2 | Methodology

This section discusses the three-step methodology for measuring LOS during the current monitoring cycle. In the first step, Alameda CTC screened days within the monitoring period to ensure that only days that were expected to result in typical commuter traffic conditions were retained. Days that may have produced lighter than usual traffic conditions such as public holidays or heavier than usual conditions such as special events were identified for later removal.

The second step consisted of the actual data collection using either commercial speed data or floating car surveys. Data was collected for the Tier 1/Tier 2 CMP network, HOV/express lanes, bridges, and OD surveys. In the final step, data was analyzed separately for commercial speed data and floating car surveys to obtain the average speed and converted to LOS using HCM methodologies.

2.1 | Screening for Data Collection Periods

As a preliminary step in the analysis, it was necessary to identify all the days and time periods during which the CMP network could be monitored. Since travel time data for 2016 was collected using a combination of commercial speed data and in-field floating car surveys, monitoring days for both data sources were reviewed and identified separately.

As a part of the preliminary analysis, all potential factors that may affect the monitoring effort were carefully examined. This included identifying school holidays across the county and any events that occurred during the monitoring period. Analyzing these additional factors was necessary to identify good quality data for the current monitoring. This in turn ensured that the LOS results are representative of typical traffic conditions experienced by a daily commuter.

2.1.1 | Base Monitoring Times

Data for the LOS monitoring is typically collected in spring when the schools are in session. For the 2016 monitoring cycle, commercial speed data collection and floating car surveys were conducted in the last week of February, and the months of March, April and May. The project team collected weekday data on Tuesdays, Wednesdays and Thursdays for the morning (7:00 a.m. to 9:00 a.m.) and afternoon (4:00 p.m. to 6:00 p.m.) peak periods. This resulted in a total of 43 monitoring days from which additional days were excluded for public holidays and school spring break. Freeways (Tier 1) were also monitored separately on weekends between 1:00 p.m. to 3:00 p.m.

2.1.2 | Public Holidays and Spring Breaks

Weeks containing public holidays and school spring break periods were expected to produce non-representative traffic patterns. The associated data were therefore removed from the commercial speed datasets. Figure 2-1 shows public holidays and spring break periods during the 2016 data collection period.

The spring break periods of Alameda County schools varied by the school district and occurred as early as March 25 and ended as late as April 15.[11] For spring break periods, data was not collected on the arterial network within the school district boundaries during their designated spring break. However, travel time data collection on the freeway and ramp networks continued during spring break periods as these facilities were expected to serve more inter-county and interregional traffic.

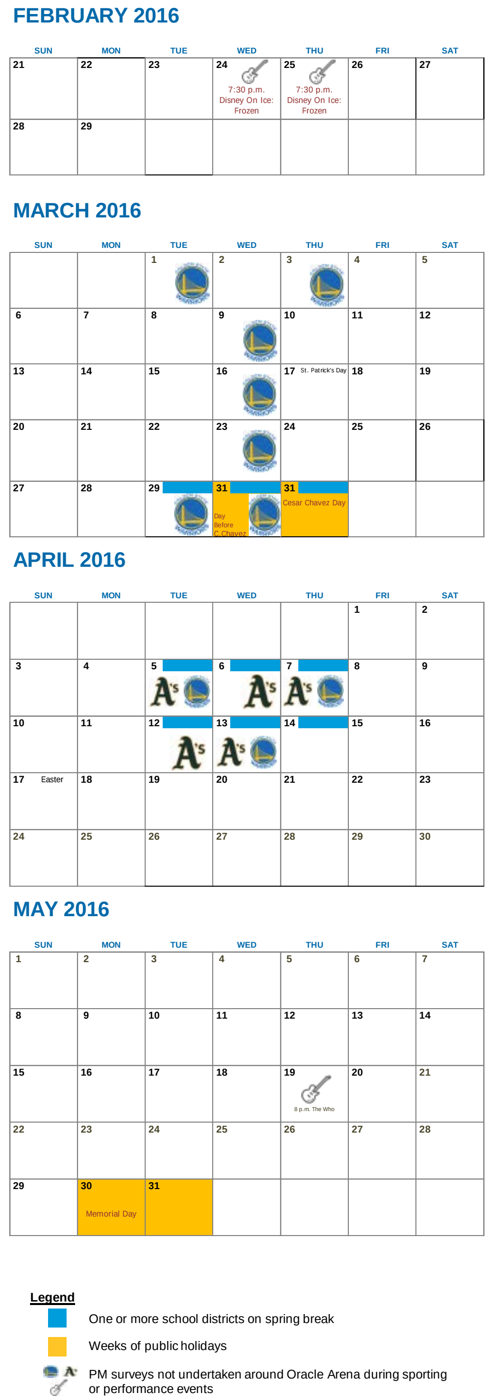


Figure 2-1: Public Holidays, Spring Break Periods, and Events in Alameda County: Spring 2016

2.1.3 | Special Events

Special events in Alameda County were reviewed to see if they occurred during or near the specified weekday monitoring times. Traffic data associated with such events was removed from monitoring due to expected irregularities.

While there were some significant regional events, the majority of the events did not occur within the monitoring period. Events in Oracle Arena, such as Warrior basketball games and Oakland A's baseball games, or concert performances were the notable exceptions (see Figure 2-1). Games were played on a number of Tuesdays, Wednesdays, and Thursdays starting at 12:35 p.m., 7:05 p.m., or 7:30 p.m. These games could have had an impact on the afternoon peak period and therefore data for all the relevant CMP segments near or approaching Oracle Arena were excluded in the afternoon peak on these event days.

2.1.4 | Weather Events

Weather events were also considered as a part of the analysis, however, no events were observed to impact traffic conditions, although some floating car surveys were rescheduled as a precaution.

2.1.5 | Construction and Maintenance

The project team reviewed various information sources to identify significant construction impacts during the monitoring period. These included the following (see Figure 2-2):

- Alameda CTC projects page;
- Other government websites (including Caltrans District 4);
- Specific construction project websites;

[11] Composite Calendar for the 2015-2016 School Year. Alameda County Office of Education. http://www.acoe.org/acoe/files/Home/CompositeCalendar2015-16.pdf

Facebook news feeds from cities, major projects

Twitter news feeds from cities, major projects

Caltrans lane closure database

PeMS lane closure database & incident feeds

Figure 2-2: Sources of Information about Construction Activities and Lane Closures

- Facebook and Twitter feeds (such as the 511 SF Bay Twitter Feed[12]); and
- Caltrans Performance Measurement System (PeMS) lane closure database.

Further, cities and the county were requested to share their construction and maintenance schedules. Both long and short term construction activities were identified. As an example of a long term construction activity, I-80 eastbound along the San Francisco-Oakland Bay Bridge experienced ongoing construction for the majority of the monitoring period in the morning peak, including a regular closure of one travel lane. In this instance, there would not be adequate alternative days to gather a suitable sample size if all the days impacted by construction were removed. Therefore, data collection days were not restricted based on such long term construction. Table 2-1 lists segments impacted by ongoing long term construction.

Short term construction activities were reviewed and evaluated separately. For example, one lane on State Route 24 (eastbound) was closed from Tuesday March 22nd at 9 p.m. to Wednesday March 23rd at 10 a.m. between the Martin Luther King Jr. Boulevard off-ramp and the Broadway on-ramp. Data collected from the days and particular CMP segments impacted by construction were removed from the monitoring data set to eliminate the potential construction impact on the traffic flows. Given the short duration of the construction activities compared to the total monitoring period, the remaining data provided an adequate sample size for monitoring.

[12] Twitter Feed for 511 SF Bay twitter.com/511SFBay

Table 2-1: Long-term Construction Projects active during Spring 2016 LOS Monitoring

Tier	Impacted Roads	Extents	Description of Work
Freeway (Tier 1)	I-80 EB Bay Bridge	Bryan St. On-ramp to SF-Alameda County Line	Road Construction
Freeway (Tier 1)	I-880	Between SR 262 (Mission Blvd.) and 42nd Ave.	Median Barrier Construction
Freeway (Tier 1)	SR 92	Between the toll plaza and I-880	Road Construction
Arterial (Tier 1)	SR 238	Between I-580 Off-ramp to 680 On-ramp	Delineation
Arterial (Tier 1)	SR 123 (San Pablo Ave.)	Between 35th St. and 53rd St.	Road Construction
Arterial (Tier 1)	SR 84	Between culvert located 1.63 miles south of Kalthoff Common, to Stanley Blvd.	Expressway Construction
Arterial (Tier 2)	Alvarado Ave WB	Fair Ranch Rd. to Fredi St.	Road Construction. Complete Road Closure.
Arterial (Tier 2)	Sunol Blvd. NB	I-680 Off-ramp to Bernal Ave.	PG&D Gas Transmission Line Upgrade
Arterial (Tier 2)	Fremont Blvd. NB	Paseo Padre Pkwy. to NB I-880 Off-ramp	Condominium project
Arterial (Tier 2)	Fremont Blvd. SB	Paseo Padre Pkwy. to Decoto Rd.	Condominium project
Arterial (Tier 2)	Fremont Blvd. NB	Paseo Padre Pkwy. to Decoto Rd.	Church improvement
Arterial (Tier 2)	Fremont Blvd. NB	Thornton Ave. to Decoto Rd.	School site construction
Arterial (Tier 2)	Fremont Blvd. NB	Adams Ave. to Stevenson Rd.	Condominium project
Arterial (Tier 2)	Fremont Blvd. NB	Blacow Rd. to Adams Ave.	Condominium project
Arterial (Tier 2)	Tassajara Rd. NB & SB	Between Gleason Dr. and Fallon Rd.	Culvert Replacement. Complete Road Closure.
Arterial (Tier 2)	Broadway in Oakland	Between Grand Ave. and 14th St.	Streetscape Improvements
Arterial (Tier 2)	Powell St. in Emeryville	Between San Pablo Ave. and I-80	Road Construction

2.1.6 | Incidents

Incidents are generally expected to impact traffic conditions, and therefore data associated with incidents has been excluded. For floating car surveys, where the driver observed an incident, the floating car survey run was repeated. For commercial speed data, freeway incident data sets from the Performance Monitoring System (PeMS) were reviewed and the speed data records for the time period corresponding to an incident were removed across all the relevant CMP segments. Figure 2-3 shows a heat map of freeway incidents using data from PeMS and qualitatively indicates incident hot spots. Locations with higher densities of incidents are shown in red.

Notable incident hotspots observed were on freeways connecting to the Bay Bridge and San Mateo Bridge.

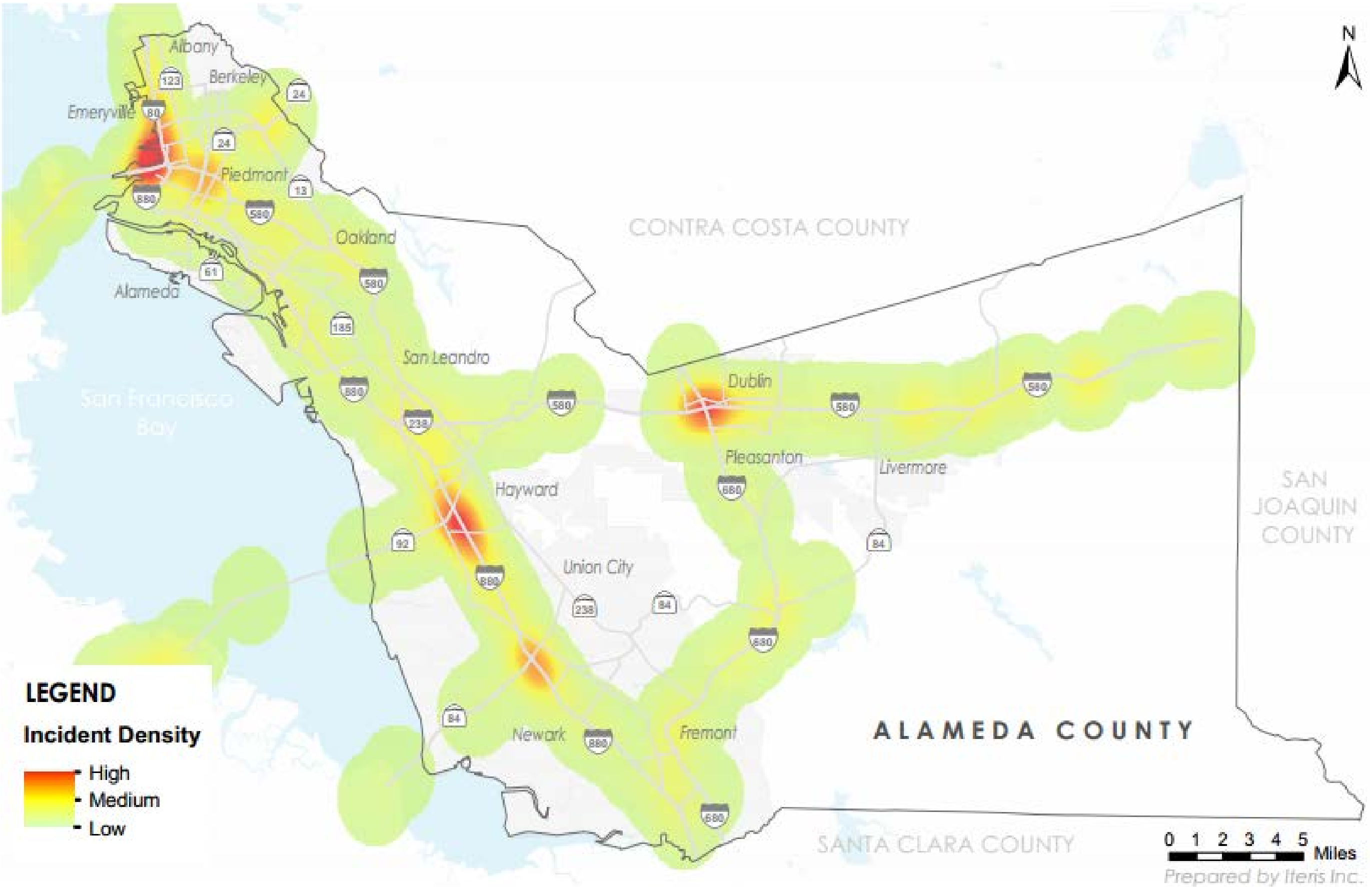


Figure 2-3: Incident Density Heat Map (Source: Freeway PeMS Incident Data, 2016)

These locations with high incident density reported around 80 to 100 incidents in the vicinity during the monitoring period. Locations with medium incident density, such as around the interchange area of I-580/ State Route 24 in Oakland, and the interchange area of State Route 84/I-880, reported around 30 to 40 incidents each during the monitoring period. Other locations with low incident densities, including I-680 along the Sunol Grade and along I-580 in East County between Livermore and the Altamont Pass, reported less than 15 incidents during the monitoring period.

2.2 | Data Collection

As in the 2014 LOS Monitoring Report, Alameda CTC used both commercial speed data and floating car surveys to measure average speed to determine the LOS. Table 2-2 and Figure 2-4 summarizes the source of travel time data for each category of CMP segment.

Table 2-2: Summary of Data Collection Methods

CMP Network Category	Miles	2014 Data Collection	2016 Data Collection
Freeways (Tier 1)	140 miles	Commercial data[1]	Commercial data
Ramp and Special Segments (Tier 1)	23 connections	Commercial data[1]	Commercial data[2]
Arterials (Tier 1)	99 miles	Floating car surveys	Floating car surveys
Arterials (Tier 2)	89 miles	65 miles Commercial data 25 miles Floating car surveys	71 miles Commercial data 18 miles Floating car surveys
HOV/Express Lanes	86 miles	Floating car surveys	Floating car surveys
Bridges	10 miles	Commercial data	Commercial data
OD surveys	10 routes	Floating car, transit and bike surveys	Floating car, transit and bike surveys. Desktop study conducted for two routes.

1. Data for two segments collected using floating car surveys.
2. Data for three segments collected using floating car surveys.

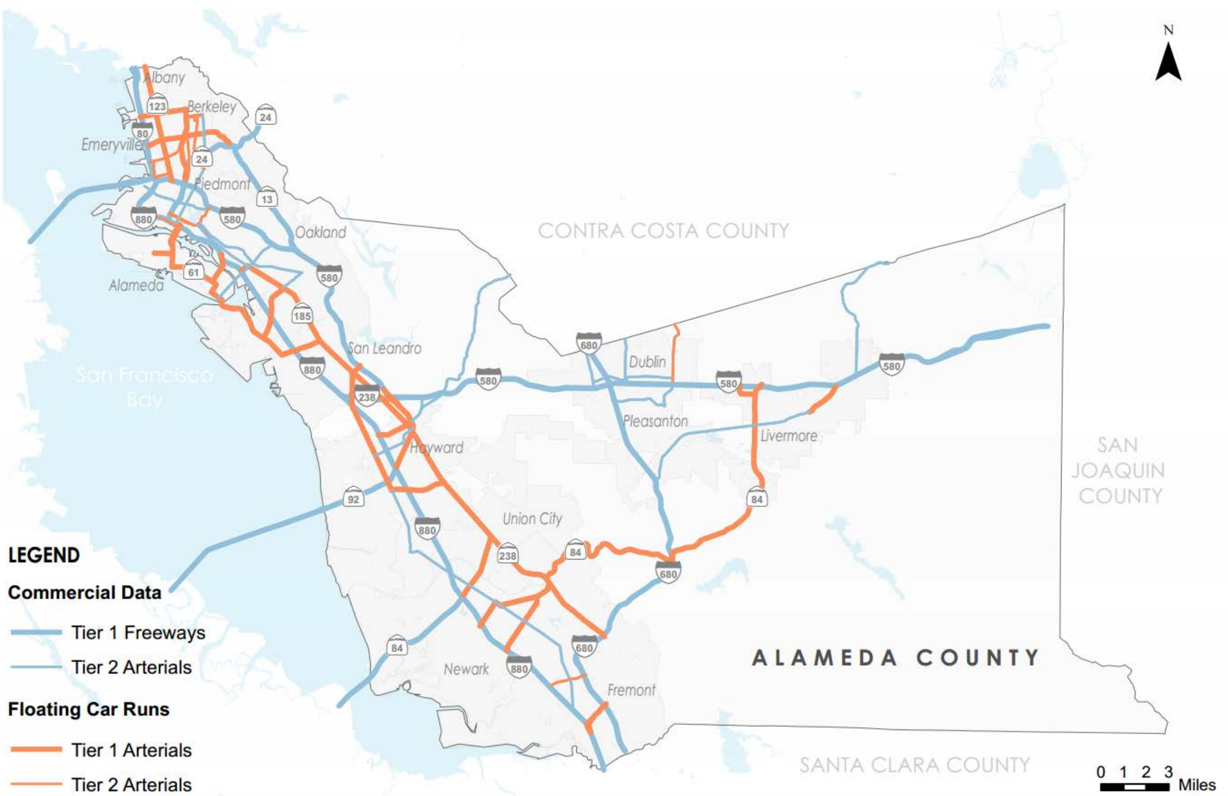
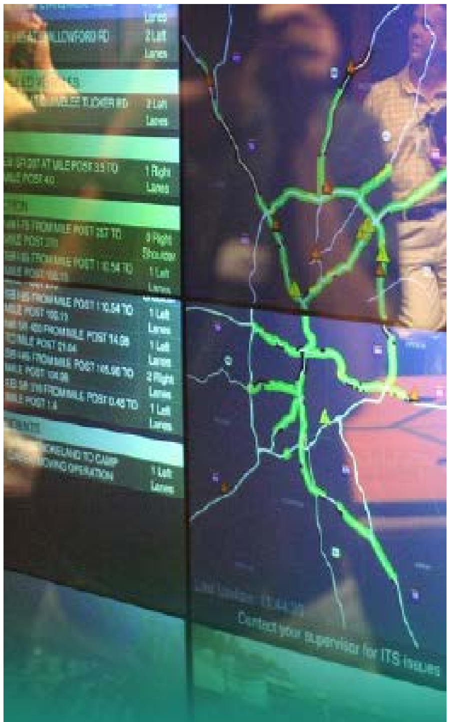


Figure 2-4: Data Collection Methodology (2016)

2.2.1 | Commercial Speed Data

In 2013, MTC contracted with a third-party commercial data vendor, INRIX, to obtain region-wide commercial speed data, and has made the data available free of charge to CMAs and other local governments for planning and monitoring purposes. This LOS Monitoring Report used the commercial speed data from INRIX through MTC's contract.



INRIX "aggregates traffic data from GPS-enabled vehicles and mobile devices, traditional road sensors and hundreds of other sources."[13] Traffic data is reported by INRIX using discrete roadway links defined as Traffic Message Channels (TMCs). Each TMC link is associated with a unique ID represented by a nine-digit code, where each individual number in the TMC code describes a portion of the geography including country, direction of travel, and roadway segment. INRIX data contains speeds aggregated at one-minute level for each TMC code in the network. For the current monitoring period, data at one minute intervals was accessed for the selected monitoring times across all the identified TMCs in Alameda County. This resulted in a sample size of approximately 3,500 data points for the majority of CMP segments. Appendix F provides technical details about this data collection.

2.2.2 | Floating Car Survey Data

Where the coverage of commercial speed data was not adequate or results were not expected to be reliable, floating car surveys were used. The floating car surveys were completed using GPS technology to determine the travel time between the start and end of each CMP segment. For each of these CMP segments on the arterials (Tier 1/Tier 2) and HOV/express lanes, the study completed six floating car surveys. Several freeway ramps, which were not covered by commercial data, were also measured using floating car survey. If a CMP segment that used floating car surveys experienced congestion (LOS F) in the afternoon peak and the segment was subject to CMP conformity, then two additional runs were generally completed. Appendix G provides additional technical details on the floating car data collection effort.

2.2.3 | OD Surveys

Travel time on ten origin-destination pairs that reflect typical Alameda County commute trips (between major residential areas and employment centers) were monitored for comparability of travel by auto and alternative modes (See Appendix E). OD surveys were completed using:

- Floating car surveys for the auto and HOV component (4 runs);
- Transit passenger travel surveys for the transit component (2 runs);
- Online transit travel surveys for the transit component (2 runs) were completed for two OD routes; and
- A bike rider for the bicycle component (2 runs).

The OD routes were monitored either in the morning or afternoon peak depending on the peak direction of the route. Consistent with the general LOS monitoring procedure, Alameda CTC conducted surveys on

[13] INRIX. http://inrix.com

Tuesdays, Wednesday and Thursdays during the route's monitoring period on two different days.

A number of surveyors traversed between the designated OD points, documenting their travel times. Transit trips were taken either on buses (AC Transit, Union City Transit, VTA, or Wheels), rail (BART or ACE), or a combination of these modes. The bicycle trip was taken on local streets in Emeryville and Berkeley. Whenever necessary, the auto and transit trip started on the same day at the same time. These survey times included walking, waiting, parking and traveling times, as applicable.

As a pilot study for the 2016 analysis cycle, the study conducted online transit surveys concurrently with some in-field transit surveys. In this method, staff at a desktop computer observed and logged the real-time departure and arrival times of transit vehicles online. This pilot tested the possibility to expand the use of Big Data to monitor transit travel countywide.

As a pilot study for the 2016 analysis cycle, the study conducted online transit surveys concurrently with some in-field transit surveys.

2.3 | Data Analysis

The methodology for deriving the LOS from raw commercial speed and floating car survey data includes two key steps. The first step consists of converting the raw speed data into average peak period speeds on every CMP segment. In the second step, average speeds are converted to estimate LOS using a specific method depending on the type of roadway.

2.3.1 | Calculate Average Peak Period Speed

The steps for converting raw speed data to average peak period speeds vary based on the data source.

- **Commercial Speed Data:** Once collected from the INRIX database, the commercial speed data points were associated to the appropriate CMP segment through a spatial mapping process. Next, data outside the monitoring period and data with poor data quality were removed. To calculate the average speed for all the data points, the data was averaged on each CMP segment for each time period. See additional technical details in Appendix F.
- **Floating Car Survey Data:** Once the floating car survey data was collected using GPS units, it was processed to extract the average speed and travel time on sub segments of each CMP segment. Alameda CTC then input sub segment average speeds and travel times into a spreadsheet that calculated aggregated average speed for each CMP segment using the segment's travel time and length. Appendix G provides additional technical details.

2.3.2 | LOS Estimation

The next step in the analysis process was to assign LOS based on the average speeds calculated on each CMP segment. As adopted in the 2013 CMP, LOS is estimated for the entire CMP network based on HCM

1985 with the exception that Tier 2 arterial segments will also be reported using HCM 2000 for comparison purposes. This study uses the LOS speed standards as shown in Tables 2-3, 2-4 and 2-5.

Table 2-3: Freeway LOS (Source: HCM 1985)

Level of Service	Speed (mph)	Density (pc/mi/ln[1])	V/C Ratio	Maximum Service Flow (pcphpl[2])
A	≥ 60	≤ 12	0.35	700
B	≥ 55	≤ 20	0.58	1,000
C	≥ 49	≤ 30	0.75	1,500
D	≥ 41	≤ 42	0.90	1,800
E	≥ 30	≤ 67	1.00	2,000
F	< 30	> 67	- [3]	-

Range for LOS F for Freeway Sections[4]
F30—Average Travel Speed < 30
F20—Average Travel Speed < 20
F10—Average Travel Speed < 10

Source: Adapted from Table 4-1, Special Report 209, HCM 1985
[1] Density measured in passenger cars per mile per lane
[2] Maximum service flow under ideal conditions, expressed as passenger cars per hour per lane
[3] Highly variable, unstable flow; V/C Ratio is not applicable
[4] Approved by Alameda CTC in June 2004 to show degrees of LOS F on congested roadways.

Table 2-4: Arterial LOS (Source: HCM 1985)

Arterial Class	I	II	III
Range of Free Flow Speed (mph)	45 to 35	35 to 30	35 to 25
Typical Free Flow Speed (mph)	40	33	27
Level of Service	**Average Travel Speed (mph)**		
A	≥ 35	≥ 30	≥ 25
B	≥ 28	≥ 24	≥ 19
C	≥ 22	≥ 18	≥ 13
D	≥ 17	≥ 14	≥ 9
E	≥ 13	≥ 10	≥ 7
F	< 13	< 10	< 7

Source: Table 12-1, Special Report 209, HCM 1985

Table 2-5: Arterial LOS (Source: HCM 2000)

Urban Street Class	I	II	III	IV
Range of Free Flow Speed (mph)	55 to 45	45 to 35	35 to 30	35 to 25
Typical Free Flow Speed (mph)	50	40	35	30
Level of Service	**Average Travel Speed (mph)**			
A	> 42	> 35	> 30	> 25
B	> 34-42	> 28-35	> 24-30	> 19-25
C	> 27-34	> 22-28	> 18-24	> 13-19
D	> 21-27	> 17-22	> 14-18	> 9-13
E	> 16-21	> 13-17	> 10-14	> 7-9
F	≤ 16	≤ 13	≤ 10	≤ 7

Source: Exhibit 15-2, HCM 2000 (U.S. Customary Units)

2.3.2.1 Freeways

Based on the average speed of the freeway in the morning and afternoon peaks and using the HCM standards as shown in Table 2-3, LOS was estimated for each CMP segment in each time period. For example, the I-80 eastbound segment between Ashby Avenue and University Avenue had an average speed of 62.9 mph during the morning peak period, which is LOS A based on the adopted standards.

2.3.2.2 Ramps and Special Segments

Based on the suggested guidelines from the HCM:

- LOS A is deemed to occur when vehicles are traveling at a free-flow speed for the given roadway conditions.
- LOS F is estimated to occur when speeds have dropped below 50 percent of the free flow speeds.
- Levels of Service B to E are calculated at even intervals between free flow speeds and LOS F speeds.

To determine LOS for these ramps, the free flow speed was obtained from special studies conducted in 1992, during off-peak low-volume conditions. There is one ramp segment that is classified as a weaving segment and is therefore not assigned a LOS consistent with previous monitoring cycles. The performance of this segment can be judged on its average speed.

2.3.2.3 Arterials

Both HCM 1985 and 2000 methods first require classification of the arterial according to its free flow speed and other road characteristics. The road classification based on HCM 1985 could be Class I, II or III and based on HCM 2000 it could be Class I, II, III or IV. The classifications for both tiers were previously determined and were obtained from previous LOS monitoring reports.

Using the classification of the street and the average travel speed, and based on relevant HCM standards as shown in Tables 2-4 and 2-5, LOS for the arterial segment is determined for both HCM methodologies. For example, Broadway southbound (between Grand Avenue and 14th Street) had an average speed of 14.5 mph during the morning peak. It was classified as HCM 1985 Class III (based on the segment's free flow speed and other road characteristics) and therefore assigned a LOS C. Using HCM 2000, it was classified as Class IV and assigned a LOS C again. In later sections where the number of LOS F segments are tallied and compared to previous years, LOS F segments were identified using the HCM 2000 methodology for Tier 2 Arterials.

2.3.2.4 Rural Roadways

A few of the Tier 1 and Tier 2 CMP routes (mostly located in the east county) are rural roadways and require a special analysis procedure. Traffic and speed characteristics are fairly uniform on these roadways.

Variations in speed are a function of roadway curvature and the presence of slower trucks in the traffic stream. One such Tier 1 roadway is State Route 84 between the southern city limit of Livermore and Mission Boulevard in Fremont. Rural roadways identified in the Tier 2 network include a portion of Vasco Road in Livermore and a part of Crow Canyon Road, both connecting to the county line.

To be consistent with the methodology used in the prior monitoring cycle, based on guidelines from HCM 1985, LOS A is deemed to occur when vehicles are traveling near the free-flow speed for the given roadway conditions. LOS F is estimated to occur when speeds have dropped below 50 percent of the free flow speeds. Levels of Service B to E are calculated at even intervals between free flow speeds and LOS F speeds. This is adapted from Table 8-1, HCM 1985. Based on this methodology, LOS is calculated for rural roadways (both Tier 1 and Tier 2) for the current monitoring cycle.

The 2014 LOS Monitoring Report indicated that the HCM 2000 methodology was not appropriate for rural roads since it used speed thresholds only for evaluating the LOS. The HCM 2000 did not recognize that rural roads take many forms with different speed limits, functions and geometric constraints. When these speed thresholds were applied to the 2014 arterial (Tier 2) data, it was apparent that the HCM 2000 methodology was not appropriate for lower speed rural roadways. For this reason, the HCM 2000 LOS is not reported in this study as well. Later versions of the HCM have been modified to accommodate the shortcomings and may be considered in future monitoring cycles[14].

[14] Highway Capacity Manual (HCM). Transportation Research Board of the National Academies, Washington D.C. 2010