		5	7:52:18	0:00:13		0	1	6
41	7:53:53		4	7:54:06	0:00:13		0	0	4
42	7:55:40		6	7:55:54	0:00:14		0	0	6
43	7:57:39		9	7:57:52	0:00:13		4	0	5
44	7:59:19		8	7:59:32	0:00:13		3	0	5
45	8:01:05		8	8:01:18	0:00:13		3	0	5
46	8:02:53		10	8:03:06	0:00:13		4	0	6
47	8:04:41		4	8:04:54	0:00:13		0	0	4
48	8:06:29		7	8:06:42	0:00:13		2	0	5
49	8:08:17		5	8:08:30	0:00:13		0	1	6
50	8:10:05		3	8:10:18	0:00:13		0	1	4
51	8:11:53		1	8:12:06	0:00:13		0	0	1
52	8:13:41		6	8:13:55	0:00:14		0	0	6
53	8:15:30		6	8:15:43	0:00:13		0	0	6
54	8:17:17		8	8:17:31	0:00:14		5	0	3
55	8:19:06		7	8:19:19	0:00:13		3	0	4
56	8:20:54		10	8:21:07	0:00:13		0	0	10
57	8:22:42		4	8:22:55	0:00:13		0	0	4
58	8:24:30		5	8:24:43	0:00:13		0	0	5
59	8:26:18		4	8:26:31	0:00:13		0	0	4
60	8:28:06		8	8:28:19	0:00:13		0	0	8
61	8:29:54		4	8:30:07	0:00:13		0	2	6
62	8:31:42		7	8:31:55	0:00:13		0	0	7
63	8:33:30		10	8:33:43	0:00:13		5	0	5
64	8:35:18		12	8:35:31	0:00:13		9	0	3
65	8:37:06		15	8:37:19	0:00:13		6	0	9
66	8:38:54		10	8:39:07	0:00:13		5	0	5
67	8:40:42		9	8:40:55	0:00:13		2	0	7
68	8:42:30		9	8:42:43	0:00:13		3	0	6
69	8:44:18		11	8:44:31	0:00:13		6	0	5
70	8:46:06		12	8:46:19	0:00:13		6	0	6
71	8:47:54		9	8:48:07	0:00:13		2	0	7
72	8:49:41		5	8:49:55	0:00:14		0	0	5
73	8:51:30		8	8:51:43	0:00:13		4	0	4

	A	B	C	D	E	F	G	H	I
74	8:53:17		7	8:53:31	0:00:14		2	0	5
75	8:55:06		6	8:55:19	0:00:13		0	0	6
76	8:56:54		8	8:57:07	0:00:13		3	0	5
77	8:58:42		9	8:58:55	0:00:13		3	0	6
78	9:00:30		8	9:00:43	0:00:13		3	0	5
79	Total volume								325

	J	K	L	M
1				
2				
3				
4				
5				
6				
7				
8	15 minute vol	Hourly vol		
9				
10				
11				
12	22	121		
13				
14				
15				
16				
17				
18				
19				
20	36	130		
21				
22				
23				
24				
25				
26				
27				
28	30	130		
29				
30				
31				
32				
33				
34				
35				
36				

	J	K	L	M
37	33	142		
38				
39				
40				
41				
42				
43				
44				
45	31	147	PHF	0.88
46			flow rate	168
47				
48				
49				
50				
51				
52				
53	36			
54				
55				
56				
57				
58				
59				
60				
61				
62	42			
63				
64				
65				
66				
67				
68				
69				
70	38			
71				
72				
73				

	J	K	L	M
74				
75				
76				
77				
78				
79				

	A	B	C	D	E	F	G	H	I
1	Location:	NM 528 & Southern							
2									
3	Date:	3/3/2010							
4									
5	Approach:	SB Left PM							
6									
7									
8	Time @ Start of	Number in Queue		Time @ End of LT Green	Effective green time	Number in Queue at the end of green(Spillover)		Number that arrive after start of Green	Total number that pass on green
9	LT Green								
10		Lane 1	Lane 2			Lane 1	Lane 2		
11		(shoulder)	(median)			(shoulder)	(median)		
12	16:00:29		9	16:00:48	0:00:19		0	0	9
13	16:02:33		4	16:02:55	0:00:22		0	0	4
14	16:04:40		5	16:05:01	0:00:21		0	1	6
15	16:06:46		6	16:07:07	0:00:21		0	1	7
16	16:08:59		5	16:09:17	0:00:18		0	0	5
17	16:10:58		4	16:11:18	0:00:20		0	2	6
18	16:13:03		1	16:13:24	0:00:21		0	0	1
19	16:15:17		5	16:15:35	0:00:18		0	1	6
20	16:17:16		9	16:17:36	0:00:20		0	1	10
21	16:19:30		3	16:19:47	0:00:17		0	1	4
22	16:21:28		5	16:21:48	0:00:20		0	1	6
23	16:23:34		9	16:23:54	0:00:20		0	1	10
24	16:25:40		5	16:26:01	0:00:21		0	1	6
25	16:27:46		9	16:28:07	0:00:21		0	0	9
26	16:29:52		6	16:30:13	0:00:21		0	2	8
27	16:32:06		3	16:32:23	0:00:17		0	3	6
28	16:34:04		9	16:34:25	0:00:21		1	0	8
29	16:36:10		5	16:36:31	0:00:21		0	0	5
30	16:38:16		10	16:38:37	0:00:21		0	0	10
31	16:40:22		5	16:40:42	0:00:20		0	0	5
32	16:42:28		6	16:42:48	0:00:20		0	0	6
33	16:44:34		5	16:44:55	0:00:21		0	0	5
34	16:46:40		6	16:47:01	0:00:21		0	1	7
35	16:48:46		10	16:49:07	0:00:21		1	2	11
36	16:51:00		11	16:51:18	0:00:18		2	0	9

	A	B	C	D	E	F	G	H	I
37	16:52:58		12	16:53:19	0:00:21		4	0	8
38	16:53:21		7	16:53:43	0:00:22		0	0	7
39	16:55:03		10	16:55:24	0:00:21		0	0	10
40	16:57:10		7	16:57:31	0:00:21		0	0	7
41	16:59:16		7	16:59:37	0:00:21		0	0	7
42	17:01:22		6	17:01:43	0:00:21		0	0	6
43	17:03:28		9	17:03:49	0:00:21		0	0	9
44	17:05:34		4	17:05:54	0:00:20		0	0	4
45	17:07:40		4	17:08:01	0:00:21		0	0	4
46	17:09:46		5	17:10:07	0:00:21		0	2	7
47	17:11:51		5	17:12:12	0:00:21		0	2	7
48	17:13:58		6	17:14:19	0:00:21		0	1	7
49	17:16:04		10	17:16:25	0:00:21		1	0	9
50	17:18:10		7	17:18:30	0:00:20		1	2	8
51	17:20:16		5	17:20:36	0:00:20		0	0	5
52	17:22:22		6	17:22:42	0:00:20		0	1	7
53	17:24:28		11	17:24:48	0:00:20		0	0	11
54	17:26:34		5	17:26:54	0:00:20		0	2	7
55	17:28:40		7	17:29:00	0:00:20		0	0	7
56	17:30:46		2	17:31:07	0:00:21		0	0	2
57	17:32:52		6	17:33:12	0:00:20		0	0	6
58	17:34:58		8	17:35:19	0:00:21		1	0	7
59	17:37:04		5	17:37:25	0:00:21		0	0	5
60	17:39:10		10	17:39:31	0:00:21		0	0	10
61	17:41:14		7	17:41:36	0:00:22		0	2	9
62	17:43:22		9	17:43:43	0:00:21		0	0	9
63	17:45:28		4	17:45:49	0:00:21		0	0	4
64	17:47:34		4	17:50:00	0:02:26		0	1	5
65	17:49:40		3	17:52:07	0:02:27		0	0	3
66	17:51:46		5	17:54:12	0:02:26		0	1	6
67	17:53:52		4	17:56:18	0:02:26		0	1	5
68	17:55:58		7	17:58:24	0:02:26		0	1	8
69	17:58:04		6	18:00:30	0:02:26		0	0	6
70	18:00:10		4	18:02:36	0:02:26		0	0	4
71	18:02:16		5	18:04:42	0:02:26		0	1	6
72	18:04:21		6	18:06:48	0:02:27		0	0	6
73	18:06:27		5	18:08:54	0:02:27		1	1	5

	A	B	C	D	E	F	G	H	I
74	18:08:33		6	18:11:00	0:02:27		0	1	7
75	18:10:39		5	18:11:24	0:00:45		0	2	7
76	18:12:46		5	18:13:06	0:00:20		0	0	5
77	18:14:51		4	18:15:12	0:00:21		0	1	5
78	18:16:57		8	18:17:18	0:00:21		0	0	8
79	18:19:03		6	18:19:24	0:00:21		0	0	6
80	18:21:09		6	18:21:30	0:00:21		0	0	6
81	18:23:16		4	18:23:36	0:00:20		0	0	4
82	18:25:21		2	18:25:42	0:00:21		0	0	2
83	18:27:27		2	18:27:48	0:00:21		0	0	2
84	18:29:34		5	18:29:54	0:00:20		0	0	5
85	Total volume								469

	A	B	C	D	E	F	G	H	I
1	Location:	NM 528 & Sara							
2									
3	Date:	3/17/2010							
4									
5	Approach:	NB Left AM							
6									
7									
8	Time @ Start of	Number in Queue		Time @ End of	Effective green	Number in Queue at the		Number that arrive after	Total number
9	LT Green			LT Green	time	end of green(Spillover)			
10		Lane 1	Lane 2			Lane 1	Lane 2		
11		(shoulder)	(median)			(shoulder)	(median)		
12	7:00:19		2	7:01:32	0:01:13		0	0	2
13	7:02:01		4	7:03:20	0:01:19		0	2	6
14	7:03:58		2	7:05:09	0:01:11		0	0	2
15	7:05:53		1	7:06:53	0:01:00		0	6	7
16	7:07:28		6	7:07:53	0:00:25		0	0	6
17	7:07:55		2	7:08:42	0:00:47		0	0	2
18	7:09:09		2	7:10:30	0:01:21		0	2	4
19	7:10:59		2	7:11:15	0:00:16		0	2	4
20	7:12:49		3	7:14:06	0:01:17		0	3	6
21	7:14:41		3	7:14:56	0:00:15		0	0	3
22	7:15:00		0	7:15:54	0:00:54		0	0	0
23	7:16:31		1	7:17:44	0:01:13		0	0	1
24	7:16:47		2	7:17:32	0:00:45		0	2	4
25	7:18:16		3	7:18:32	0:00:16		0	0	3
26	7:18:34		2	7:19:31	0:00:57		0	3	5
27	7:20:09		5	7:20:27	0:00:18		0	0	5
28	7:20:29		1	7:21:19	0:00:50		0	1	2
29	7:21:48		2	7:22:06	0:00:18		0	3	5
30	7:22:08		1	7:23:07	0:00:59		0	1	2
31	7:23:42		2	7:23:56	0:00:14		0	0	2
32	7:23:58		0	7:24:54	0:00:56		0	0	0
33	7:25:28		4	7:25:44	0:00:16		0	0	4
34	7:25:48		1	7:26:43	0:00:55		0	0	1
35	7:27:13		2	7:27:26	0:00:13		0	0	2
36	7:27:29		1	7:28:31	0:01:02		0	0	1

	A	B	C	D	E	F	G	H	I
37	7:29:04		5	7:30:34	0:01:30		0	5	10
38	7:30:53		5	7:32:10	0:01:17		0	0	5
39	7:32:40		0	7:33:56	0:01:16		0	0	0
40	7:34:26		1	7:35:43	0:01:17		0	0	1
41	7:36:20		2	7:36:35	0:00:15		0	0	2
42	7:36:38		2	7:37:30	0:00:52		0	0	2
43	7:38:03		5	7:39:18	0:01:15		0	0	5
44	7:39:54		1	7:41:06	0:01:12		0	0	1
45	7:41:37		2	7:42:54	0:01:17		0	0	2
46	7:43:29		5	7:43:51	0:00:22		0	0	5
47	7:43:53		2	7:44:42	0:00:49		0	0	2
48	7:45:20		2	7:46:31	0:01:11		0	0	2
49	7:47:08		7	7:48:19	0:01:11		0	0	7
50	7:48:47		4	7:49:07	0:00:20		0	5	9
51	7:49:10		6	7:50:07	0:00:57		0	0	6
52	7:50:27		1	7:50:37	0:00:10		0	0	1
53	7:50:40		3	7:51:55	0:01:15		0	0	3
54	7:52:36		1	7:52:44	0:00:08		0	0	1
55	7:52:47		0	7:53:33	0:00:46		0	5	5
56	7:54:18		0	7:55:33	0:01:15		0	7	7
57	7:56:09		0	7:57:19	0:01:10		0	2	2
58	7:57:56		4	7:58:15	0:00:19		0	0	4
59	7:58:18		0	7:59:06	0:00:48		0	2	2
60	7:59:42		5	8:00:01	0:00:19		0	9	14
61	8:00:03		0	8:01:00	0:00:57		0	2	2
62	8:01:32		2	8:01:50	0:00:18		0	0	2
63	8:01:52		0	8:03:06	0:01:14		0	7	7
64	8:03:41		0	8:04:57	0:01:16		0	2	2
65	8:05:33		2	8:05:48	0:00:15		0	0	2
66	8:05:50		0	8:06:43	0:00:53		0	1	1
67	8:07:09		0	8:08:28	0:01:19		0	6	6
68	8:09:24		1	8:09:35	0:00:11		0	0	1
69	8:09:38		0	8:10:16	0:00:38		0	1	1
70	8:10:30		2	8:10:44	0:00:14		0	0	2
71	8:10:47		0	8:11:59	0:01:12		0	1	1
72	8:12:35		2	8:12:50	0:00:15		0	0	2
73	8:12:52		0	8:13:44	0:00:52		0	0	0

	A	B	C	D	E	F	G	H	I
74	8:14:14		0	8:15:29	0:01:15		0	1	1
75	8:15:59		2	8:16:17	0:00:18		0	3	5
76	8:16:20		0	8:17:14	0:00:54		0	0	0
77	8:17:46		2	8:18:03	0:00:17		0	3	5
78	8:18:06		0	8:19:00	0:00:54		0	0	0
79	8:19:30		0	8:20:45	0:01:15		0	2	2
80	8:21:16		0	8:21:26	0:00:10		0	1	1
81	8:21:29		0	8:22:29	0:01:00		0	4	4
82	8:23:03		2	8:23:24	0:00:21		0	4	6
83	8:23:27		0	8:24:13	0:00:46		0	0	0
84	8:24:41		1	8:25:06	0:00:25		0	6	7
85	8:25:09		0	8:25:55	0:00:46		0	2	2
86	8:26:29		0	8:27:41	0:01:12		0	8	8
87	8:28:17		0	8:29:26	0:01:09		0	3	3
88	8:30:01		0	8:31:12	0:01:11		0	0	0
89	8:31:42		8	8:32:05	0:00:23		0	0	8
90	8:32:08		0	8:32:56	0:00:48		0	1	1
91	8:33:38		2	8:33:48	0:00:10		0	0	2
92	8:33:52		0	8:34:41	0:00:49		0	1	1
93	8:35:21		3	8:35:37	0:00:16		0	0	3
94	8:35:40		0	8:36:27	0:00:47		0	1	1
95	8:37:00		0	8:38:12	0:01:12		0	0	0
96	8:38:54		2	8:39:06	0:00:12		0	0	2
97	8:39:09		0	8:39:57	0:00:48		0	0	0
98	8:40:37		0	8:41:43	0:01:06		0	2	2
99	8:42:19		2	8:42:30	0:00:11		0	0	2
100	8:42:34		0	8:43:28	0:00:54		0	2	2
101	8:44:00		0	8:44:13	0:00:13		0	1	1
102	8:45:50		0	8:46:59	0:01:09		0	4	4
103	8:47:34		1	8:47:45	0:00:11		0	0	1
104	8:47:49		0	8:48:44	0:00:55		0	1	1
105	8:49:26		2	8:49:38	0:00:12		0	4	6
106	8:49:42		0	8:50:28	0:00:46		0	0	0
107	8:50:43		0	8:52:11	0:01:28		0	2	2
108	8:52:50		4	8:53:05	0:00:15		0	0	4
109	8:53:09		0	8:53:56	0:00:47		0	1	1
110	8:54:36		3	8:54:52	0:00:16		0	0	3

	A	B	C	D	E	F	G	H	I
111	8:54:54		0	8:55:41	0:00:47		0	0	0
112	8:55:18		5	8:56:36	0:01:18		0	0	5
113	8:56:39		0	8:57:27	0:00:48		0	0	0
114	8:57:57		0	8:59:12	0:01:15		0	7	7
115	9:00:09		8	9:00:24	0:00:15		2	0	6
116	Total volume								315

	J	K	L	M
1				
2				
3				
4				
5				
6				
7				
8	15 minute vol	Hourly vol		
9				
10				
11				
12	42	177	PHF	0.70
13			flow rate	252
14				
15				
16				
17				
18				
19				
20				
21				
22	47	165		
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				

	J	K	L	M
37				
38	25	161		
39				
40				
41				
42				
43				
44				
45				
46				
47				
48	63	161		
49				
50				
51				
52				
53				
54				
55				
56				
57				
58				
59				
60				
61	30	138		
62				
63				
64				
65				
66				
67				
68				
69				
70				
71				
72				
73				

	J	K	L	M
74				
75	43			
76				
77				
78				
79				
80				
81				
82				
83				
84				
85				
86				
87				
88	25			
89				
90				
91				
92				
93				
94				
95				
96				
97				
98				
99				
100				
101				
102	40			
103				
104				
105				
106				
107				
108				
109				
110				

	J	K	L	M
111				
112				
113				
114				
115				
116				

	A	B	C	D	E	F	G	H	I
1	Location:	NM 528 & Sara							
2									
3	Date:	3/17/2010							
4									
5	Approach:	NB Left PM							
6									
7									
8	Time @ Start of	Number in Queue		Time @ End of LT Green	Effective green time	Number in Queue at the end of green(Spillover)		Number that arrive after start of Green	Total number that pass on green
9	LT Green								
10		Lane 1	Lane 2			Lane 1	Lane 2		
11		(shoulder)	(median)			(shoulder)	(median)		
12	16:00:24		13	16:00:59	0:00:35		0	0	13
13	16:01:02		0	16:01:49	0:00:47		0	0	0
14	16:02:22		24	16:03:05	0:00:43		0	0	24
15	16:03:08		4	16:03:55	0:00:47		0	0	4
16	16:04:35		20	16:05:11	0:00:36		0	0	20
17	16:05:14		0	16:05:59	0:00:45		0	0	0
18	16:06:38		20	16:07:15	0:00:37		0	0	20
19	16:07:18		0	16:08:11	0:00:53		0	0	0
20	16:09:00		13	16:09:22	0:00:22		0	0	13
21	16:09:25		0	16:10:11	0:00:46		0	2	2
22	16:10:49		19	16:11:27	0:00:38		0	0	19
23	16:11:30		0	16:12:17	0:00:47		0	1	1
24	16:12:56		17	16:13:33	0:00:37		0	0	17
25	16:13:36		0	16:14:23	0:00:47		0	1	1
26	16:15:02		8	16:15:39	0:00:37		0	10	18
27	16:15:42		0	16:16:30	0:00:48		0	0	0
28	16:17:11		15	16:17:46	0:00:35		0	2	17
29	16:17:49		0	16:18:36	0:00:47		0	1	1
30	16:19:15		19	16:19:53	0:00:38		0	0	19
31	16:19:55		0	16:20:42	0:00:47		0	3	3
32	16:21:41		18	16:22:13	0:00:32		0	0	18
33	16:22:15		0	16:22:55	0:00:40		0	1	1
34	16:23:32		16	16:24:04	0:00:32		0	0	16
35	16:24:06		0	16:24:54	0:00:48		0	2	2
36	16:25:32		20	16:26:11	0:00:39		0	0	20

	A	B	C	D	E	F	G	H	I
37	16:26:13		0	16:27:00	0:00:47		0	3	3
38	16:27:42		10	16:28:16	0:00:34		0	2	12
39	16:28:18		0	16:29:06	0:00:48		0	0	0
40	16:29:46		12	16:30:23	0:00:37		0	9	21
41	16:30:25		0	16:31:13	0:00:48		0	1	1
42	16:31:46		13	16:32:30	0:00:44		0	8	21
43	16:32:32		0	16:33:19	0:00:47		0	1	1
44	16:33:56		16	16:34:36	0:00:40		0	3	19
45	16:34:38		0	16:35:25	0:00:47		0	1	1
46	16:35:55		17	16:36:38	0:00:43		0	1	18
47	16:36:41		0	16:37:28	0:00:47		0	4	4
48	16:38:24		13	16:38:47	0:00:23		0	0	13
49	16:38:49		0	16:39:35	0:00:46		0	0	0
50	16:40:15		18	16:40:52	0:00:37		0	0	18
51	16:40:54		0	16:41:41	0:00:47		0	2	2
52	16:42:19		17	16:42:58	0:00:39		0	1	18
53	16:43:00		0	16:43:46	0:00:46		0	1	1
54	16:44:26		14	16:45:04	0:00:38		0	0	14
55	16:45:06		0	16:45:52	0:00:46		0	1	1
56	16:46:33		4	16:47:10	0:00:37		0	12	16
57	16:47:12		0	16:47:59	0:00:47		0	1	1
58	16:48:38		10	16:49:15	0:00:37		0	6	16
59	16:49:17		0	16:50:05	0:00:48		0	3	3
60	16:50:46		13	16:51:22	0:00:36		0	3	16
61	16:51:24		0	16:52:11	0:00:47		0	1	1
62	16:52:50		18	16:53:28	0:00:38		0	0	18
63	16:53:30		0	16:54:17	0:00:47		0	9	9
64	16:54:58		15	16:55:34	0:00:36		0	1	16
65	16:55:36		0	16:56:23	0:00:47		0	4	4
66	16:57:01		2	16:57:40	0:00:39		0	6	8
67	16:57:43		0	16:58:31	0:00:48		0	6	6
68	16:59:09		8	16:59:45	0:00:36		0	2	10
69	16:59:48		0	17:00:36	0:00:48		0	0	0
70	17:01:10		10	17:01:53	0:00:43		0	2	12
71	17:01:55		0	17:02:41	0:00:46		0	1	1
72	17:03:14		4	17:03:59	0:00:45		0	2	6
73	17:04:01		0	17:04:49	0:00:48		0	1	1

	A	B	C	D	E	F	G	H	I
74	17:05:26		16	17:06:05	0:00:39		0	3	19
75	17:06:05		0	17:06:55	0:00:50		0	1	1
76	17:07:33		12	17:08:11	0:00:38		0	6	18
77	17:08:13		0	17:09:00	0:00:47		0	2	2
78	17:09:38		9	17:10:16	0:00:38		0	8	17
79	17:10:19		0	17:11:07	0:00:48		0	0	0
80	17:11:46		15	17:12:24	0:00:38		0	2	17
81	17:12:24		0	17:13:13	0:00:49		0	5	5
82	17:13:39		15	17:14:29	0:00:50		0	3	18
83	17:13:44		0	17:15:17	0:01:33		0	3	3
84	17:15:50		1	17:16:34	0:00:44		0	1	2
85	17:16:36		0	17:17:23	0:00:47		0	5	5
86	17:17:59		6	17:18:40	0:00:41		0	10	16
87	17:18:42		0	17:19:29	0:00:47		0	1	1
88	17:20:04		12	17:20:46	0:00:42		0	8	20
89	17:20:48		0	17:21:34	0:00:46		0	1	1
90	17:22:10		5	17:22:52	0:00:42		0	6	11
91	17:22:54		0	17:23:40	0:00:46		0	0	0
92	17:24:18		14	17:24:54	0:00:36		0	3	17
93	17:24:56		0	17:25:47	0:00:51		0	2	2
94	17:26:22		9	17:27:04	0:00:42		0	5	14
95	17:27:06		0	17:27:53	0:00:47		0	2	2
96	17:28:34		3	17:29:10	0:00:36		0	6	9
97	17:29:12		0	17:29:59	0:00:47		0	4	4
98	17:30:34		5	17:30:54	0:00:20		0	0	5
99	17:30:56		0	17:32:10	0:01:14		0	11	11
100	17:32:54		3	17:33:07	0:00:13		0	0	3
101	17:33:11		0	17:34:21	0:01:10		0	2	2
102	17:34:56		8	17:35:22	0:00:26		0	0	8
103	17:35:25		0	17:36:18	0:00:53		0	0	0
104	17:36:54		10	17:37:24	0:00:30		0	2	12
105	17:37:27		0	17:38:16	0:00:49		0	0	0
106	17:39:12		12	17:39:35	0:00:23		2	0	10
107	17:39:38		0	17:40:20	0:00:42		0	2	2
108	17:40:51		6	17:41:12	0:00:21		0	1	7
109	17:41:15		0	17:42:11	0:00:56		0	5	5
110	17:42:48		3	17:43:16	0:00:28		0	10	13

	A	B	C	D	E	F	G	H	I
111	17:43:19		0	17:44:08	0:00:49		0	2	2
112	17:45:05		10	17:45:27	0:00:22		0	1	11
113	17:45:29		0	17:46:12	0:00:43		0	0	0
114	17:46:44		12	17:47:10	0:00:26		0	0	12
115	17:47:12		0	17:48:02	0:00:50		0	0	0
116	17:48:38		13	17:49:06	0:00:28		0	0	13
117	17:49:09		0	17:49:59	0:00:50		0	2	2
118	17:50:35		5	17:50:55	0:00:20		0	0	5
119	17:50:58		0	17:51:56	0:00:58		0	5	5
120	17:52:32		10	17:53:06	0:00:34		0	2	12
121	17:53:04		0	17:53:53	0:00:49		0	5	5
122	17:54:30		2	17:54:44	0:00:14		0	0	2
123	17:54:47		0	17:55:50	0:01:03		0	0	0
124	17:56:26		16	17:56:56	0:00:30		3	0	13
125	17:56:58		0	17:57:47	0:00:49		0	0	0
126	17:58:24		13	17:58:53	0:00:29		0	3	16
127	17:58:55		0	17:59:44	0:00:49		0	3	3
128	18:00:16		12	18:00:47	0:00:31		0	0	12
129	18:00:50		0	18:01:39	0:00:49		0	0	0
130	18:02:16		0	18:03:36	0:01:20		0	4	4
131	18:04:13		7	18:04:39	0:00:26		0	2	9
132	18:04:41		0	18:05:33	0:00:52		0	5	5
133	18:06:08		2	18:06:22	0:00:14		0	4	6
134	18:07:24		0	18:07:30	0:00:06		0	0	0
135	18:08:07		10	18:08:34	0:00:27		0	2	12
136	18:08:37		0	18:09:27	0:00:50		0	4	4
137	18:10:03		4	18:10:32	0:00:29		0	6	10
138	17:10:35		0	18:11:24	1:00:49		0	3	3
139	18:12:00		1	18:12:12	0:00:12		0	2	3
140	18:12:14		0	18:13:21	0:01:07		0	7	7
141	18:13:58		2	18:14:24	0:00:26		0	6	8
142	18:14:26		0	18:15:18	0:00:52		0	2	2
143	18:15:49		3	18:16:05	0:00:16		0	0	3
144	18:16:08		0	18:17:16	0:01:08		0	9	9
145	18:17:53		10	18:18:20	0:00:27		0	0	10
146	18:18:23		0	18:19:12	0:00:49		0	9	9
147	18:19:48		1	18:20:00	0:00:12		0	0	1

	A	B	C	D	E	F	G	H	I
148	18:20:03		0	18:21:10	0:01:07		0	10	10
149	18:21:45		1	18:23:07	0:01:22		0	3	4
150	18:23:41		10	18:24:12	0:00:31		0	2	12
151	18:24:15		0	18:25:04	0:00:49		0	6	6
152	18:25:39		8	18:26:07	0:00:28		0	0	8
153	18:26:10		0	18:27:01	0:00:51		0	2	2
154	18:27:18		0	18:28:58	0:01:40		0	4	4
155	18:29:33		4	18:29:54	0:00:21		0	0	4
156	18:29:57		0	18:30:55	0:00:58		0	2	2
157	Total volume								1113

	A	B	C	D	E	F	G	H	I	J
1	Location:	NM 528 & Sara								
2										
3	Date:	3/17/2010								
4										
5	Approach:	SB Left AM (Permitted/Protected Phase)								
6										
7										
8	Time @ Start of	Number in Queue		Time @ End of LT Green	Effective green time	Number in Queue at the end of green(Spillover)		Number that arrive after start of Green	Total number that pass on green	
9	LT Green					Lane 1	Lane 2			
10		Lane 1	Lane 2			Lane 1	Lane 2			
11		(shoulder)	(median)			(shoulder)	(median)			
12	7:00:00		2	7:01:32	0:01:32		0	0	2	
13	7:02:00		2	7:03:20	0:01:20		0	0	2	
14	7:03:59		1	7:05:07	0:01:08		0	0	1	
15	7:05:53		1	7:06:54	0:01:01		0	0	1	
16	7:07:55		2	7:08:41	0:00:46		0	0	2	
17	7:09:09		1	7:10:30	0:01:21		0	0	1	
18	7:11:16		1	7:12:18	0:01:02		0	0	1	
19	7:12:49		1	7:14:06	0:01:17		0	0	1	
20	7:14:41		1	7:14:52	0:00:11		0	0	1	
21	7:14:59		2	7:15:54	0:00:55		0	0	2	
22	7:16:43		0	7:17:43	0:01:00		0	0	0	
23	7:18:34		0	7:19:31	0:00:57		0	0	0	
24	7:20:29		1	7:21:19	0:00:50		0	0	1	
25	7:22:08		0	7:23:07	0:00:59		0	0	0	
26	7:23:58		1	7:24:54	0:00:56		0	0	1	
27	7:25:28		1	7:25:40	0:00:12		0	0	1	
28	7:25:47		1	7:26:43	0:00:56		0	0	1	
29	7:27:13		1	7:27:26	0:00:13		0	0	1	
30	7:27:29		0	7:28:32	0:01:03		0	0	0	
31	7:29:00		0	7:30:20	0:01:20		0	0	0	
32	7:30:53		1	7:32:08	0:01:15		0	0	1	
33	7:32:40		1	7:33:56	0:01:16		0	0	1	
34	7:34:28		1	7:35:43	0:01:15		0	0	1	
35	7:36:20		2	7:36:29	0:00:09		0	0	2	
36	7:36:38		2	7:37:30	0:00:52		0	0	2	
37	7:38:04		0	7:38:12	0:00:08		0	0	0	
38	7:38:04		0	7:39:18	0:01:14		0	0	0	

	A	B	C	D	E	F	G	H	I	J
39	7:39:54		1	7:40:04	0:00:10		0	0	1	
40	7:39:54		0	7:41:06	0:01:12		0	0	0	
41	7:41:37		0	7:42:54	0:01:17		0	0	0	
42	7:43:54		0	7:44:42	0:00:48		0	0	0	
43	7:45:20		3	7:46:31	0:01:11		0	0	3	
44	7:47:08		1	7:48:19	0:01:11		0	0	1	
45	7:49:10		2	7:50:07	0:00:57		0	0	2	
46	7:50:40		0	7:51:55	0:01:15		0	0	0	
47	7:52:47		2	7:53:43	0:00:56		0	0	2	
48	7:54:18		0	7:55:32	0:01:14		0	0	0	
49	7:56:10		2	7:56:19	0:00:09		0	0	2	
50	7:56:10		0	7:57:20	0:01:10		0	0	0	
51	7:58:18		2	7:59:07	0:00:49		0	0	2	
52	7:59:44		1	7:59:52	0:00:08		0	0	1	
53	8:00:03		2	8:01:00	0:00:57		0	0	2	
54	8:01:52		0	8:03:06	0:01:14		0	0	0	
55	8:03:43		0	8:04:57	0:01:14		0	0	0	
56	8:05:50		0	8:06:43	0:00:53		0	0	0	
57	8:07:09		1	8:08:28	0:01:19		0	0	1	
58	8:09:38		0	8:10:13	0:00:35		0	0	0	
59	8:10:47		2	8:11:59	0:01:12		0	0	2	
60	8:12:52		1	8:13:43	0:00:51		0	0	1	
61	8:14:16		2	8:15:29	0:01:13		0	0	2	
62	8:16:20		0	8:17:14	0:00:54		0	0	0	
63	8:18:06		1	8:18:59	0:00:53		0	0	1	
64	8:19:30		1	8:20:44	0:01:14		0	0	1	
65	8:21:29		0	8:22:29	0:01:00		0	0	0	
66	8:23:27		0	8:24:13	0:00:46		0	0	0	
67	8:24:41		0	8:25:58	0:01:17		0	0	0	
68	8:25:09		1	8:27:41	0:02:32		0	0	1	
69	8:26:26		1	8:28:30	0:02:04		0	0	1	
70	8:28:17		2	8:29:26	0:01:09		0	0	2	
71	8:28:17		1	8:31:12	0:02:55		0	0	1	
72	8:32:11		0	8:32:57	0:00:46		0	0	0	
73	8:33:38		1	8:33:46	0:00:08		0	0	1	*
74	8:33:53		1	8:34:41	0:00:48		0	0	1	
75	8:35:40		1	8:36:27	0:00:47		0	0	1	
76	8:37:01		0	8:38:12	0:01:11		0	0	0	
77	8:38:53		1	8:39:02	0:00:09		0	0	1	*

	A	B	C	D	E	F	G	H	I	J
78	8:39:09		0	8:39:57	0:00:48		0	0	0	
79	8:40:37		1	8:40:47	0:00:10		0	0	1	*
80	8:40:37		4	8:41:43	0:01:06		0	0	4	
81	8:42:34		2	8:43:28	0:00:54		0	0	2	
82	8:44:00		0	8:45:13	0:01:13		0	0	0	
83	8:45:51		1	8:46:58	0:01:07		0	0	1	
84	8:47:49		1	8:48:44	0:00:55		0	0	1	
85	8:49:26		1	8:49:35	0:00:09		0	0	1	*
86	8:49:42		1	8:50:28	0:00:46		0	0	1	
87	8:50:43		1	8:52:11	0:01:28		0	0	1	
88	8:52:50		1	8:53:00	0:00:10		0	0	1	*
89	8:53:09		0	8:53:56	0:00:47		0	0	0	
90	8:54:36		1	8:54:45	0:00:09		0	0	1	*
91	8:54:54		0	8:55:41	0:00:47		0	0	0	
92	8:56:18		2	8:56:31	0:00:13		0	0	2	*
93	8:56:39		1	8:57:27	0:00:48		0	0	1	
94	8:57:57		2	8:59:11	0:01:14		0	0	2	
95	9:00:09		1	9:00:18	0:00:09		0	0	1	
96	Total volume								79	
97		* Left turn phase								

	A	B	C	D	E	F	G	H	I	J	K
1	Location:	NM 528 & Sara									
2											
3	Date:	3/17/2010									
4											
5	Approach:	SB Left PM (Permitted/Protected Phase)									
6											
7											
8	Time @ Start of	Number in Queue		Time @ End of LT Green	Effective green time	Number in Queue at the end of green(Spillover)		Number that arrive after start of Green	Total number that pass on green		15 minute vol
9	LT Green										
10		Lane 1	Lane 2			Lane 1	Lane 2				
11		(shoulder)	(median)			(shoulder)	(median)				
12	16:00:24		1	16:00:34	0:00:10		0	0	1	*	4
13	16:01:02		0	16:01:49	0:00:47		0	0	0		
14	16:03:08		0	16:03:55	0:00:47		0	0	0		
15	16:05:14		0	16:05:59	0:00:45		0	1	1		
16	16:07:18		0	16:08:05	0:00:47		0	0	0		
17	16:09:25		0	16:10:11	0:00:46		0	0	0	*	
18	16:10:52		0	16:11:02	0:00:10		0	1	1		
19	16:11:30		0	16:12:17	0:00:47		0	0	0		
20	16:13:36		0	16:14:23	0:00:47		0	0	0		
21	16:15:42		0	16:16:30	0:00:48		0	1	1		7
22	16:17:49		0	16:18:36	0:00:47		0	1	1		
23	16:19:55		0	16:20:42	0:00:47		0	0	0		
24	16:21:41		0	16:21:50	0:00:09		0	1	1	*	
25	16:22:15		0	16:22:55	0:00:40		0	1	1		
26	16:23:30		1	16:23:39	0:00:09		0	0	1		
27	16:24:07		0	16:24:54	0:00:47		0	0	0		
28	16:26:13		1	16:27:01	0:00:48		0	0	1		
29	16:27:42		1	16:27:51	0:00:09		0	0	1	*	
30	16:28:19		0	16:29:06	0:00:47		0	0	0		
31	16:30:25		0	16:31:13	0:00:48		0	0	0		7
32	16:31:46		1	16:31:57	0:00:11		0	0	1	*	
33	16:32:32		1	16:33:19	0:00:47		0	0	1		
34	16:34:38		0	16:35:23	0:00:45		0	0	0		
35	16:35:56		1	16:36:08	0:00:12		0	0	1	*	
36	16:36:41		1	16:37:28	0:00:47		0	0	1		
37	16:38:49		0	16:39:34	0:00:45		0	0	0		
38	16:40:53		1	16:41:40	0:00:47		0	0	1		
39	16:43:00		0	16:43:46	0:00:46		0	2	2		
40	16:45:06		1	16:45:52	0:00:46		0	0	1		9
41	16:47:12		1	16:47:58	0:00:46		0	0	1		

	A	B	C	D	E	F	G	H	I	J	K
42	16:49:17		2	16:50:05	0:00:48		0	0	2		
43	16:50:46		1	16:50:56	0:00:10		0	0	1		
44	16:51:24		1	16:52:11	0:00:47		0	0	1		
45	16:53:30		1	16:54:17	0:00:47		0	0	1		
46	16:55:36		0	16:56:23	0:00:47		0	0	0		
47	16:57:42		2	16:58:29	0:00:47		0	0	2		
48	16:59:48		0	17:00:36	0:00:48		0	0	0		
49	17:01:10		1	17:01:23	0:00:13		0	0	1		6
50	17:01:55		0	17:02:41	0:00:46		0	0	0		
51	17:03:14		1	17:03:26	0:00:12		0	0	1	*	
52	17:04:01		0	17:04:48	0:00:47		0	0	0		
53	17:06:08		1	17:06:54	0:00:46		0	0	1		
54	17:08:13		0	17:09:00	0:00:47		0	0	0		
55	17:09:39		1	17:10:16	0:00:37		0	0	1	*	
56	17:10:19		0	17:11:07	0:00:48		0	0	0		
57	17:12:25		2	17:13:13	0:00:48		0	0	2		
58	17:14:32		0	17:15:17	0:00:45		0	0	0		
59	17:16:36		1	17:17:23	0:00:47		0	0	1		6
60	17:18:00		0	17:18:40	0:00:40		0	0	0	*	
61	17:18:41		1	17:19:29	0:00:48		0	0	1		
62	17:20:48		1	17:21:34	0:00:46		0	0	1		
63	17:22:10		1	17:22:52	0:00:42		0	0	1	*	
64	17:22:54		1	17:23:40	0:00:46		0	0	1		
65	17:24:18		1	17:24:54	0:00:36		0	0	1		
66	17:24:59		0	17:25:47	0:00:48		0	0	0		
67	17:27:06		0	17:27:53	0:00:47		0	0	0		
68	17:28:34		0	17:29:10	0:00:36		0	0	0	*	
69	17:29:12		0	17:29:59	0:00:47		0	0	0		
70	17:30:35		1	17:30:54	0:00:19		0	0	1		6
71	17:30:56		1	17:32:10	0:01:14		0	0	1		
72	17:32:54		0	17:33:09	0:00:15		0	0	0	*	
73	17:33:11		0	17:34:21	0:01:10		0	0	0		
74	17:34:56		1	17:35:22	0:00:26		0	0	1		
75	17:35:24		0	17:36:18	0:00:54		0	0	0		
76	17:36:54		0	17:37:02	0:00:08		0	0	0		
77	17:37:27		0	17:38:17	0:00:50		0	0	0		

	A	B	C	D	E	F	G	H	I	J	K
78	17:39:13		0	17:39:22	0:00:09		0	0	0	*	
79	17:39:37		0	17:40:20	0:00:43		0	0	0		
80	17:40:52		0	17:41:01	0:00:09		0	0	0	*	
81	17:41:16		0	17:42:11	0:00:55		0	0	0		
82	17:42:48		0	17:42:57	0:00:09		0	0	0	*	
83	17:43:19		3	17:44:08	0:00:49		0	0	3		
84	17:45:05		0	17:45:13	0:00:08		0	0	0	*	6
85	17:45:30		2	17:46:12	0:00:42		0	0	2		
86	17:46:44		1	17:46:54	0:00:10		0	0	1	*	
87	17:47:12		0	17:48:02	0:00:50		0	0	0		
88	17:48:38		2	17:48:51	0:00:13		0	0	2	*	
89	17:49:09		0	17:49:59	0:00:50		0	0	0		
90	17:50:58		0	17:51:56	0:00:58		0	0	0		
91	17:53:04		0	17:53:54	0:00:50		0	0	0		
92	17:54:47		0	17:55:50	0:01:03		0	0	0		
93	17:56:58		0	17:57:49	0:00:51		0	0	0		
94	17:58:24		1	17:58:36	0:00:12		0	0	1	*	
95	17:58:55		0	17:59:44	0:00:49		0	0	0		
96	18:00:50		0	18:01:39	0:00:49		0	0	0		5
97	18:02:16		2	18:03:36	0:01:20		0	0	2		
98	18:04:13		1	18:04:25	0:00:12		0	0	1	*	
99	18:04:41		0	18:05:33	0:00:52		0	0	0		
100	18:06:24		1	18:07:30	0:01:06		0	0	1		
101	18:08:37		0	18:09:27	0:00:50		0	0	0		
102	17:10:35		0	18:11:24	1:00:49		0	0	0		
103	18:12:14		0	18:13:22	0:01:08		0	0	0		
104	18:13:58		1	18:14:10	0:00:12		0	0	1	*	
105	18:14:26		0	18:15:18	0:00:52		0	0	0		
106	18:16:08		0	18:17:16	0:01:08		0	0	0		5
107	18:17:53		1	18:18:05	0:00:12		0	0	1	*	
108	18:18:23		0	18:19:13	0:00:50		0	0	0		
109	18:20:03		0	18:21:10	0:01:07		0	0	0		
110	18:21:46		1	18:21:58	0:00:12		0	0	1		
111	18:21:46		0	18:23:07	0:01:21		0	0	0	*	
112	18:24:15		1	18:25:05	0:00:50		0	0	1		
113	18:26:10		1	18:27:01	0:00:51		0	0	1		
114	18:27:17		1	18:27:28	0:00:11		0	0	1	*	
115	18:27:17		0	18:28:58	0:01:41		0	0	0		
116	18:29:57		0	18:30:55	0:00:58		0	0	0		
117	Total volume								60		
118		* Left turn phase									

	L	M	N
1			
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7			
8	Hourly vol		
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11			
12	27		
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14			
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16			
17			
18			
19			
20			
21	29	PHF	0.81
22		flow rate	36
23			
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30			
31	28		
32			
33			
34			
35			
36			
37			
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40	27		
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	A	B	C	D	E	F	G	H	I
1	Location:	NM 528 & Westside							
2									
3	Date:	3/24/2010							
4									
5	Approach:	SB Left AM							
6									
7									
8	Time @ Start of	Number in Queue		Time @ End of	Effective green	Number in Queue at the		Number that arrive after	Total number
9	LT Green			LT Green	time	end of green(Spillover)			
10		Lane 1	Lane 2			Lane 1	Lane 2		
11		(shoulder)	(median)			(shoulder)	(median)		
12	7:00:05	1	0	7:00:17	0:00:12	0	0	0	1
13	7:04:11	3	0	7:04:31	0:00:20	0	0	2	5
14	7:10:40	1	0	7:10:54	0:00:14	0	0	1	2
15	7:12:46	2	0	7:12:59	0:00:13	0	0	1	3
16	7:16:08	2	0	7:16:21	0:00:13	0	0	0	2
17	7:17:56	2	0	7:18:09	0:00:13	0	0	0	2
18	7:21:49	0	1	7:22:01	0:00:12	0	0	1	2
19	7:23:33	2	1	7:23:46	0:00:13	0	0	0	3
20	7:27:07	1	0	7:27:19	0:00:12	0	0	1	2
21	7:30:33	1	0	7:30:48	0:00:15	0	0	0	1
22	7:32:33	1	0	7:32:45	0:00:12	0	0	0	1
23	7:34:09	2	0	7:34:27	0:00:18	0	0	1	3
24	7:37:42	1	0	7:37:58	0:00:16	0	0	1	2
25	7:39:42	3	0	7:39:58	0:00:16	0	0	0	3
26	7:41:38	1	0	7:41:51	0:00:13	0	0	0	1
27	7:48:11	3	0	7:48:28	0:00:17	0	0	0	3
28	7:50:14	1	0	7:50:45	0:00:31	0	0	0	1
29	7:52:33	4	0	7:52:53	0:00:20	0	0	1	5
30	7:55:04	3	0	7:55:14	0:00:10	0	0	0	3
31	7:58:51	3	1	7:59:05	0:00:14	0	0	0	4
32	8:03:11	1	0	8:03:26	0:00:15	0	0	0	1
33	8:08:43	3	0	8:08:58	0:00:15	0	0	1	4
34	8:10:51	1	0	8:11:02	0:00:11	0	0	0	1
35	8:12:25	1	1	8:12:36	0:00:11	0	0	0	2
36	8:14:10	1	0	8:14:21	0:00:11	0	0	1	2
37	8:19:49	1	1	8:20:00	0:00:11	0	0	1	3
38	8:23:48	1	0	8:24:01	0:00:13	0	0	0	1
39	8:28:12	2	0	8:28:25	0:00:13	0	0	0	2
40	8:33:26	1	0	8:33:38	0:00:12	0	0	0	1
41	8:36:39	0	2	8:36:52	0:00:13	0	0	0	2

	A	B	C	D	E	F	G	H	I
42	8:40:25	0	2	8:40:42	0:00:17	0	0	1	3
43	8:43:45	1	1	8:43:58	0:00:13	0	0	0	2
44	8:47:11	0	1	8:47:27	0:00:16	0	0	0	1
45	8:49:20	2	0	8:49:34	0:00:14	0	0	0	2
46	8:50:56	1	0	8:51:11	0:00:15	0	0	0	1
47	8:59:24	1	0	8:59:37	0:00:13	0	0	0	1
48	9:01:32	1	1	9:01:36	0:00:04	0	0	0	2
49	Total volume								80

	A	B	C	D	E	F	G	H	I
1	Location:	NM 528 & Westside							
2									
3	Date:	3/24/2010							
4									
5	Approach:	WB Left AM							
6									
7									
8	Time @ Start of	Number in Queue		Time @ End of	Effective green	Number in Queue at the		Number that arrive after	Total number
9	LT Green			LT Green	time	end of green(Spillover)			
10		Lane 1	Lane 2			Lane 1	Lane 2		
11		(shoulder)	(median)			(shoulder)	(median)		
12	7:01:32	0	1	7:01:44	0:00:12	0	0	0	1
13	7:03:42	1	0	7:03:53	0:00:11	0	0	0	1
14	7:08:01	1	0	7:08:11	0:00:10	0	0	0	1
15	7:12:14	1	1	7:12:25	0:00:11	0	0	0	2
16	7:14:02	0	0	7:14:14	0:00:12	0	0	0	0
17	7:15:51	1	0	7:16:05	0:00:14	0	0	0	0
18	7:19:27	1	0	7:19:35	0:00:08	0	0	1	2
19	7:23:03	2	0	7:23:18	0:00:15	0	0	0	1
20	7:24:51	1	0	7:25:04	0:00:13	0	0	0	2
21	7:28:27	0	1	7:28:38	0:00:11	0	0	0	1
22	7:32:03	1	1	7:32:16	0:00:13	0	0	0	1
23	7:35:39	1	1	7:35:53	0:00:14	0	0	0	2
24	7:39:15	1	0	7:39:26	0:00:11	0	0	0	2
25	7:47:35	1	0	7:47:46	0:00:11	0	0	0	1
26	7:49:45	1	2	7:49:58	0:00:13	0	0	0	3
27	7:51:58	0	0	7:52:08	0:00:10	0	0	0	0
28	7:54:06	1	0	7:54:23	0:00:17	0	0	0	1
29	7:58:25	1	0	7:58:36	0:00:11	0	0	0	1
30	8:00:37	1	0	8:00:48	0:00:11	0	0	0	1
31	8:02:42	0	1	8:02:56	0:00:14	0	0	2	3
32	8:08:27	2	0	8:08:40	0:00:13	0	0	0	2
33	8:10:12	1	1	8:10:24	0:00:12	0	0	0	2
34	8:11:57	2	1	8:12:10	0:00:13	0	0	0	3
35	8:13:42	1	0	8:13:55	0:00:13	0	0	1	2
36	8:17:14	0	1	8:17:42	0:00:28	0	0	1	2

	A	B	C	D	E	F	G	H	I
37	8:19:20	1	0	8:19:33	0:00:13	0	0	0	1
38	8:21:26	0	1	8:27:37	0:06:11	0	0	0	1
39	8:25:37	2	1	8:26:08	0:00:31	0	0	0	3
40	8:29:24	1	0	8:29:36	0:00:12	0	0	0	1
41	8:32:54	1	0	8:33:06	0:00:12	0	0	0	1
42	8:34:39	2	2	8:34:52	0:00:13	0	0	0	4
43	8:36:24	3	0	8:36:37	0:00:13	0	0	0	3
44	8:38:09	0	2	8:38:22	0:00:13	0	0	1	3
45	8:39:54	1	1	8:40:22	0:00:28	0	0	0	2
46	8:41:40	1	0	8:41:51	0:00:11	0	0	1	2
47	8:45:09	2	2	8:45:22	0:00:13	0	0	0	4
48	8:48:39	2	2	8:48:52	0:00:13	0	0	0	4
49	8:50:24	1	1	8:50:37	0:00:13	0	0	2	4
50	8:52:10	1	0	8:52:20	0:00:10	0	0	1	2
51	8:53:55	1	1	8:54:06	0:00:11	0	0	0	2
52	8:55:41	1	0	8:55:51	0:00:10	0	0	0	1
53	8:57:26	0	1	8:57:37	0:00:11	0	0	0	1
54	8:59:11	1	1	8:59:27	0:00:16	0	0	0	2
55	Total volume								78
56		28	19		56			9	
57		33	24						
58	Lane Utilization Factor(fLU)	0.862							

	J	K	L	M
1				
2				
3				
4				
5				
6				
7				
8	15 minute vol	Hourly vol		
9				
10				
11				
12	5	22		
13				
14				
15				
16				
17	6	30		
18				
19				
20				
21				
22	5	32		
23				
24				
25	6	42		
26				
27				
28				
29				
30	13	56	PHF	0.7
31			flow rate	80
32				
33				
34				
35				
36	8			

	J	K	L	M
37				
38				
39				
40				
41	15			
42				
43				
44				
45				
46				
47	20			
48				
49				
50				
51				
52				
53				
54				
55				
56				
57				
58				

	A	B	C	D	E	F	G	H	I
1	Location:	NM 528 & Westside							
2									
3	Date:	3/24/2010							
4									
5	Approach:	WB Left PM							
6									
7									
8	Time @ Start of	Number in Queue		Time @ End of	Effective green	Number in Queue at the		Number that arrive after	Total number
9	LT Green			LT Green	time	end of green(Spillover)			
10		Lane 1	Lane 2			Lane 1	Lane 2		
11		(shoulder)	(median)			(shoulder)	(median)		
12	16:00:32	3	2	16:01:06	0:00:34	0	0	0	5
13	16:02:43	3	1	16:03:06	0:00:23	0	0	0	4
14	16:04:44	2	4	16:05:27	0:00:43	0	0	3	9
15	16:06:48	2	2	16:07:12	0:00:24	0	0	2	6
16	16:08:59	3	3	16:09:17	0:00:18	0	0	1	7
17	16:10:59	3	1	16:11:15	0:00:16	0	0	0	4
18	16:13:06	3	3	16:13:25	0:00:19	0	0	1	7
19	16:15:17	2	1	16:15:30	0:00:13	0	0	1	4
20	16:17:23	4	2	16:17:41	0:00:18	0	0	0	6
21	16:19:29	2	3	16:19:46	0:00:17	0	0	0	5
22	16:21:35	2	0	16:21:49	0:00:14	0	0	0	2
23	16:23:37	2	1	16:23:50	0:00:13	0	0	0	3
24	16:25:47	2	1	16:26:05	0:00:18	0	0	1	4
25	16:27:53	3	0	16:28:13	0:00:20	0	0	1	4
26	16:29:54	1	1	16:30:07	0:00:13	0	0	0	2
27	16:32:05	3	4	16:32:22	0:00:17	0	0	0	7
28	16:34:11	4	2	16:34:30	0:00:19	0	0	2	8
29	16:36:12	2	0	16:36:45	0:00:33	0	0	0	2
30	16:38:18	2	1	16:38:42	0:00:24	0	0	0	3
31	16:40:24	1	1	16:40:40	0:00:16	0	0	0	2
32	16:42:36	2	2	16:43:33	0:00:57	0	0	2	6
33	16:44:42	2	1	16:44:58	0:00:16	0	0	1	4
34	16:46:43	2	1	16:47:30	0:00:47	0	0	3	6
35	16:48:54	2	0	16:49:10	0:00:16	0	0	0	2
36	16:51:06	3	1	16:51:30	0:00:24	0	0	1	5

	A	B	C	D	E	F	G	H	I
37	16:53:03	4	2	16:53:27	0:00:24	0	0	0	6
38	16:55:09	3	0	16:55:28	0:00:19	0	0	1	4
39	16:57:11	2	0	16:57:29	0:00:18	0	0	1	3
40	16:59:17	2	0	16:59:36	0:00:19	0	0	0	2
41	17:01:27	3	0	17:01:44	0:00:17	0	0	0	3
42	17:03:29	1	1	17:03:57	0:00:28	0	0	1	3
43	17:05:40	3	2	17:05:58	0:00:18	0	0	2	7
44	17:07:47	2	2	17:08:00	0:00:13	0	0	2	6
45	17:09:48	0	1	17:10:13	0:00:25	0	0	3	4
46	17:11:58	1	0	17:12:15	0:00:17	0	0	0	1
47	17:14:00	1	0	17:14:16	0:00:16	0	0	0	1
48	17:16:06	4	2	17:16:24	0:00:18	0	0	0	6
49	17:18:17	1	0	17:18:33	0:00:16	0	0	0	1
50	17:22:30	1	1	17:22:42	0:00:12	0	0	0	2
51	17:24:31	1	0	17:24:49	0:00:18	0	0	1	2
52	17:26:42	1	2	17:27:08	0:00:26	0	0	0	3
53	17:28:43	1	0	17:29:10	0:00:27	0	0	0	1
54	17:31:27	1	1	17:31:40	0:00:13	0	0	0	2
55	17:33:40	1	1	17:33:59	0:00:19	0	0	0	2
56	17:36:07	3	3	17:36:36	0:00:29	0	0	2	8
57	17:42:06	1	1	17:42:20	0:00:14	0	0	0	2
58	17:45:58	3	1	17:46:22	0:00:24	0	0	0	4
59	17:47:55	1	0	17:48:09	0:00:14	0	0	1	2
60	17:50:04	1	0	17:50:16	0:00:12	0	0	0	1
61	17:51:55	1	0	17:52:04	0:00:09	0	0	0	1
62	17:53:47	1	2	17:54:09	0:00:22	0	0	0	3
63	17:55:44	1	0	17:56:09	0:00:25	0	0	0	1
64	17:57:41	1	0	17:58:09	0:00:28	0	0	0	1
65	17:59:38	1	0	17:59:49	0:00:11	0	0	0	1
66	18:01:35	1	0	18:01:46	0:00:11	0	0	0	1
67	18:03:32	3	0	18:04:29	0:00:57	0	0	3	6
68	18:08:26	2	2	18:08:41	0:00:15	0	0	1	5
69	18:10:47	2	0	18:11:04	0:00:17	0	0	0	2
70	18:13:07	4	2	18:13:24	0:00:17	0	0	0	6
71	18:15:15	1	1	18:15:26	0:00:11	0	0	0	2
72	18:17:12	5	3	18:17:30	0:00:18	0	0	0	8
73	18:19:09	2	0	18:19:22	0:00:13	0	0	0	2

	A	B	C	D	E	F	G	H	I
74	18:21:07	3	4	18:21:23	0:00:16	0	0	0	7
75	18:23:03	1	0	18:23:15	0:00:12	0	0	0	1
76	18:25:00	2	3	18:25:14	0:00:14	0	0	0	5
77	18:26:55	0	2	18:27:07	0:00:12	0	0	1	3
78	18:28:51	0	1	18:29:17	0:00:26	0	0	0	1
79	Total volume								249
80		71	40		132			21	
81		82	51						
82	Lane Utilization Factor(fLU)	0.810							

	J	K	L	M
1				
2				
3				
4				
5				
6				
7				
8	15 minute vol	Hourly vol		
9				
10				
11				
12	42	132	PHF	0.79
13			flow rate	168
14				
15				
16				
17				
18				
19	30	115		
20				
21				
22				
23				
24				
25				
26				
27	32	100		
28				
29				
30				
31				
32				
33				
34	28	82		
35				
36				

	J	K	L	M
37				
38				
39				
40				
41	25	68		
42				
43				
44				
45				
46				
47				
48	15	63		
49				
50				
51				
52				
53				
54	14	77		
55				
56				
57				
58	14			
59				
60				
61				
62				
63				
64				
65				
66	20			
67				
68				
69				
70				
71	29			
72				
73				

	J	K	L	M
74				
75				
76				
77				
78				
79				
80				
81				
82				

	A	B	C	D	E	F	G	H	I
1	Location:	NM 528 & Westside							
2									
3	Date:	3/24/2010							
4									
5	Approach:	NB Left PM							
6									
7									
8	Time @ Start of	Number in Queue		Time @ End of LT Green	Effective green time	Number in Queue at the end of green(Spillover)		Number that arrive after start of Green	Total number that pass on green
9	LT Green								
10		Lane 1	Lane 2			Lane 1	Lane 2		
11		(shoulder)	(median)			(shoulder)	(median)		
12	16:01:10	5	8	16:01:44	0:00:34	0	0	3	16
13	16:03:09	5	10	16:03:42	0:00:33	0	0	4	19
14	16:05:30	7	9	16:05:56	0:00:26	0	0	1	17
15	16:07:16	3	6	16:07:39	0:00:23	0	0	1	10
16	16:09:39	10	9	16:10:07	0:00:28	0	0	0	19
17	16:11:33	7	10	16:12:04	0:00:31	0	0	0	17
18	16:13:49	6	9	16:14:19	0:00:30	0	0	2	17
19	16:15:48	7	9	16:16:13	0:00:25	0	0	0	16
20	16:18:02	3	6	16:18:22	0:00:20	0	0	0	9
21	16:20:03	3	10	16:20:38	0:00:35	0	0	6	19
22	16:22:21	4	7	16:22:44	0:00:23	0	0	0	11
23	16:24:23	8	10	16:24:51	0:00:28	0	0	0	18
24	16:26:20	4	6	16:26:40	0:00:20	0	0	0	10
25	16:28:35	7	10	16:29:03	0:00:28	0	0	0	17
26	16:30:27	3	11	16:31:09	0:00:42	0	0	2	16
27	16:32:40	6	9	16:33:15	0:00:35	0	0	2	17
28	16:34:45	4	8	16:35:08	0:00:23	0	0	0	12
29	16:36:48	8	11	16:37:28	0:00:40	0	0	9	28
30	16:38:46	6	7	16:39:07	0:00:21	0	0	1	14
31	16:40:43	8	14	16:41:39	0:00:56	0	0	6	28
32	16:43:36	5	8	16:43:57	0:00:21	0	0	0	13
33	16:45:24	9	7	16:45:51	0:00:27	0	0	0	16
34	16:47:34	6	11	16:47:57	0:00:23	0	0	0	17
35	16:49:54	4	7	16:50:15	0:00:21	0	0	0	11
36	16:51:33	0	10	16:52:07	0:00:34	0	0	1	11

	A	B	C	D	E	F	G	H	I
37	16:53:30	4	9	16:54:04	0:00:34	0	0	3	16
38	16:55:44	4	11	16:56:14	0:00:30	0	0	0	15
39	16:57:45	3	5	16:58:09	0:00:24	0	0	0	8
40	16:59:54	5	10	17:00:29	0:00:35	0	0	1	16
41	17:02:01	3	6	17:02:23	0:00:22	0	0	2	11
42	17:04:00	2	9	17:04:35	0:00:35	0	0	0	11
43	17:06:14	3	6	17:06:48	0:00:34	0	0	3	12
44	17:08:19	3	9	17:08:45	0:00:26	0	0	1	13
45	17:10:16	7	8	17:10:48	0:00:32	0	0	2	17
46	17:12:32	5	9	17:12:57	0:00:25	0	0	0	14
47	17:14:51	6	6	17:15:13	0:00:22	0	0	2	14
48	17:16:46	0	4	17:17:03	0:00:17	0	0	0	4
49	17:18:49	6	10	17:19:18	0:00:29	0	0	0	16
50	17:20:36	2	4	17:20:52	0:00:16	0	0	0	6
51	17:23:04	8	11	17:23:33	0:00:29	0	0	0	19
52	17:25:05	2	10	17:25:41	0:00:36	0	0	3	15
53	17:27:12	2	4	17:27:29	0:00:17	0	0	0	6
54	17:29:13	1	6	17:29:35	0:00:22	0	0	1	8
55	17:33:19	7	11	17:33:44	0:00:25	0	0	3	21
56	17:35:39	5	5	17:36:04	0:00:25	0	0	1	11
57	17:37:49	5	6	17:38:09	0:00:20	0	0	0	11
58	17:39:46	4	7	17:40:05	0:00:19	0	0	4	15
59	17:41:43	2	6	17:42:03	0:00:20	0	0	1	9
60	17:43:40	5	6	17:44:00	0:00:20	0	0	0	11
61	17:45:37	3	9	17:45:55	0:00:18	0	0	1	13
62	17:47:32	2	4	17:47:51	0:00:19	0	0	1	7
63	17:49:41	3	7	17:50:00	0:00:19	0	0	0	10
64	17:51:32	0	3	17:51:49	0:00:17	0	0	1	4
65	17:53:24	6	8	17:53:43	0:00:19	0	0	0	14
66	17:55:20	2	3	17:55:41	0:00:21	0	0	2	7
67	17:57:18	4	7	17:57:38	0:00:20	0	0	1	12
68	17:59:15	1	2	17:59:35	0:00:20	0	0	4	7
69	18:03:09	1	4	18:03:29	0:00:20	0	0	7	12
70	18:05:38	1	5	18:06:03	0:00:25	0	0	1	7
71	18:07:59	2	3	18:08:23	0:00:24	0	0	1	6
72	18:12:39	3	5	18:13:04	0:00:25	0	0	3	11
73	18:14:52	2	8	18:15:12	0:00:20	0	0	0	10

	A	B	C	D	E	F	G	H	I
74	18:16:49	1	7	18:17:07	0:00:18	0	0	1	9
75	18:18:46	3	6	18:19:06	0:00:20	0	0	1	10
76	18:20:43	7	9	18:21:03	0:00:20	0	0	0	16
77	18:22:40	1	3	18:23:00	0:00:20	0	0	0	4
78	18:24:37	2	6	18:24:57	0:00:20	0	0	0	8
79	18:26:34	3	10	18:26:52	0:00:18	0	2	1	12
80	18:28:28	4	9	18:28:48	0:00:20	0	1	1	13
81	18:30:25	4	3	18:30:45	0:00:20	0	0	0	7
82	Total volume								896
83		154	257		453			42	
84		175	278						
85	Lane Utilization Factor(fLU)	0.815							

	J	K	L	M
1				
2				
3				
4				
5				
6				
7				
8	15 minute vol	Hourly vol		
9				
10				
11				
12	115	453	PHF	0.88
13			flow rate	512
14				
15				
16				
17				
18				
19	100	430		
20				
21				
22				
23				
24				
25				
26	128	404		
27				
28				
29				
30				
31				
32				
33	110	354		
34				
35				
36				

	J	K	L	M
37				
38				
39				
40				
41	92	318		
42				
43				
44				
45				
46				
47				
48	74	272		
49				
50				
51				
52				
53				
54				
55	78	277		
56				
57				
58				
59				
60				
61	74			
62				
63				
64				
65				
66				
67				
68				
69	46			
70				
71				
72				
73				

	J	K	L	M
74	79			
75				
76				
77				
78				
79				
80				
81				
82				
83				
84				
85				

Traffic Models Predicted Left Turn Queue Lengths								
Intersection	Traffic Models							
	Synchro		Simtraffic		HCS		Teapac	
	50% Queue	95% Queue	50% Queue	95% Queue	50% Queue	95% Queue	50% Queue	90% Queue
NM528 & Southern (EB-AM)	6	8	7	10	8	15	8(HCM)	11
NM528 & Southern (SB-AM)	4	7	6	10	5	9	11(MBQ)	9
NM528 & Southern (EB-PM)	9	13	12	17	12	23	10(MBQ)	11
NM528 & Southern (SB-PM)	9	13	10	12	12	22	7(MBQ)	12
NM528 & Sara (SB-AM)	1	1	1	3	1	2	1(HCM)	2
NM528 & Sara (NB-AM)	5	8	6	10	5	9	7(MBQ)	9
NM528 & Sara (SB-PM)	1	1	1	3	1	2	1(HCM)	2
NM528 & Sara (NB-PM)	19	27	27	41	20	33	23(MBQ)	30
NM528 & Westside (WB -AM)	1	2	1	3	1	3	1(MBQ,HCM)	2
NM528 & Westside (SB -AM)	1	1	1	2	1	3	1(MBQ,HCM)	2
NM528 & Westside (WB -PM)	3	4	3	6	4	7	3(HCM)	6
NM528 & Westside (NB -PM)	8	11	10	14	10	19	6(HCM)	14

Sim traffic values are divided by 19.5

Maximum queue observed
12
15
13
12
2
8
3
24
3
4
5
14

Queue may be longer than this. Video not so clear

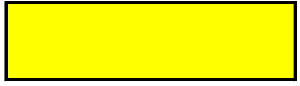
Traffic Models Predicted Left Turn Queue Lengths								
Intersection	Traffic Models							
	Synchro		Simtraffic		HCS		Teapac	
	50% Queue	95% Queue	50% Queue	95% Queue	50% Queue	95% Queue	50% Queue	90% Queue
NM528 & Southern (EB-AM)	7	8	7	10	10	18	8(HCM)	13
NM528 & Southern (SB-AM)	3	5	5	9	3	7	5(MBQ)	10
NM528 & Southern (EB-PM)	9	13	11	16	13	23	9(MBQ)	15
NM528 & Southern (SB-PM)	9	13	9	13	13	22	9(MBQ)	16
NM528 & Sara (SB-AM)	1	1	1	3	1	2	2(MBQ,HC M)	3
NM528 & Sara (NB-AM)	5	6	6	10	5	9	7(MBQ)	9
NM528 & Sara (SB-PM)	1	1	1	5	1	2	1(HCM)	2
NM528 & Sara (NB-PM)	20	30	21	34	20	34	23(MBQ)	31
NM528 & Westside (WB -AM)	1	2	1	3	1	3	1(MBQ,HC M)	2
NM528 & Westside (SB -AM)	1	1	1	2	1	2	1(MBQ,HC M)	2
NM528 & Westside (WB -PM)	3	4	3	6	3	6	3(HCM/MB Q)	5
NM528 & Westside (NB -PM)	8	10	8	12	9	17	8(MBQ)	14
Broadmoor &High Resort(WB-AM)	1(1)	2(2)	2(2)	4(4)	1(1)	3(3)	2(HCM/MB Q)	4
Broadmoor &High Resort(SB-AM)	5(2)	10(5)	8(5)	12(8)	14(3)	25(6)	8	13
Broadmoor &High Resort(WB-PM)	2(2)	4(4)	3(4)	6(6)	2(2)	5(4)	3	6

Broadmoor & High Resort(SB-PM)	4(4)	5(5)	8(7)	13(13)	5(6)	10(11)	11	12
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Sim traffic values are divided by 19.5

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Maximum queue observed
12
15
13
12
2
8
3
24
3
4
5
14
3



v/c
0.83
0.51
1.04
0.94
0.17
0.82
0.23
1.12
0.31
0.32
0.51
0.73

Queue is actually longer longer than thid value. Video not clear

() min green less than ped time

|

Traffic Models Predicted Left Turn Queue Lengths							
Intersection	Traffic Models						
	Synchro	Simtraffic(unadjusted volumes and simulated for 10 minutes)	Simtraffic (95th%ile adjusted and simulated for 2 min)	Simtraffic(unadjusted for PHF and 95th% ile) and simulated for 1 hr	HCS	Teapac	Maximum queue observed
	95% Queue	95% Queue	95% Queue	95% Queue	95% Queue	90% Queue	
NM528 & Southern (EB-AM)	8	10	12	10	18	13	12
NM528 & Southern (SB-AM)	9	10	16	10	14	9	15
NM528 & Southern (EB-PM)	13	16	15	16	23	15	13
NM528 & Southern (SB-PM)	13	13	14	13	22	16	12
NM528 & Sara (SB-AM)	1	3	3	3	2	2	2
NM528 & Sara (NB-AM)	7	10	8	8	9	8	8
NM528 & Sara (SB-PM)	1	5	5	5	2	1	3
NM528 & Sara (NB-PM)	30	34	33	48	34	37	24
NM528 & Westside (WB -AM)	2	3	4	3	3	2	3
NM528 & Westside (SB -AM)	2	2	3	2	2	2	4
NM528 & Westside (WB -PM)	4	6	6	4	6	5	5
NM528 & Westside (NB -PM)	10	12	17	12	17	15	14
Broadmoor &High Resort(WB-AM)	2	4	3	4	3	3	
Broadmoor &High Resort(SB-AM)	5	8	11	8	6	7	

Broadmoor & High Resort(WB-PM)	4	6	6	5	4	5	
Broadmoor & High Resort(SB-PM)	5	13	11	9	11	8	12

Note:

Different volumes were modelled in SimTraffic:

First Column: volume was unadjusted for PHF and 95%ile and simulated for simTraffic's default 10 minutes interval.

Second Column: volume was adjusted for only 95th %ile and simulated for 2 and 10 minutes. 2 minutes because simtTraffic says to get the 95th queue, the volume Compare with 10 minutes simulation.

Third Column: volume adjusted for both PHF and 95th %ile and simulated for both 2 and 10 minutes.

Fourth Column: volume unadjusted and simulated for 1hour. This is an alternative to adjusting for the 95th percentile; the queue lengths are way too high. Repeated the simluations but got the same lengths.

The shaded cells are the SimTraffic's results for NM528 arterial. I wanted to see if the upstream and downstream intersections have an effect on the queue length:

Did not run for Broadmoor & High resort because of the controller type and also the arrival type which is random.

v/c	Harmon Poisson		Harwick
0.83	18	96.5%	16
0.85	8	96.4%	6
1.04	20	95%	
0.94	12	95.8%	11
0.17	3	96.5%	2
0.82	9	95.5%	6
0.23	3	98.0%	2
1.12	26	95.3%	17
0.31	3	98.4%	
0.32	2	94.9%	
0.51	7	96.3%	5
0.73	19	95.9%	17
0.21	4	95.2%	3
0.93	11	94.5%	8

g/C<15%

Queue is actually longer longer than this value. Video not clear

g/C<15%

g/C<15%

0.28	7	94.1%	6
0.69	13	94.8%	9

ϵ should be adjusted and simulated for the cycle length interval.

5.