TRAFFIC LEVEL OF SERVICE ANALYSIS GUIDELINES

SANTA CLARA COUNTY TRANSPORTATION AUTHORITY

CONGESTION MANAGEMENT PROGRAM

ADOPTED | JANUARY 1995

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SANTA CLARA Valley Transportation Authority

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Santa Clara Valley Transportation Authority
CONGESTION MANAGEMENT PROGRAM

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Introduction

The statewide Congestion Management Agency (CMA) legislation requires that a uniform method be used to evaluate traffic level of service (LOS) for each element (i.e., urban arterials, freeways and rural highways) of CMA roadways. The use of uniform methods to evaluate LOS provides the CMA and local jurisdictions with a common basis to make capital improvement, land development and transportation planning decisions for CMA roadway facilities. The legislation gives CMAs the choice in the LOS analysis method adopted. The CMA in Santa Clara County is Santa Clara Valley Transportation Authority (VTA). This document presents the LOS analysis methodologies that must be used to evaluate LOS on CMP roadway facilities within Santa Clara County. These guidelines serve to update guidelines adopted by VTA in October 1997.[1]

Chapter 1 of this document describes the methodologies that must be used to evaluate traffic LOS for urban arterials, freeways and rural highways that are part of the CMP roadway network in Santa Clara County. Chapter 2 describes the software, TRAFFIX, approved by VTA as the standard traffic LOS analysis software package for CMP signalized intersections. Chapter 3 describes types of traffic and related situations that are excluded from the requirements of the CMA legislation.

In addition to these LOS analysis guidelines, VTA has also adopted guidelines for assessing the transportation impacts of land use decisions, guidelines for assessing the consistency of local transportation models with VTA's countywide transportation demand model and guidelines for preparing local deficiency plans. These technical guidelines are available from VTA.

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[1] Traffic Level of Service Analysis Guidelines, Santa Clara Valley Transportation Authority, Congestion Management Program, October, 1997.

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1.   CMP Traffic Level of Service Analysis Methods

This chapter presents an overview of the traffic LOS methodologies adopted by VTA for evaluating CMP roadway facilities. The following items are discussed in this chapter: adoption of specific LOS analysis methods for CMP roadway facilities, specifics on the LOS analysis method selected for each of the three types of CMP roadway facilities and annual CMP monitoring and conformance reporting.

1.1   Adoption of Uniform LOS Analysis Methodology

The CMA legislation requires the use of uniform methods to evaluate LOS for CMA roadway facilities. The legislation gives CMAs the choice in the LOS analysis method adopted.

In 1991, the Santa Clara County CMA[2] adopted the *1985 Highway Capacity Manual* (*1985 HCM*)[3] methods to evaluate LOS on CMP roadway facilities. The CMA's decision to adopt the *1985 HCM* methods was based upon an evaluation of several potential methods. The primary reason for the adoption of the *1985 HCM* methods for Santa Clara County was that these methods were the most current and widely accepted methods at the time.

In 1995, methods for evaluating Santa Clara County CMP roadway facilities were refined and documented in *Traffic Level-of-Service Analysis Guidelines*.[4] This document maintained analysis consistent with the *1985 HCM* even though an update to the *1985 HCM*, the *1994 HCM*,[5] had been published.

In 1997, methods for evaluating Santa Clara County CMP roadway facilities were further refined and documented in *Traffic Level of Service Analysis Guidelines*. This update resulted in the use of the higher ideal freeway capacities and the rural highway LOS analysis methods from the *1994 HCM*. However, the decision was made to stay with the *1985 HCM* operational method for evaluation of LOS for signalized intersections.

The major change in this 2003 update of the guidelines is migration of LOS analysis in Santa Clara County to criteria and methods from *HCM2000*.[6] Signalized intersection LOS must be calculated using the methodology from "Chapter 16" of *HCM2000*. The primary measure for freeway LOS is density, but with deviations from the LOS thresholds in *HCM2000*. Rural highway LOS must be calculated using the methodology from "Chapter 20" of *HCM2000*.

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[2] The Santa Clara County CMA was the predecessor to Santa Clara Valley Transportation Authority as Santa Clara County's designated congestion management agency.

[3] Highway Capacity Manual, Special Report 209, Transportation Research Board, National Research Council, Washington, D.C., 1985.

[4] Traffic Level-of-Service Analysis Guidelines, Santa Clara County Transit District, Congestion Management Program, January 5, 1995.

[5] Highway Capacity Manual, Special Report 209, Third Edition, Transportation Research Board, National Research Council, Washington, D.C., 1994.

[6] Highway Capacity Manual, Transportation Research Board, National Research Council, Washington, D.C., 2000.

The remainder of this section describes the adopted LOS analysis method for each type of CMP roadway facility (i.e., urban arterials, freeways and rural highways). Particular details regarding the application of the LOS analysis methods for CMP monitoring purposes and preparing transportation impact studies are also provided.

1.2   Urban Arterials

Level of service on CMP urban arterials is determined by evaluating LOS at designated signalized intersections using the operational method detailed in "Chapter 16" of *HCM2000*. This method determines LOS for signalized intersections on the basis of average control delay. Average control delay includes not only the delay while stopped at an intersection, but also delays due to oversaturation queues, movements at slower speeds and stops and slow downs on intersection approaches as vehicles move in queues or slow down upstream of an intersection. One deviation from the *HCM200* operational method is that default saturation flow rates are used instead of using adjustment factors to calculate saturation flow rates.

In order to ensure that CMP intersections are evaluated in a uniform manner throughout Santa Clara County, VTA approved the use of TRAFFIX as the standard software package in 1997. TRAFFIX continues as the standard software for analyzing signalized intersections. Refer to Chapter 2 for more details on the *HCM2000* operational method and directions on the use of TRAFFIX. The following paragraphs describe the use of TRAFFIX and the *HCM2000* operational method for annual CMP monitoring and transportation impact analyses (TIAs).

Annual Monitoring Program -- Each Member Agency is responsible for monitoring traffic LOS on CMP urban arterials by evaluating designated signalized intersections within its jurisdiction using the operational method from "Chapter 16" of *HCM2000*. This analysis of signalized intersection LOS for annual monitoring must be completed using the TRAFFIX program with the procedures and standard values outlined in Chapter 2 of this document. Data are to be collected annually during September and October during the PM peak period on Tuesdays, Wednesdays, or Thursdays of non-school vacation weeks.

Transportation Impact Analyses -- Member Agencies are responsible for evaluating the impact of development projects on traffic conditions on urban arterials using TRAFFIX and the procedures and standard values outlined in "Chapter 2" of this document. More details on evaluating LOS at signalized intersection for TIA purposes are available in VTA's *Transportation Impact Analysis Guidelines*.

1.3   Freeway Segments

The HCM methods for evaluating LOS of freeway segments are based on density, expressed as passenger cars per mile per lane (pcpmpl), for two reasons:

1. Although speed can also be used as an indicator of level of service for motorists on freeways, density is better able to give an indication of the proximity of vehicles to one another and the motorists' ability to maneuver in the traffic stream.

2. The correlation of traffic flow rate to density is less ambiguous than is the correlation between traffic flow rate and speed. Increasing traffic flow rate always means increasing density. Whereas, a low traffic flow rate can be associated with both free flow speeds and congested flow speeds.

The adopted parameter for freeway LOS in Santa Clara County is density. The adopted LOS criteria based on density are provided in Table 1. Table 1 also includes matching speed ranges for the density ranges. The density values for the LOS A/B, B/C and C/D thresholds are based on values from *HCM2000*. The LOS D/E and E/F thresholds are essentially based on Santa Clara County conditions and are almost identical to those in the 1997 VTA *Traffic LOS Analysis Guidelines* document.

Table 1: Freeway LOS Criteria

Level of Service	Density (passenger cars/mile/lane)	Speed (miles/hour)
A	density ≤ 11.0	67.0 ≤ speed
B	11.0 < density ≤ 18.0	66.5 ≤ speed < 67.0
C	18.0 < density ≤ 26.0	66.0 ≤ speed < 66.5
D	26.0 < density ≤ 46.0	46.0 ≤ speed < 66.0
E	46.0 < density ≤ 58.0	35.0 ≤ speed < 46.0
F	58.0 < density	speed < 35.0

Annual Monitoring Program -- VTA is responsible for the annual freeway LOS monitoring program. All freeways in Santa Clara County are evaluated annually in the AM and PM peak periods for CMP monitoring purposes. All CMP monitoring programs after the 2002 monitoring program will use the density ranges provided in Table 1 for determining freeway LOS. Density data for the CMP monitoring program are collected using aerial photography techniques. From the aerial photographs, it is possible to measure density, and calculate average travel speed and flow rate. These data are tabulated and graphed in the annual CMP monitoring and conformance report.

Transportation Impact Analyses – One criterion for assessing the impact of a development project on freeways is LOS. As in the CMP monitoring program, density is the parameter for determining LOS for freeway segments in TIAs. The relationship between density, speed and volume (or flow rate) is described as follows:

$$d = \frac{V}{N \times S}$$

where: d = density (passenger cars per mile per lane, pcpmpl)

V = peak hour volume (passenger cars per hour, pcph)
N = number of travel lanes (lanes)
S = average travel speed (miles per hour, mph)

A new density for the "Project" scenario can be calculated using the above equations by adding the appropriate project trips to the base traffic volumes (as documented in the CMP monitoring report of record) for affected freeway segments.   Additional details regarding freeway LOS evaluation for transportation impact studies are contained in VTA's *Transportation Impact Analysis Guidelines*.

1.4   Rural Highways

Traffic level of service on rural highways is based upon percent time spent following (PTSF) and average travel speed. The analysis methodology is described in "Chapter 20" of *HCM2000*.

The LOS on a two-lane rural highway is determined by computing the PTSF and average travel speed from the average flow rate and assumptions for directional distribution of traffic, percentage of heavy vehicles, lane widths, shoulder widths, type of terrain, percentage of no passing zones, free flow speed, highway classification, segment length and the number of access points per mile.

Annual Monitoring Program -- VTA is responsible for evaluating LOS on rural highways as part of its annual monitoring program. The annual monitoring program includes the evaluation of twelve rural highway segments. Analysis assumptions for the twelve segments are documented in the annual CMP monitoring and conformance report.

Transportation Impact Analyses – One criterion for assessing the impact of a development project on a rural highway is LOS. In many cases, it is appropriate for the TIA to use the *HCM2000* two-lane highway LOS analysis method as described above; however, it may also be appropriate to evaluate adjacent rural highway intersections using the appropriate methods from the *HCM2000* to determine intersection impacts by the project.

1.5   Annual LOS Monitoring and Conformance Report

VTA publishes an annual summary of traffic LOS on CMP System intersections, freeways, and rural highways. This summary is included in the CMP's annual monitoring and conformance report, which is published after VTA Board of Director's adoption of final conformance findings. The report also includes information on land-use approvals during the subject year.

2. CMP Intersection Level of Service Analysis Procedures

In order to ensure that CMP intersections are evaluated in a uniform manner, VTA has adopted a standard intersection LOS analysis software package. In July 1997, VTA approved TRAFFIX as the standard software package to evaluate LOS for CMP signalized intersections in Santa Clara County.

VTA originally purchased licensed copies of TRAFFIX 7.1 for each Member Agency in the County in 1997. In 2003, VTA purchased the upgrade to TRAFFIX 7.6 for each Member Agency. TRAFFIX 7.6 includes many new features beyond those available in TRAFFIX 7.1, and contains the *HCM2000* methodologies. TRAFFIX 7.6 requires Windows 95 or higher, with a minimum recommended computer configuration of a 90-Mhz 486 computer with at least 16 MB of RAM.

The remainder of this chapter describes the use of TRAFFIX 7.6 (referred to as TRAFFIX in these guidelines) to evaluate LOS for CMP intersections in Santa Clara County. The purpose of the information in this chapter is to provide guidance on the general use of TRAFFIX in a manner consistent with VTA requirements. For a more detailed description on the use of the software, please refer to the TRAFFIX User's Manual.

The evaluation of intersection LOS in TRAFFIX is designed around HCM standards. The VTA guidelines for intersection LOS evaluation are based on HCM standards with certain modifications. The information in this chapter describes where in TRAFFIX the necessary volume, geometric and signal timing data should be entered to conduct an LOS evaluation. Included in the descriptions are default values for program parameters per VTA guidelines.

Section 2.1 describes procedures for setting up a TRAFFIX database for evaluating LOS at CMP signalized intersections. Section 2.2 describes procedures for creating intersections for analysis in the database. Sections 2.3 through 2.5 describe the use of three general types of data required for conducting LOS evaluations: traffic volumes, intersection geometry and signal timing. Sections 2.3 through 2.5 also describe the input of these data into TRAFFIX. Section 2.6 describes queuing analysis in TRAFFIX. Section 2.7 describes the procedures for saving files in TRAFFIX. Section 2.8 describes procedures for conducting an LOS evaluation in TRAFFIX. Finally, Section 2.9 describes the procedure for printing a TRAFFIX LOS evaluation report.

Following Chapter 3 is a Glossary containing the definition of key terms related to LOS evaluation and the definition of key elements in TRAFFIX (e.g., intersection pop-up menu, dialog box, right clicking and left clicking). An Appendix containing CMP default values for global and intersection parameters in TRAFFIX is included after the Glossary.

2.1   TRAFFIX Database

TRAFFIX stores data in a geographical information system (GIS) format, meaning that data for each intersection are linked to a mapped graphical representation of the intersection. Upon loading TRAFFIX, the user is presented with a start-up screen.

The TRAFFIX program includes a file called DEFAULTS.TFX, which is a TRAFFIX database with global and intersection parameters already set to VTA default values. Entry of default values is not necessary, if the DEFAULTS.TFX database is used as a starting point for analysis. However, if there is a need to recreate this file, the information necessary to do so is provided in the Appendix.

The DEFAULTS.TFX database should be opened and used as the starting point for conducting signalized intersection LOS evaluations for CMP intersections. The DEFAULTS.TFX database is opened by left clicking **File** on the menu bar and selecting **Open Database** from the pull-down menu. Alternatively, the database can be opened by clicking on the button second from the left above the network drawing/editing tool bar.

A white background editing window will appear to the right of the network drawing/editing tool bar with a single intersection icon in the window. The name of the database will be displayed in the upper left corner of the window.

The first action should be to save this database under another name so that the contents of the DEFAULTS.TFX database are not changed. The database may be saved under a new name by left clicking **File** on the menu bar and selecting **Save Database As** from the pull-down menu.

A title may be specified for each analysis that is conducted. Analysis conducted for the CMP monitoring program could include a title with the following information: the year of the CMP monitoring program (e.g., 2003 CMP Monitoring Program), name of agency and peak hour of analysis (e.g., PM peak hour). This information can be specified at **Options** on the pull down menu by selecting **Titles** from the **Global Data** menu item (or by activating the **Global Data** menu by right clicking in the editing window). It is also recommended that the name of the person conducting the evaluation and the date of the evaluation be entered in the **Comment** field of the **Titles** screen.

LOS Criteria – The average control delay ranges (in seconds per vehicle) corresponding to each LOS for analysis of signalized intersections along CMP roadways in Santa Clara is presented in Table 2. The delay ranges in Table 2 are based on those provided in Exhibit 16-2 of *HCM2000*, with the addition of the plus/minus grades. For example, the LOS B+ to B- range in Table 2 is the same as the LOS B range in *HCM2000*. The average control delay threshold between LOS E and LOS F is 80 seconds per vehicle. The previous version of these guidelines relied on the 1985 HCM operations method that is based on average stopped delay. The threshold value between LOS E and LOS F for average stopped delay is 60 seconds per vehicle.

Table 2: Signalized Intersection LOS Criteria

Level of Service	Average Control Delay (seconds/vehicle)
A	delay $\leq$ 10.0
B+	10.0 < delay $\leq$ 12.0
B	12.0 < delay $\leq$ 18.0
B-	18.0 < delay $\leq$ 20.0
C+	20.0 < delay $\leq$ 23.0
C	23.0 < delay $\leq$ 32.0
C-	32.0 < delay $\leq$ 35.0
D+	35.0 < delay $\leq$ 39.0
D	39.0 < delay $\leq$ 51.0
D-	51.0 < delay $\leq$ 55.0
E+	55.0 < delay $\leq$ 60.0
E	60.0 < delay $\leq$ 75.0
E-	75.0 < delay $\leq$ 80.0
F	delay > 80.0

Saturation Flow Rates -- The LOS analysis described in this chapter relies on the use of default saturation flow rates as presented in Table 3. These default rates are to be used in lieu of using the standard HCM saturation flow rate calculation method based on various factors. The default rates are set by applying adjustment factors to the default ideal saturation flow rate. In the case of the *HCM2000* method, the default ideal saturation flow rate is 1900 vph. Consequently, a saturation flow rate of 1800 vph is represented in TRAFFIX by the factor 0.947368, which is the equivalent of 1800 divided by 1900. The TRAFFIX adjustment factor corresponding to each default VTA saturation flow rate is shown in Table 3. **These adjustment factors should <u>not</u> be modified under any circumstance.** If the desire is to specify a non-standard saturation flow rate for a particular intersection movement, please refer to the discussion under **User Saturation Adjustment** in **Section 2.5** of these guidelines.

The saturation flow rate for multiple turn lanes is calculated by applying an 80 percent reduction to the single lane saturation flow rate for each additional turn lane. The saturation flow rates for turning movements in Table 3 apply for protected operations (i.e., when the movement can move unopposed with its own signal phase) only.

Table 3: Default Saturation Flow Rates

Movement	Default Saturation Flow Rate (vph) (Default TRAFFIX Adjustment Factor)			
	1 Lane	2 Lanes	3 Lanes	4 Lanes
Left Turn	1750 (0.921053)	3150 (0.828947)	4550 (0.798421)	
Left-Through	1800 (0.947368)			
Through	1900 (1.000000)	3800 (1.000000)	5700 (1.000000)	7600 (1.000000)
Right-Through	1800 (0.947368)			
Right Turn	1750 (0.921053)	3150 (0.828947)	4550 (0.798421)	
Left-Through-Right	1750 (0.921053)			

2.2 Creating Intersections for Analysis

After saving a database, the intersections to be evaluated should be created. The DEFAULTS.TFX database includes an intersection in the editing window already configured with VTA default values. As a result, the creation of all intersections to be evaluated is accomplished simply by duplicating this "template" intersection.

The following procedures should be followed for duplicating the "template" intersection. Select the **Grab** drawing tool on the network drawing/editing tool bar and left click on the "template" intersection. The intersection outline square should change to a blue color indicating that the intersection has been selected. Left clicking **Edit** on the menu bar and selecting **Duplicate** on the pull-down menu (or alternatively typing CTRL-D) will create a second intersection with input identical to the "template" intersection. Repeated duplications can be conducted until the required number of intersections is represented in the editing window.

Each added intersection is indexed sequentially from the lowest numbered intersection in the editing window. Activating the intersection pop-up menu can change the assigned index. Clicking the right mouse button with the cursor arrow on the intersection activates this menu. Accessing Change Index changes the index. If the index is to start from another number other than 1, the **Change Index** feature can be use to change the index of the "template" intersection. For example, if the index is to start at 101, the **Change Index** feature should be used to change the index of the "template" intersection from 1 to 101. The next intersection created will have index number 102, and so on and so forth.

As mentioned earlier, a selected intersection will be enclosed in a blue square. The following are the possible intersection indications:

- **Red Square:** indicates that the intersection has not been selected for any operation.
- **Yellow Square:** indicates that the intersection has been selected for LOS evaluation.
- **Blue Square:** indicates that the intersection has been selected for editing or LOS evaluation.

For intersection LOS evaluation, the intersection icon should be enclosed in a yellow square, indicating that the intersection is selected for evaluation. Intersections can be selected for evaluation by right clicking on the traffic signal icon in the network editing/drawing tool bar, and by selecting the **Select All for Evaluation** option in the pop-up menu that appears.

Intersection data are entered by accessing the intersection pop-up menu, accomplished by right clicking on an intersection. The intersection name can be entered by selecting **Name** in the menu.

Traffic volume, intersection geometry and signal timing data are entered in the **Volume** and **Geometry** selections in the intersection pop-up menu. Entry of these data is described in the next three sections.

2.3   Traffic Volume Data

Traffic volume data are needed for conducting an LOS evaluation. In TRAFFIX, traffic volume data are entered by selecting the **Volume** option in the intersection pop-up menu that is accessed by right clicking with the cursor arrow over the intersection under analysis. Selection of this option will activate eight tabbed dialog screens. Peak hour volumes for analysis are entered in the **Volume** dialog screen. This dialog screen has twelve data fields, one data field for each movement at a four-legged intersection. Use the TAB key to move around the screen to each of the data fields.

The date of the traffic count can be entered in the cell titled **Volume Count Date**.

For evaluation of protected-permitted and permitted-protected left turns, an estimate of the number of left turns moving permissively must be entered in the **Base Volume Reduction** dialog screen.

The number of left turns moving permissively for protected-permitted or permitted-protected phasing should be calculated as two per signal cycle for left turn movements that oppose uncoordinated through movements or coordinated through movements with no excess green time. Thus, the total number of permissive left turns is:

$$LT_p = 2 * C$$

where: LT_p = Number of Left Turns Moving Permissively

$$C = \text{Number of Signal Cycles} = 3600 / (\text{Average Cycle Length in seconds})$$

For left turn movements that oppose coordinated through movements with excess green time, the number of left turns moving permissively per signal cycle should be calculated through field measurement. The number of permissive left turns should be counted for five signal cycles and the average per signal cycle should be calculated (rounded down to the nearest whole number). This number should be inserted in place of the "2" in the above equation.

If the calculated number of left turns moving permissively is more than the total number of left turns, then the number of left turns moving permissively should be set to the total number of left turns.

County expressway intersections with HOV lanes include an adjustment to account for HOV traffic volumes. This adjustment can be found on the **Volume Adjustment** dialog screen and represents the percentage of the total counted traffic volume that is HOV traffic. The reason for this adjustment is to remove HOV traffic from the LOS analysis.

Entry of data in the other five **Volume** dialog screens is usually not needed.

2.4   Intersection Geometry Data

Intersection geometry data are needed for conducting an LOS evaluation. In TRAFFIX, traffic volume data are entered by selecting the **Geometry** option in the intersection pop-up menu (accessed by right clicking with the cursor arrow over the intersection under analysis). Selection of this option will activate eight tabbed dialog screens. Geometry data are entered in the **Lanes** dialog screen. This dialog screen has six data fields for each intersection approach. There is one data field next to each of five types of lanes depicted for each approach. For example, if there are three through lanes, then the number three would be entered in the data field next to the through movement only arrow. There is a sixth data field for entry of the number of shared left-through-right lanes. Use the TAB key to move around the screen to each of the data fields.

2.5   Signal Timing Data

Signal timing data are needed for conducting an LOS evaluation. In TRAFFIX, signal timing data are entered by selecting the **Geometry** option in the intersection pop-up menu that is accessed by right clicking with the cursor arrow over the intersection under analysis. Selection of this option will activate eight tabbed dialog screens. Signal timing data are entered in six of these dialog screens as defined below:

Signal Controls -- This dialog screen is for entry of the type of signal control for the intersection. There are five options: protected, split phase, permitted, protected+permitted

and permitted+protected. The following describes the situations for using each of the options:

- **<u>Protected</u>:** should be selected to specify an approach with protected left turn operation.
- **<u>Split Phase</u>:** should be selected to specify an approach with all movements moving at the same time.
- **<u>Permitted</u>:** should be selected to specify an approach with left turns moving permissively with opposing through movements.
- **<u>Protected+Permitted</u>:** should be selected to specify an approach with left turns given an exclusive phase first, followed by a permitted period where left turns must use gaps in the opposing traffic stream to pass through the intersection.
- **<u>Permitted+Protected</u>:** should be used to specify the reverse of Protected+Permitted.

Use the TAB key to move around the screen to select the appropriate option for each of the data fields.

> The signal control type (based on left turn operations) for each intersection approach should be specified in the **Signal Controls** dialog screen.

Signal Timing -- This dialog screen is for entry of minimum green times, right turn treatment, cycle length, loss time and the LOS analysis method. Data entry for the various data fields on this screen is described below:

> **<u>Minimum Green Times</u>:** The minimum green times for vehicular traffic should be set according to the defaults shown in Table 4. The minimum green times are based on the signal control type for an intersection approach. The minimum green time for movements that do not exist at an intersection should be set to zero.
>
> The "template" intersection in the DEFAULTS.TFX database, as described in **Creating a Template Intersection** in the Appendix, has minimum green times of 7, 10 and 10 set for left turns, throughs and right turns, respectively. This is because the majority of CMP intersections have protected left turn signal phasing.
>
> Determining whether minimum green time should be based on the minimum phase time for pedestrians depends on engineering judgment. If there are very few activations of the pedestrian signals, the vehicular minimum green times in Table 4 should be used. For movements with substantial amounts of pedestrian activity, the minimum green time should be set to the time required to service the pedestrian traffic, which is the sum of the Walk and Flashing Don't Walk (FDW) intervals set in the signal controller. This information can be found on the signal timing card for the intersection.

Table 4: Minimum Green Times

	Minimum Green Time		
Signal Control Type	Left Turn	Through	Right Turn
Protected	7	10	10
Split Phase	10	10	10
Permitted	10	10	10
Protected+Permitted	7	10	10
Permitted+Protected	7	10	10

Right Turn Treatment: There are three options for right turn treatment. These include the following:

- **Ignore:** This option should be used when a right turn movement is not controlled by the traffic signal <u>and</u> the right turn queue does not affect the operation of the intersection. The right turn movement should be possible from an exclusive lane directly without any lane change to a receiving lane.

- **Include:** This option should be used for a right turn movement from a shared through-right turn lane. This option should also be used for a right turn movement from an exclusive right turn lane, when right turns on red (RTORs) are prohibited or are infrequent. This is the default selection in the program. Selection of this option means that RTORs reductions are not considered in the calculations.

- **Overlap:** This option should be used for a right turn movement that is displayed a green right arrow while the cross street left turn phase is active. This option may also be used to account for RTORs for a right turn movement from an exclusive right turn lane that operates as if it were shown a green right turn arrow.

Cycle Time: The signal cycle length for the peak hour of analysis should be entered in the **Cycle Time** data field. The cycle length should be calculated as follows:

- **For Coordinated Signals:** The cycle length should be the coordinated cycle length during the peak hour of analysis.

- **For Uncoordinated Signals:** The cycle length should be the average measured cycle length during the peak hour of analysis. The cycle length should be measured as the time from the start of the yellow interval for the main street through movement to the next occurrence of the start of the yellow interval for the main street through movement. If either street can equally qualify as the "main" street, then just choose one street to be the main street.

Min Cycle and Max Cycle: There is no need to change the value for **Min Cycle**. The default value of 180 for **Max Cycle** should be changed only if the value in **Cycle Time** is greater than 180. If this is so, **Max Cycle** should be set equal to **Cycle Time**.

Loss Time: The minimum amount of loss time for CMP analysis is three seconds per critical phase. The number of critical phases for an intersection is dependent on the signal phasing. The minimum loss time values for the possible intersection phasing scenarios are shown in Table 5.

Ylw+All Red: The value in this data field represents the yellow plus all red interval time in seconds per phase. There is no need to change the value for yellow plus all red, unless the intersection has permitted left turns. The value in this data field is used only in the calculation of the saturation flow rate for permitted left turns.

LOS Method: The LOS analysis method is specified in this data field. For CMP intersections, the LOS analysis method is "2000 HCM Operations." Under **Parameters & Title** in the Appendix, a procedure for setting this data field for all intersections in the database is described. Also, the box titled **Use 2002 HCM Update?** should be checked so that the 2002 updates to *HCM2000* are used.

Table 5: Minimum Loss Times For Signalized Intersections

Signal Phasing Scenario	# of Critical Phases	Loss Time (seconds)
One phase for each street.	2	6
T-intersection with no left turn phase.	2	6
T-intersection with left turn phase.	3	9
Left turn phasing on one street and second street with one phase for all movements.	3	9
Left turn phasing on one street and second street with split phasing.	4	12
Left turn phasing on all four intersection approaches.	4	12

For CMP analysis, (a) the minimum green time should be set according to signal control type as shown in Table 4; (b) the right turn treatment should reflect right turn movements are controlled; (c) the cycle length should be either the coordinated cycle length or an average measured cycle length; (d) the minimum amount of loss time is calculated as three seconds per critical phase as shown in Table 5; and (e) the LOS analysis method must be set as "2000 HCM Operations."

User Saturation Adjustment -- This dialog screen is for entry of adjustments to the default saturation flow rates specified in Table 2. For example, if the saturation flow rate for a dual left turn movement is to be 3500 vph rather than the default value of 3150 vph, the adjustment factor equal to 3500/3150 (1.1111) should be entered in the appropriate data

field. This adjustment will be applied to 3150 vph so that 3500 vph is used as the saturation flow rate. This is an intersection specific adjustment.

> For CMP analysis, an entry in one of the data fields of this dialog screen is needed only if the saturation flow rate for an intersection movement needs to be adjusted from the default value shown in Table 2.

HCM Saturation Calc Input -- This dialog screen is for entry of the signal type. This screen is also where signal control mode (coordinated or not), street type (main or side) and arrival type data for calculation of progression adjustment factors are entered. Modifications to the other data fields on this screen are unnecessary since the VTA LOS analysis approach does not include the calculation of saturation flow rates per HCM methods. The following are data entry considerations for this dialog screen:

> **Signal Type:** The entry in this data field should be set to reflect the signal type at the given intersection, either "Fixed Time, Actuated, or Semi-Actuated." The selection of signal type affects the calculation of k, the incremental delay factor that is dependent on controller settings, in the second delay term, d_2. The values for k are provided in Exhibit 16-13 of *HCM2000*. The value of k is also dependent on the unit extension entered in the **Delay Adjustment** dialog screen and the degree of saturation. Pretimed or nonactuated movements always have a k-value of 0.50.

> **Coordinated?:** The entry in this data field should be set to reflect whether the signal is coordinated. If this field is set to "No," then the program will not calculate progression adjustment factors.

> **Main/Side Street:** The entry in this data field should be set to indicate which approaches are the coordinated main streets. The program uses the information in this field to determine whether a progression adjustment factor (PF) should be calculated as described in the decision matrix in Table 6.

Table 6: **Progression Adjustment Factor Decision Matrix**

Coordinated?	Signal Type	Street Type	Calculate PF?
Yes	Fixed	Main or Side	Yes
Yes	Semi-Actuated	Main	Yes
Yes	Semi-Actuated	Side	No
Yes	Actuated	Main	Yes
Yes	Actuated	Side	No
No	Any	Main or Side	No

> **Arrival Type (1 to 6):** The other information needed to calculate the PF is the quality of signal progression as described by the parameter Arrival Type. This is accomplished by entering a value of 1 (very poor progression) to 6 (exceptional progression) in each of the four arrival type fields. Values for PFs based on the arrival type and the proportion of green time available to a movement (green to cycle length ratio, g/C) are provided in Exhibit 16-12 of *HCM2000*. The PF is applied only

to the uniform delay term, d_1. The VTA default is to not include the use of PFs in the analysis (i.e., the default arrival type is 3 to set PF to 1.00). Changes to arrival type in an analysis of a CMP intersection should be reviewed first with the jurisdictional local agency and/or VTA.

Calculate HCM Sat Adj: The entry in this data field should be set to "No" because the HCM calculated saturation flow rates are not used for LOS evaluation of CMP intersections (instead the default saturation flow rates in Table 3 should be used). Using the DEFAULT.TFX database with VTA default values predefined in an analysis will result in the use of these default saturation flow rates. If the analysis output sheet does not include these default saturation flow rates, the analysis should be rechecked.

Use MLF?: The entry in this data file should be set to "Yes."

For CMP analysis, the actual signal type (fixed time, semi-actuated or actuated) should be entered. Signal Type affects the calculation of second delay term. Entry in the Coordinated?, Main?Side Street and Arrival Type (1-6) fields may be necessary to incorporate PFs in the analysis. For CMP intersections, any use of or changes to PFs beyond those already provided by the jurisdictional agency should be reviewed first with the jurisdictional agency and/or VTA.

Delay Adjustment -- This dialog screen is for the entry of a factor for adjusting the calculated delay. This screen could be used for manually entering progression adjustment factors (PFs) based on Exhibit 16-12 of *HCM2000* or any other adjustment to the calculated delay.

This dialog screen is also used for entering values for analysis time period and unit extension:

Analysis Time Period: The standard analysis period of 15 minutes (0.25 hours) is used in the VTA analysis approach. However, it should be recognized that the delay estimate could be improved by increasing the analysis period or by conducting calculations over multiple analysis periods for instances where the volume to capacity ratio is greater than 1.00. Changing the analysis approach would provide a better opportunity to account for delays due to residual queues in a standard 15-minute period analysis.

Unit Extension: An entry in this data field is needed to calculate k, the incremental delay factor that is dependent on controller settings, in the second delay term, d_2. The default value for unit extension is 3.0.

For CMP analysis, data entry is not needed for this dialog screen. This dialog screen may be used for manual entry of progression adjustment factors or entry of an adjustment to delay for other reasons, for selecting an alternate analysis period or for modifying the unit extension.

Base Green Per Cycle -- This dialog screen is for the entry of the green time for any movement where this information is known, as in the case of pretimed or fixed time traffic signals. The green time data can be entered in terms of seconds or as a green time to cycle length ratio. Any movement for which a green time is not specified will have its green time calculated by TRAFFIX. If both data fields for any movement are non-zero, an error message will be produced.

> For CMP monitoring, an entry of data in this dialog screen is unnecessary. An entry should only be entered if the green time is known, as in the case of pretimed traffic signals and a calculation of green times by the program is not wanted.

2.6   Queuing Analysis

TRAFFIX allows the user to select from four different methodologies to compute the queue length per lane group, in number of vehicles. Intersections created from the VTA defaults database signalized intersection will be set to calculate the TRAFFIX default queue, the *HCM2000* Average Back of Queue. This queue will be reported on the one-page TRAFFIX LOS output sheet.

If a different method is desired, then users must select the desired method from the **Options...Global Data...Parameters** dialog box. Note that there is a field provided here for the average vehicle length to be used. This is needed for the Design Queue calculation method, but the queue lengths are still reported in terms of vehicles (not distance) in the TRAFFIX output sheet. The four queue calculation options are described below:

> **Australian Method:** calculates the mean back of queue after start of green. This method includes a term that calculates the number of vehicles remaining after the end of green. A design queue can be calculated by further applying a peaking factor. This method is documented in Australian Road Research Report 123.[7]

> **Average Queue Length:** is the mean maximum back of queue some time after the start of green based on the mean maximum queue length at the start of green. The maximum back of queue is intended to capture vehicles that join the back of the queue after the start of green.

> **Design Queue Length:** is computed by multiplying the Average Queue Length by 2.

> **Back of Queue Method:** is the method described in Appendix G of *HCM2000*. This method is modeled after the Australian Method to provide a back of queue measurement that takes into account vehicles remaining after the end of the green signal phase, also referred to as the initial queue. In addition to the average back of queue, the user can request computation of the 70th, 85th, 90th, 95th, and/or 98th

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[7] Akcelik, R. Traffic Signal: Capacity and Timing Analysis. Research Report ARR 123. Australian Road Research Board, Victoria, Australia, 1981.

percentile back of queues through the application of adjustment factors as documented in Appendix G of HCM2000.

TRAFFIX reports queues in terms of total vehicles by lane group, regardless of method. If stacking distance per lane in feet (or meters) is needed, the queue output in TRAAFFIX needs to be multiplied by an average vehicle length in feet (or meters) and divided by the number of lanes in the lane group.

Queuing calculations from TRAFFIX and from HCM2000 provide a way to assess the impact of queues on traffic operations that takes into account the full signal cycle. However, this does not mean that the resulting maximum back of queue is the one that should be used for design purposes. Agencies often have their own guidelines for determining the needed design storage for vehicle movements. Many of these guidelines are based on a queue accumulation based on part or all of the signal cycle that is then adjusted to a 90th or 95th percentile design queue using a Poisson or other statistical approximation

A common approach is to calculate an average queue based on the flow rate and either the red signal time or the full signal cycle length (or some average numbers for these two measures if the signal is not coordinated). These queues are usually calculated using some form of the following equation:

$$Q_{50\%} = V \times \frac{(C-g)}{3600}$$

where:

$Q_{50\%}$ = average queue (vehicles)

V = volume or flow rate (vehicles per hour)

C = cycle length (seconds)

g = green time (seconds); set to zero to calculate for entire cycle

This average queue can then be used to calculate a design queue of some confidence level using a Poisson or other approximation. The following is the equation for converting an average queue into a 95th percentile queue using a Poisson approximation:

$$F(x:\lambda) = \sum_{k=0}^{x} \frac{\lambda^x e^{-\lambda}}{x!}$$

where:

x = queue length series up to the 95th percentile queue

$\lambda = Q_{50\%}$, the average queue

Many transportation engineering and planning firms have developed spreadsheets for calculating design queues in this manner.

2.7   Saving the Database

A new database is saved by left clicking **File** on the menu bar and then selecting **Save Database** (or alternatively by typing CTRL-S). This will save the database in the active editing window. The database can be saved subsequent times by repeating this process. It is recommended that the database be saved and saved often.

For analysis of CMP intersections, the DEFAULTS.TFX database should be used as the starting point as described in **Section 2.1** of these guidelines. After this database is loaded, it should be saved under a name other than DEFAULTS.TFX. This can be done by left clicking **File** on the menu bar and selecting **Save Database <u>A</u>s** from the pull-down menu. It is recommended that this be done immediately after the DEFAULTS.TFX database is loaded.

2.8   Conducting an LOS Evaluation

Before an LOS evaluation is conducted, the following is recommended: (a) save the database as described in **Section 2.7** of these guidelines, (b) specify the desired **Output File** name under the **Global Data** option at **Options** on the pull down menu and (c) make sure that the two LOS analysis reports have been selected. These two reports are the LOS Base Compute Report and the Level of Service Summary Report under **Reports** on the **Global Data** menu. The output file name should include a three letter extension, e.g., *.OUT. Make sure that the intersections have been selected for evaluation. Intersections selected for evaluation will be enclosed in a yellow square.

The LOS evaluation is conducted by left clicking **Tools** on the pull down menu and selecting **Evaluate...Forecast All** (or alternatively with CTRL-right click). During the evaluation process, a series of warning messages will flash on the screen. TRAFFIX is writing the warning messages to a log file for possible later viewing and also producing an output file with the LOS evaluation results.

After the evaluation process finishes, buttons appear that can be selected to review the warning and error messages and/or review the evaluation results. The warning and error messages should be reviewed after the forecast run to check for problems in the evaluation. The evaluation results can be viewed by selecting the **View Report** button.

2.9   Printing the Results

The LOS evaluation results can be printed by selecting the **Print** button on the forecast screen. Either a highlighted portion of the report or the entire output report can be printed by selecting the appropriate toggle button on the **Print Range Selection** dialog box.

The results can also be printed from outside TRAFFIX by either: (a) importing the output file into a word processing program or (b) using the DOS command "copy <output filename> <printer port>."

3.   Traffic LOS Conformance Exemptions

Certain types of traffic and situations are exempt from the analysis of traffic LOS for conformance based on the exclusions defined in the CMA legislation. Excluding traffic from LOS calculations is not commonly performed in traffic engineering studies; however, there are many possible ways in which types of traffic and situations could be excluded from analysis. This chapter describes the traffic situations exempt from LOS conformance and a methodology for excluding specific traffic and situations from conformance for Santa Clara County CMP roadways.

It should be emphasized that, while technically the traffic problems caused by these situations are exempt from LOS conformance based on the CMA legislation, local jurisdictions should try to develop solutions to improve traffic problems caused by these situations on the CMP network. CMP staff will assist local jurisdictions in this effort.

3.1   Legislative Exclusions

The CMA legislation excludes certain types of traffic from the traffic LOS conformance requirements. According to the California Government Code Section 65089.4 (b):

> *The agency shall calculate the impact subject to exclusion pursuant to subdivision (f) of this section, after consultation with the regional agency, the department, and the local air quality management district or air pollution control district. If the calculated traffic level of service following exclusion of these impacts is consistent with the level of service standard, the agency shall make a finding at a publicly noticed meeting that no deficiency plan is required and so notify the affected local jurisdiction.*

Section 65089.4 was added by AB 1963 in 1994. This addition was recommended by a statewide task force organized to recommend changes to the CMA Statute. This text was taken from the section on monitoring and conformance with traffic LOS standards (65089.3) and included in a new section on deficiency plans. This change was an effort to have the state CMA requirements more closely resemble the federal Congestion Management System (CMS) requirements. Subdivision (f) of 65089.4 includes the same exclusions originally included in 65089.3 with some additional language included in the definition of high density housing (see language underlined below). Specifically Section 65089.4 (f) states:

> *The analysis of the cause of the deficiency prepared pursuant to paragraph (1) of subdivision (c) shall exclude the following:*
>
> *(1)   Inter-regional travel.*
>
> *(2)   Construction, rehabilitation, or maintenance of facilities that impact the system.*

(3)   Freeway ramp metering.

(4)   Traffic signal coordination by the state or multi-jurisdictional agencies.

(5)   Traffic generated by the provision of low and very low income housing.

(6)   (A) Traffic generated by high density residential development located within one-fourth of a mile of a fixed rail passenger station.

(B) Traffic generated by any mixed use development located within one-fourth of a mile of a fixed rail passenger station, if more than half of the land area, or floor area, of the mixed use development is used for high density residential housing, as determined by the agency.

(g) For purposes of this section, the following terms have the following meanings:

(1) High density means residential density which <u>contains a minimum of 24 dwelling units per acre and a minimum density per acre which</u> is equal to or greater than 120 percent of the maximum residential density allowed under the local general plan and zoning ordinance. <u>A project providing a minimum of 75 dwelling units per acre shall automatically be considered high density.</u>

(2) Mixed use development means development that integrates compatible commercial or retail uses, or both, with residential uses and which due to the proximity of job locations, shopping opportunities, and residences, will discourage new trip generation.

Subsections (1) through (5) were included in the original CMA legislation. Subsection (6) was added to the chapter when AB 3093 was passed by the Legislature in 1991. As outlined above, Section (g) was removed from subsection (6) as part of AB 1963 in 1994 and the definition of high density housing was changed (see underlined text).

Exemption of Facilities Affected by Transit Operations -- In addition to the specific exclusions identified in the CMA legislation, VTA offers an exemption for facilities affected by priority control for transit operations. This exemption allows local jurisdictions to exclude the effect of priority treatment for transit operations in the calculation of traffic LOS. In other words, traffic operations at an intersection with transit priority can be analyzed as if priority treatment for transit did not exist. This exemption, as it promotes transit use, is consistent with the intent of the CMA legislation.

3.2   Structure of Traffic LOS Exclusions

It is useful to think of the legislative exclusions in terms of:

- **Situations** in which the CMP traffic LOS standards do not apply, including: construction, freeway ramp metering, traffic signal coordination, and priority treatment for transit operations, and

- **Types of Traffic** that are excluded from the CMP traffic LOS conformance standards, including traffic from: inter-regional travel, low and very low income housing, high density development within one-quarter mile of a fixed rail transit station, and mixed-use development within one-quarter mile of a fixed rail transit station.

The traffic type and situation exemptions each require a different strategy for addressing the legislative mandate to exclude them from the LOS calculations. There are two important points to understand regarding the traffic LOS exclusion process.

First, it should be understood that while some CMP network facilities are legislatively exempted from meeting CMP traffic LOS conformance standards, in all cases these facilities must be analyzed and monitoring data must be provided to the CMP. It is critical that the CMP have information on all parts of the CMP Roadway Network.

Second, traffic LOS standard conformance is important in two different parts of the CMP: the annual traffic LOS monitoring program and the transportation impact analysis process. Traffic LOS exclusions are carried out differently for these two parts of the CMP, as well as for each traffic type or situation excluded. Methods for each exclusion type and situation are presented in the following two sections.

3.3 Methodology for Situations Excluded from CMP Traffic LOS Conformance Standards

This section describes how LOS should be calculated in the annual traffic LOS monitoring program and for transportation impact analyses, when there are situations exempted from the CMP traffic LOS conformance process.

Traffic LOS Monitoring -- On parts of the CMP Roadway Network that are affected by the situations (construction, freeway ramp metering, or traffic signal coordination) identified in the CMA legislation or VTA's exemption for priority control for transit vehicles, the following process should be followed as part of the Member Agency's regular traffic LOS monitoring process:

Step 1: Member Agency calculates traffic LOS for the CMP roadway facility using the CMP's uniform method of analysis for the particular facility type.

Step 2: If the LOS for the facility is unacceptable, and one of the identified situations applies, then the Member Agency's monitoring report should include the following in its LOS Monitoring Report:

(i) A statement to the CMP that LOS on the specific facility was affected by an exempted situation.

(ii) Specification of the particular exempted situation.

(iii) Show LOS with the exempted situation.

(iv) Show LOS without the exempted situation.

The following specific methodologies should be used for each exempted situation:

Construction: There are two ways in which a facility can be affected by construction: first, part of the facility can be closed to allow construction; and second, construction traffic from a major project could add traffic to the facility or divert traffic from another facility on a temporary basis. The method for addressing these situations is described as follows:

> If part or all of a facility is closed by construction or if the facility is affected by construction traffic from another project or diverted traffic caused by construction, the Member Agency may request an exemption from the calculation of traffic LOS during construction. The Member Agency must make this request in writing to VTA's CMP. VTA's Technical Advisory Committee (TAC) and its Systems Operations and Management (SOM) Subcommittee will review the request and make a recommendation to the CMP. The recommendation will be to grant an exemption or to not grant an exemption, and provide an approach for calculating LOS.

Ramp Metering: If the facility is affected by freeway ramp metering, the Member Agency should provide an analysis of how the traffic impacts of ramp metering in the particular situation can be minimized. This requirement will help meet the intent of the legislation to improve transportation conditions. The analysis should show that without ramp metering, the facility would operate within the CMP traffic LOS standard.

The Member Agency should provide VTA's CMP with copies of the LOS analysis using actual measured volumes with the exempted situation and LOS analysis with adjustments to estimate traffic conditions without ramp metering.

Traffic Signal Coordination: The Member Agency should show that without traffic signal coordination the intersection would operate within the CMP traffic LOS standard.

The Member Agency should provide VTA's CMP with copies of the LOS analysis using actual measured volumes and LOS analysis with adjustments to estimate traffic conditions without coordinated signal operations.

Priority Control for Transit Operations: Priority control for transit is used in Santa Clara County. For example, preferential treatment is given to light rail vehicles (LRVs) where they cross intersections; and signal preemption is used where Caltrain crosses intersections. The traffic signals at these intersections may be interconnected with other traffic signals on the road or expressway, or the traffic signal may be an isolated traffic signal (uncoordinated with other traffic signals).

If the facility is affected by priority treatment for transit, LOS should be evaluated as if the priority treatment for transit did not exist. For example, a traffic signal with priority control for LRVs should be evaluated as if there were no priority treatment. The analysis should show that without the transit priority control, the intersection would operate within the CMP traffic LOS standard.

In order to analyze LOS at an intersection with a traffic signal with priority control for transit vehicles, the following procedures shall be followed:

> 1. If the traffic signal at the intersection is coordinated with other traffic signals, then the intersection LOS should be calculated using the coordinated signal cycle using the TRAFFIX program as outlined in Chapter 2 of these guidelines or be calculated according to any exemptions that are granted. The appropriate progression adjustment factors should be used.
>
> 2. If the traffic signal is not coordinated with other traffic signals, then the intersection LOS should be calculated using a measured average cycle length using the TRAFFIX program as outlined in Chapter 2 of these guidelines. The appropriate progression adjustment factors should be used.

It should be emphasized that the above processes should be followed only if a facility is found **not** to conform to the CMP traffic LOS standard. If the facility conforms to the standard, no action is required of the Member Agency, even if one of the situations applies.

Transportation Impact Analysis -- Some of the situations outlined above could affect traffic LOS forecasts included in a transportation impact analysis (TIA) prepared for a development project. In most cases, the process that should be used to evaluate traffic LOS is the same as for traffic LOS monitoring. The following specific information is noted:

> **Construction:** The TIA should show that when the construction is complete, the facility would operate within the CMP traffic LOS standard.
>
> **Ramp Metering:** The TIA should show that without ramp metering, the intersection would operate within the CMP traffic LOS standard.
>
> **Traffic Signal Coordination:** The TIA should show that without the coordination program, the intersection would operate within the CMP traffic LOS standard.

Priority Treatment for Transit Vehicles: The TIA should show that without priority treatment for transit vehicles, the intersection would operate within the CMP traffic LOS standard.

3.4   Exclusion of Traffic Types from LOS Conformance Standards

The CMP legislation lists four *types* of traffic to be excluded from CMP traffic LOS conformance: inter-regional travel, and traffic generated by low and very low income housing, high density development within one-quarter mile of a fixed rail transit station and mixed use development within one-quarter mile of a fixed rail station. The methods for addressing these traffic *type* exclusions are more complicated than those used to address the excluded *situations*.

The legislation's intent in providing these traffic type exclusions seems to be two-fold: first, to exclude from the CMP traffic LOS standard the impact of trips that are not under the control of Member Agencies; and second, to encourage certain types of development (e.g., low and very low income housing, high density housing near fixed rail transit stations and mixed use projects near fixed rail transit stations). Each of these types of exclusions is described separately below.

Inter-regional Travel -- For CMP purposes, inter-regional trips are defined by statute as trips that pass through the County (external to external) and trips that originate outside the County and end inside the County (external to internal).

The CMA legislation gives the Metropolitan Transportation Commission (MTC), Caltrans, and the Bay Area Air Quality Management District power to assist in the traffic exclusion process. Because these agencies currently have data on inter-regional travel, estimates provided by these agencies will be used to estimate inter-regional traffic volumes.

It should be noted that to date, Bay Area CMAs in general do not exclude inter-regional traffic from LOS calculations. VTA's intent to improve traffic conditions and this means taking into account all the traffic on the area roadways. VTA's method for addressing inter-regional travel in monitoring and transportation impact analyses is presented below.

> **Traffic LOS Monitoring:** The freeway segment analysis procedures based on density outlined in Chapter 1 of these guidelines should be used to evaluate LOS without inter-regional traffic volumes. The calculations shall be based on reduced traffic volumes and travel speeds measured in the field during the LOS monitoring process.

> **Transportation Impact Analysis:** The same process as mentioned above for traffic LOS monitoring should be used for evaluating traffic conditions with inter-regional travel excluded.

Encouraged Development Types -- The CMA legislation excludes traffic from low and very low income housing, from high density housing within one-quarter mile of a fixed rail

transit station, and from mixed use development within one-quarter mile of a fixed rail transit station from the traffic LOS standard conformance calculation. The exemption of these development types from the CMP traffic LOS standard means that a local jurisdiction could approve one of these types of projects without imposing mitigation measures necessary to maintain the CMP traffic LOS standard.

Since the intent of excluding traffic from these types of development from the CMP traffic LOS standard seems to be to encourage this type of construction, only traffic from *new* development should be excluded from the traffic LOS standard conformance. New development is defined as development that is constructed and occupied within the year of the current monitoring program.

Glossary

The following are terms used in these guidelines. The technical terms are those associated with the various LOS evaluation procedures and the TRAFFIX software.

Technical Terms

Average Control Delay: This is a measure of driver discomfort and frustration, fuel consumption and lost travel time used in the HCM operational analysis procedure to define level of service for signalized intersections. Average control delay is expressed in terms of seconds of delay per vehicle. The Santa Clara County CMP level of service is based on the *HCM2000* calculation of average control delay.

Capacity: The capacity of a facility as defined in the HCM is the maximum hourly rate at which vehicles or persons are able to pass a given point or through a uniform section of a lane or roadway during a stated time period under prevailing roadway, traffic and control conditions. For vehicular traffic, capacity is usually expressed in terms of vehicles per hour.

Cycle Length: This is the time required for a traffic signal to complete one sequence of signal indications. Cycle length is expressed in terms of seconds. For coordinated signals, the cycle length is the length of the coordinated signal cycle. This signal cycle can be field measured by timing from the start of the yellow interval of the coordinated movements to the next occurrence of the start of the coordinated movement yellow interval. For uncoordinated signals, the cycle length varies depending on the traffic demand. The cycle length can be measured by timing from the start of the yellow interval of the main street through movement to the next occurrence of the start of the main street through movement. If either street can equally qualify as the "main" street, then one street should be chosen as the main street.

Degree of Saturation: This is a term most commonly associated with signalized intersections, and is a reference to the volume-to-capacity ratio for a signalized intersection, and is defined as [(volume/capacity) x (cycle length/green time)] for any intersection movement.

Density: This is the number of vehicles occupying a given length of a lane or roadway at any given instance. The Santa Clara County CMP uses density as the standard for evaluating freeway segment LOS in transportation impact analyses. The TIA density thresholds for LOS for CMP freeway segments are documented in Table 2 of these guidelines.

Minimum Green Time: This is the minimum time for a green interval. It is either the minimum time required for vehicles or pedestrians. In the various LOS analysis software packages, this parameter is used for setting the green time for intersection movements. The Santa Clara County CMP uses default minimum green times based on vehicular traffic requirements as shown in Table 5 of these guidelines or calculated minimum green times based on pedestrian traffic requirements as described in these guidelines.

Permitted-Protected: This is a type of left turn signal phasing in which left turn movements have a permissive green interval during which they can move through the intersection using gaps in the opposing traffic stream followed by a protected green interval during which the left turn movements can move through the intersection unopposed.

Protected-Permitted: This is a type of left turn signal phasing in which left turn movements have a protected green interval during which they can move through the intersection unopposed followed by a permissive green interval during which the left turn movements can move through the intersection using gaps in the opposing traffic stream.

Saturation Flow Rate: This is the flow that can be accommodated by a lane group assuming that the green phase is always available to the lane group. Saturation flow rate is expressed in terms of vehicle per hour. The Santa Clara County CMP uses default saturation flow rates for the various lane configurations. These are documented in Table 4 of these guidelines.

Split Phase: This is the type of signal phasing where all movements on one intersection approach move through the intersection unopposed in a green interval, followed by all movements on the opposite intersection approach moving through the intersection unopposed in a separate green interval.

TRAFFIX for Windows Related Terms

Data Fields: These are entry cells in the program where user entry is possible.

Dialog Box: This is an entry box with at least one field for data entry usually presented to the user when a menu item is selected. The TAB key can be used to move from field to field.

Editing Window: This is the white background area that appears when a new database is created or an existing database is opened. The intersections under analysis appear in the editing window. Each open database will appear in its own editing window.

Grab Drawing Tool: This is the "hand" icon on the network drawing/editing tool bar that can be used to move items in the editing window.

Intersection Pop-up Menu: This is a menu that can be activated by right clicking with the cursor on an intersection in the editing window.

Left Clicking: This is the term for pressing the left mouse button.

Menu Bar: This is the bar at the top of the program start-up screen with the following menu items: File, Edit, Arrange, Options, Window, Tools and Help.

Network Drawing/Editing Tool Bar: This is a vertical tool bar on the start-up screen located to the left of the area reserved for editing windows.

Pull-Down Menu: This is the menu that appears when one of the menu bar items is selected. The menu items can be activated by left clicking on the menu bar items or by typing ALT and the underlined letter of the menu bar item.

Right Clicking: This is the term for pressing the right mouse button.

Tabbed Dialog Box: These are the dialog boxes that appear when Geometry or Volume is selected in the intersection pop-up menu.

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APPENDIX

Creating the DEFAULTS.TFX Database

The TRAFFIX program disks include a file called DEFAULTS.TFX which is a TRAFFIX database with global and intersection parameters already set to VTA default values. If for any reason there is a need to recreate this file, the information in this Appendix may be used to set the VTA default values.

Creating a New Database -- The first step in the process for creating the DEFAULTS.TFX database is the creating of a new database by left clicking **File** on the menu bar and selecting **New Database** from the pull-down menu. Alternatively, a new database can be created by clicking on the left-most button above the network drawing/editing tool bar. The name DEFAULTS should be entered for the name of the new database.

A white background editing window will appear to the right of the network drawing/editing tool bar when the new database is created. The name of the new database, in this case DEFAULTS, will be displayed in the upper left corner of the window.

Setting Global Data -- Global parameters for the DEFAULTS.TFX database should be set to CMP default values by clicking **Options** on the menu bar and selecting **Global Data** from the pull-down menu. Alternatively, the global parameters pull-down menu can be activated by right clicking in any part of the editing window. The following are the choices under **Global Data** that require entry:

> **Scenario...Edit Scenarios**: This is where separate analysis scenarios are defined. For example, to define separate AM peak and PM peak analysis scenarios, two scenarios named AM Peak and PM Peak can be created. Associated with each scenario are nine data sets: command, volume, geometry, impact fee, trip generation, trip distribution, path, route and configuration. Separate names for every type of data set that will vary from scenario to scenario should be specified.

> The DEFAULTS.TFX database should include: a PM Peak scenario with a **Volume** data set named Existing PM Peak Hour and a **Geometry** data set named Existing. A specific name does not need to be defined for the other data sets.

> **Reports**: This is where the output reports are defined. Many of the reports are for features in TRAFFIX (e.g., trip generation, trip distribution and arterial LOS) not utilized when conducting only LOS evaluations.

> The DEFAULTS.TFX database should include: only the LOS Base Compute Report and the Level of Service Summary Report.

> **Titles**: This is where the title for the reports, global adjustment factors, the maximum cycle length, the LOS analysis method, calculation of saturation flow rates per HCM, the LOS grade modifiers (e.g., B+, B- and C+), report G/C ratio or green times and use of metric units are specified.

If the three lines of the title field on this screen are left blank, the one-page output that is customary for Santa Clara County analysis will include three additional lines of data. The data that are added in this case are the uniform delay, incremental delay and the progression adjustment factor (represented as "Delay Adj").

The global parameters are used only if there is no entry in the data field that corresponds to the global parameter for a given intersection. The default LOS analysis method for signalized intersections in TRAFFIX is the *HCM2000* operational method. Thus, whenever a new signalized intersection is created, the analysis method indicated will be the *HCM2000* operational method. By using the **Parameters** input screen, it is possible to over-ride this default method specified by TRAFFIX.

The following is a procedure to set the VTA analysis method as the analysis method for all intersections if the **Signalized LOS Method** data field in **Parameters** already indicates the CMP analysis method. Select another analysis method other than the standard CMP analysis method. When "OK" is selected, the following message will be displayed: **Global Signalized LOS Method Change. Apply to ALL Signalized Intersections?** Select "No" to this question, and go back into **Parameters**. This time select the standard VTA analysis method and select "Yes" to **Global Signalized LOS Method Change. Apply to ALL Signalized Intersections?** The analysis method for all intersections then will be set to the standard VTA analysis method.

The easier way to ensure that all intersections have the standard VTA analysis method selected is to copy a template intersection already set with the VTA analysis method. Procedures for creating this template intersection are described under "Creating a Template CMP Intersection" later in this section.

Parameters includes a data field to specify plus/minus levels of service. The **Report LOS Grade Modifier?** data field should be set to "Yes" to specify use of plus/minus levels of service. The average stopped delay thresholds with plus/minus levels of service for CMP intersections are shown in Table A-1. These are the standard LOS thresholds for CMP intersections.

The DEFAULTS.TFX database should include: (a) a title indicating the year of the CMP monitoring program (e.g., 2003 CMP Monitoring Program), name of agency and peak hour of analysis (e.g., PM peak) should be specified (not including a title provides three additional lines that allows for output of uniform delay, incremental delay and progression adjustment factor); (b) all volume, growth and delay adjustment factors set to 1.0; (c) the **Signalized LOS Method** set to " HCM 2000 Operations"; (d) the **Cal Sat Adj** check box as not marked; (e) the **Report G/C or Green Time?** data field set to "Green"; (f) the **Report LOS Grade Modifier?** data field set to "Yes"; and (g) the name of the person conducting LOS evaluations and date of evaluations entered in the **Comment** field.

LOS Parameters...2000 HCM Operations Method: This is where the default saturation flow rates, passenger car equivalents for permitted left turn movements, and universal volume adjustment factors are specified.

Table A-1: Signalized Intersection LOS Criteria

Level of Service	Average Control Delay (seconds/vehicle)
A	delay ≤ 10.0
B+	10.0 < delay ≤ 12.0
B	12.0 < delay ≤ 18.0
B-	18.0 < delay ≤ 20.0
C+	20.0 < delay ≤ 23.0
C	23.0 < delay ≤ 32.0
C-	32.0 < delay ≤ 35.0
D+	35.0 < delay ≤ 39.0
D	39.0 < delay ≤ 51.0
D-	51.0 < delay ≤ 55.0
E+	55.0 < delay ≤ 60.0
E	60.0 < delay ≤ 75.0
E-	75.0 < delay ≤ 80.0
F	delay > 80.0

The VTA recommended default saturation flow rates are shown in Table A-2. In TRAFFIX, these saturation flow rates are specified through the use of adjustment factors and a default ideal saturation flow rate. In the case of the *HCM2000* operational method, the default ideal saturation flow rate is 1900 vph. Consequently, a saturation flow rate of 1800 vph is represented in TRAFFIX by the factor 0.947368, which is the same as 1800 divided by 1900. These adjustment factors shown in the **Universal Saturation Flow** fields are included in Table A-2 below the corresponding saturation flow rate. These values should **not** be modified under any circumstance. If the desire is to specify a non-standard saturation flow rate for a particular movement at an intersection, this should be done as described under **User Saturation Adjustment** in **Section 2.5 Signal Timing Data** of these guidelines.

The saturation flow rate for multiple turn lanes is calculated by applying an 80 percent reduction to the single lane saturation flow rate for each additional turn lane. The saturation flow rates for turning movements applies for protected operations (i.e., when the movement can move unopposed with its own signal phase) only.

The **Universal Volume Adjustment Factors** in TRAFFIX are based on HCM standards for lane utilization factor. These factors should be set to 1.00 for Santa Clara County CMP analyses.

The DEFAULTS.TFX database should include: (a) **Universal Volume Adjustment Factors** all set to 1.00; (b) the **Universal Saturation Flow** fields set to the adjustment factors shown in Table A-2; and (c) the other fields on this screen do

not need to be changed. Specification of a non-standard saturation flow rate should be done by using the **User Saturation Adjustment** screen under **Geometry** of the intersection pop-up menu.

Table A-2: Default Saturation Flow Rates

Movement	Default Saturation Flow Rate (vph) (Default TRAFFIX Adjustment Factor)			
	1 Lane	2 Lanes	3 Lanes	4 Lanes
Left Turn	1750 (0.921053)	3150 (0.828947)	4550 (0.798421)	
Left-Through	1800 (0.947368)			
Through	1900 (1.000000)	3800 (1.000000)	5700 (1.000000)	7600 (1.000000)
Right-Through	1800 (0.947368)			
Right Turn	1750 (0.921053)	3150 (0.828947)	4550 (0.798421)	
Left-Through-Right	1750 (0.921053)			

Output File: This is where the user can specify a name for the output file. The output file is where the results of the analysis are stored. The default output filename in the program is "Existing.out", but the user may select a different name. The user should select a unique output filename for each distinct analysis scenario.

Modifications to the remaining five options under **Options...Global Data** are not necessary for configuring the DEFAULTS.TFX database.

Creating a Template Intersection -- A template intersection with VTA default values should be created in the editing window as follows:

1. Select the traffic signal icon in the network drawing/editing tool bar by clicking on it with the left mouse button.
2. Click the left mouse button in the editing window to place the intersection. A traffic signal icon, representing an intersection, should appear in the editing window.

Data for this intersection is set to VTA default values by accessing the intersection pop-up menu by right clicking on the intersection representation. The following default values should be entered:

- **Geometry...Signal Timing:** The **LOS Method** should be set to "2000 HCM Operations - Default Sat. Flows." The minimum green times should be set to seven seconds for left turns and ten seconds for throughs and right turns.

- **Geometry...HCM Saturation Calc Input:** The entry in this data field should be set to reflect the signal type at the given intersection, either "Fixed Time, Actuated, or Semi-Actuated." The selection of signal type affects the calculation of k, the incremental delay factor that is dependent on controller settings, in the second delay term, d_2. The values for k are provided in Exhibit 16-13 of *HCM2000*. The value of k is also dependent on the unit extension entered in the **Delay Adjustment** dialog screen and the degree of saturation. Pretimed or nonactuated movements always have a k-value of 0.50. The **Calculate HCM Sat Adj** field should be set to "No."

Creation of a new database with a template intersection should result in the creation of the DEFAULTS.TFX database with VTA default values.

The database should be saved by left clicking **File** on the menu bar and then selecting **Save Database** (or alternatively by typing CTRL-S).