Appendix A | Methodology

Appendix A summarizes the methodology for auto and transit data analysis for the 2024 monitoring cycle.

A.1 Auto Methodology

This section discusses the methodology used for measuring level of service (LOS) in the current monitoring cycle. Overall, the data cleaning process was intended to ensure that LOS data was only analyzed for days and times that were representative of normal traffic conditions.

The monitoring period, which spans March to May of 2024, was first screened to identify and remove days that may have produced lighter than usual traffic conditions (such as public holidays) or heavier than usual traffic (such as special events).

The second step consisted of the actual data collection using either probe-vehicle based commercial speed data (e.g., INRIX data) or floating car survey data (if applicable).[1] Data was collected for 134 miles of freeways, 71 miles of State highways, and 341 miles of the arterial network.

In the final step, INRIX speed data was analyzed to assign LOS based on Highway Capacity Manual (HCM) methodologies.

A.1.1 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. This process was necessary to identify data that is generally representative of normal conditions on the CMP network for the current monitoring cycle.

[1] For the current monitoring cycle, only INRIX data was used and no field data using floating car surveys was collected.

All potential factors that may adversely impact traffic conditions were examined so that monitoring results are an accurate reflection of the average driving conditions experienced by daily commuters. The following sections describe each of these screening steps in more detail.

A.1.1a LOS Monitoring Times

LOS monitoring data was collected in spring 2024, when schools were in session.

Weekday data was collected on Tuesdays, Wednesdays, and Thursdays between March 1 and May 31, 2024, for the morning and afternoon peak-periods. The morning peak-period was defined as 7:00 AM to 9:00 AM, and the afternoon peak-period was defined as 4:00 PM to 6:00 PM. These windows are consistent with typical time periods during which peak travel occurs (highest volumes and congestion).

Weekend monitoring period data was collected on Saturdays and Sundays, between March 1 and May 31, 2024, between 1:00 PM to 3:00 PM on freeways only.

A.1.1b Public Holidays

Roads are typically less congested on public holidays, and are therefore screened for removal from the monitoring period. Upon review, no public holidays occurred on midweek days, Saturdays, or Sundays during the 2024 monitoring period.

A.1.1c School Breaks

For different schools in the County, spring break ranged from March 26 through April 19 in 2024. The midweek days during these periods were removed from the dataset for nearby arterials. This was done by identifying the arterials that were within the school district boundary for each school district based on their respective spring break. No changes were made to freeway segment data.

A.1.1d Special Events

Special events typically produce more congestion, although the effects are more localized and are often most noticeable on roadways near the event area. Traffic data associated with the major league baseball Oakland A’s home games were removed from the monitoring dataset in the vicinity of the event area. The specific segments to be removed were discussed with Alameda CTC and were determined based on the potential routes accessing the Oakland A's stadium. These included I-880 from SR-185 to SR-112, San Leandro Street from Fruitvale Avenue to East 14th Street, and Hegenberger Road from Edgewater Drive to SR-185.

A.1.1e Weather Events

The monitoring period was also screened for severe weather events such as heavy rainstorms or fog events, which could alter traffic patterns. No significant weather events were observed as impacting traffic conditions during the 2024 monitoring period.

A.1.1f Construction and Maintenance

The project team reviewed various information sources to identify significant construction and maintenance projects that may have impacted typical traffic patterns during the monitoring period. These included the following:

- Alameda CTC projects webpage;
- Other government websites (including Caltrans District 4 and local agency traffic advisory websites);
- Specific construction project websites;
- Facebook and Twitter feeds (such as the 511 SF Bay Twitter Feed);[2] and
- Caltrans Performance Measurement System (PeMS) lane closure database.

The project team classified construction and maintenance events during the monitoring period into two categories: short-term (occurring on three midweek days or fewer) and long-term (extending beyond three midweek days). The data associated with short-term construction events were removed from the monitoring dataset. The data associated with long-term construction events were kept in the dataset and flagged during the analysis, as segments that were significantly impacted by long-term construction and fell below the adopted standard are exempt from deficiency findings.

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

A.1.1g Incidents

Incidents (collisions, broken down vehicles, etc.) negatively impact traffic conditions, and therefore data associated with those incidents was excluded. The project team reviewed freeway incident datasets from PeMS and monitored 511 SF Bay social media channels for reported incidents. The INRIX speed data records for the time period corresponding to an incident were removed from the CMP segments where the incident occurred.

A.1.2 Data Collection

To calculate LOS, speed data was first collected from probe vehicle-based commercial speed data (i.e. INRIX). If commercial speed data lacked either spatial or temporal coverage, floating car surveys would be used. In the 2024 cycle, floating car surveys were not needed.

A.1.2a Commercial Speed Data

The 2024 Monitoring Report primarily utilized INRIX XD data, which reflects aggregated auto speeds in five-minute increments collected from GPS-enabled devices and other sources, to analyze roadway operational performance.

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 congestion management agencies (CMAs) such as Alameda CTC and other local governments for planning and monitoring purposes. This LOS Monitoring effort 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."[3] Traffic data, including travel speeds, is reported by INRIX using discrete roadway links defined as INRIX XD segments. INRIX and MTC changed their approach to roadway segmentation in 2019 to use XD segments, which offer greater granularity and are better able to adapt quickly to changes in road networks than Traffic Message Channels (TMC) segments. In addition, INRIX regularly updates the XD segmentation about twice every year, which

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

includes merging, splitting, or changing the extent of the XD segments. Therefore, for the 2024 cycle, the project team conflated the CMP network with INRIX's XD segments and a new list was created.

It is also worth noting the following differences between TMC and XD data in general:

- XD links are contiguous along corridors whereas the TMC segments had occasional gaps between segments and occasional segment overlaps.
- On arterial roadways (non-freeway segments) the XD links beginning and ending points are aligned with roadway intersections whereas the TMC segments many times ended mid-block.
- The TMC segments were relatively long in rural or non-urbanized areas. The XD links are all generally less than a mile or so in length.

For the 2024 monitoring cycle, the five-minute raw INRIX XD data was used, as it is of high quality without data gaps and aggregating five-minute data onto CMP segments will run more efficiently and accurately than at a more granular one-minute level. The average vehicular speed reported for each five-minute period on each XD link culminates in millions of lines of data for a three-month countywide dataset.

A.1.3 Data Analysis

The methodology for deriving LOS from raw commercial speed 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 and classification of roadway.

A.1.3a Calculate Average Peak-Period Speed

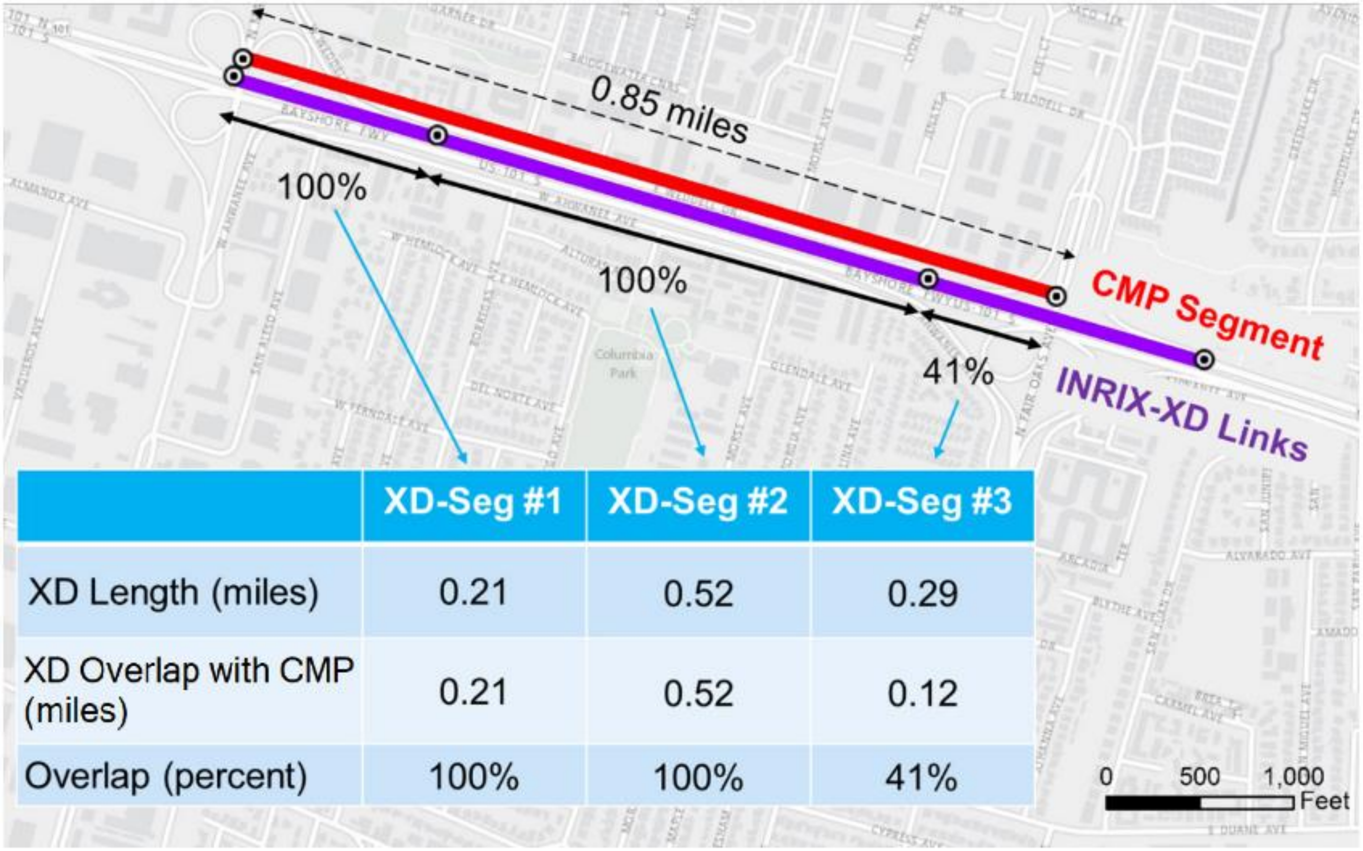
The following sections document the steps for converting raw speed data to average peak-period speed. Once collected from the INRIX database, commercial speed data points were conflated to the appropriate CMP segment through a spatial mapping process. As previously discussed, data outside the monitoring period and data with poor data quality (such as locations with low available sample sizes) was eliminated. To calculate average speed for all data points, the data was averaged on each CMP segment for each peak-period using the harmonic mean.

Step 1. Mapping INRIX XD links onto CMP Segments

Commercial speed data collected by INRIX was reported for predefined INRIX XD segments. For the purposes of the 2024 Multimodal Monitoring Report, it was required that the average speed be reported against an Alameda CTC CMP segment. CMP segments are typically longer sections of roadway, averaging approximately 1.2 miles in length (ranging from 0.2 to 5.0 miles). Therefore, INRIX XD links needed to be aligned against or mapped onto the CMP segments.

It should be noted that for some CMP segments, the ends of the CMP did not align with the ends of the INRIX XD segments. Figure A-1 shows a schematic example to explain this concept. It shows one CMP segment that is made up of three INRIX XD segments. However, the end of the last INRIX XD segment does not align with the end of the CMP segment. In these instances, only the overlapping portion of the XD length was used to calculate the average speed.

Figure A-1. Example Showing End Points of CMP and INRIX XD that Do Not Align



	XD-Seg #1	XD-Seg #2	XD-Seg #3
XD Length (miles)	0.21	0.52	0.29
XD Overlap with CMP (miles)	0.21	0.52	0.12
Overlap (percent)	100%	100%	41%

Step 2. Filter Raw Data

The raw INRIX data was filtered to remove:

- Times outside the morning peak, afternoon peak, and weekend periods;
- Data points impacted by special events (e.g., incidents, construction, major events); and data points with lower data quality scores:
    - INRIX includes a data quality score that accompanies every INRIX data point. The score value is defined as:
        - Score of 30: Data is exclusively generated from real-time sources.

- Score of 20: A mix of historical and real-time sources are used.
- Score of 10: Data is exclusively generated from historical data.

Only raw speeds that were directly measured were used for computing LOS in the CMP network. As such, data points with scores of 10 and 20 were removed, and only data with scores of 30 (equivalent to 100% real-time data) was kept, as illustrated in Figure A-2.

The quantity of remaining data points was tracked so the sample sizes of score 30 were known. The sample sizes are presented in conjunction with all associated commercial speed data results.

Figure A-2. Example of Filtering Process based on INRIX Data Score

Time Period	XD1	XD2	XD3	XD4	Length
1	20	30	30	30	¾
2	20	30	30	30	¾
3	30	30	30	30	1
4	30	30	30	30	1
5	30	30	30	30	1
6	20	30	20	30	½
7	30	30	20	30	¾

Step 3. Spatial and Temporal Data Aggregation - Average Speed Computations

This step covers the methodology of aggregating the data, both spatially and temporally.

Spatial Aggregation

Using the mapping created in Step 1 and the filtered INRIX data from Step 2, the INRIX XD data was spatially aggregated to corresponding CMP segments. In cases where multiple INRIX XD segments span a single CMP segment, the travel time was summed for all INRIX XD segments. If an INRIX XD segment only partially overlaps with the CMP segment, the weighted travel time was calculated based on the length of overlap.

$$CMP\ Travel\ Time = XD_1 + XD_2 + \cdots + XD_n$$

Temporal Aggregation

Temporal aggregation involved the translation of the CMP travel time metric for each five-minute increment into one average speed value corresponding to each CMP segment for the entire monitoring period. The following formula was used for this:

$$Average\ CMP\ Speed = \frac{\sum CMP\ Length}{\sum CMP\ Travel\ Time}$$

Sample size information was retained to assess the confidence level in the computed statistics.

Sample Size

The sample size is the number of data points that contributed to the final calculation of average speed. The sample size varied on each INRIX XD segment due to data filtering (e.g., school breaks, construction, maintenance, and incidents). As a CMP segment is typically made up of multiple INRIX XD segments, the lowest sample size of the corresponding INRIX XD segments was reported for the applicable CMP segment.

A.1.3b Assign LOS

The next step in the analysis process was to assign LOS based on the average speeds calculated for each CMP segment. As adopted in the 2013 CMP, LOS is estimated for the entire CMP network based on HCM 1985 with the exception of Tier 2 arterial segments, which are also reported using HCM 2000 for comparison purposes. This study uses the LOS speed standards as shown in Table A-1, Table A-2, and Table A-3.

Table A-1. Freeway LOS (Source: HCM 1985)

Level of Service	Speed (mph)	Density (pc/mi/ln) [1]	Volume-to-Capacity (V/C) Ratio[2]	Maximum Service Flow (pcphpl) [3]
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	-[4]	-
LOS F Sub-Designations for Freeways:[5] F30—Average Travel Speed < 30 mph F20—Average Travel Speed < 20 mph F10—Average Travel Speed < 10 mph				

Source: Adapted from Table 4-1, Special Report 209, HCM 1985

[1] Density measured in passenger cars per mile per lane

[2] V/C is the ratio between roadway demand (vehicle volumes) and roadway supply (carrying capacity). Volume refers to the number of vehicles using a roadway during a period of time, while capacity is defined as the ability to support that volume based on its design and number of lanes.

[3] Maximum service flow under ideal conditions, expressed as passenger cars per hour per lane

[4] Highly variable, unstable flow; V/C Ratio is not applicable

[5] Approved by Alameda CTC in June 2004 to show degrees of LOS F on congested roadways.

Table A-2. Arterial LOS (Source: HCM 2000)

Urban Street Class	I	II	III	IV
Range of free-flow speed (mph)	45-55	35-45	30-35	25-35
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)

Table A-3. Arterial LOS (Source: HCM 1985)

Urban Street Class	I	II	III
Range of free-flow speed (mph)	35-45	30-35	25-35
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

Assigning LOS - Freeways

LOS was estimated for each CMP segment during each monitored time period using the average freeway speed and HCM standards as shown in Table A-1.

Based on the suggested guidelines from HCM:

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

Assigning LOS - Ramps and Special Segments

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

Assigning LOS - Arterials

Both HCM 1985 and 2000 methods 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.

Using the classification of the street and the average travel speed, and based on relevant HCM standards as shown in Table A-2 and Table A-3, LOS for the arterial segment was determined following both HCM methodologies. For the number of LOS F segments being tallied and compared to previous years, HCM 2000 methodology was used for mapping Tier 2 Arterials results. The HCM 1985 methodology was used to calculate congestion mileages to maintain consistency with previous reporting cycles.

A.2 Transit Methodology

To better measure progress towards the agency's multimodal goals, Alameda CTC began to measure transit performance data along with the legislatively required auto performance data in 2018. This methodology allows the agency to compare transit and auto speed and performance on the same roads at the same time for a true apples-to-apples comparison of performance. Transit monitoring was paused for the 2020 monitoring cycle due to the COVID-19 pandemic, but was resumed in the 2022 cycle and continued in the 2024 cycle.

A.2.1 Transit Data

Transit speed monitoring was performed using data provided by AC Transit and LAVTA. Each agency provided a primary data source for measuring speeds: AC Transit provided data from Automatic Vehicle Location (AVL) units on their buses and LAVTA provided manually collected Running Time data.

AC Transit has onboard GPS devices in buses that keep track of geospatial movement throughout the network. These GPS devices monitor and archive the bus location (longitude and latitude) and a datetime stamp of when the Longitude/Latitude data was recorded. The AVL data shows snapshots of bus locations along the routes. They are called snapshots because each data record identifies one bus location at one specific point in time, like a series of photos or snapshots, rather than being a continuous recording. The time interval between data recordings is not necessarily constant, meaning it can differ from one bus to another and/or may be different for the same bus from day to day. An initial analysis showed that the time interval between the AC Transit recordings varies from a few seconds to several minutes. Since 2018, AC Transit has updated onboard AVL units, and consequently the quality of the transit data has improved. The date range for the requested AVL data was weekdays between March 1 to May 31, 2024. The data covered a full 24-hour period for each weekday.

AVL data was not available for LAVTA's buses along the CMP routes, as LAVTA currently does not have AVL units on their buses. LAVTA provided what is commonly called "Running Time" data, which is aggregated travel time between major bus stops. The LAVTA data was averaged over 15-minute periods for each route per direction. Like AC Transit data, the date range for the requested LAVTA Running Time data was weekdays between March 1 and May 31, 2024, with data covering a full 24-hour period for each weekday.

Additional information, such as published bus route maps and bus schedules, was used during the analysis to clean, filter, and interpret the location data, and to perform reality checks as well as quality control on the data and resulting transit speeds. The following list documents the datasets used for monitoring transit performances on CMP segments:

- AC Transit Data: AVL, AC Transit bus route maps and schedules, and bus route GIS shapefiles.
- LAVTA Data: Running times, bus route maps and schedules.

A.2.2 Transit Data Analysis

To align with the auto monitoring period, both AC Transit and LAVTA data was screened to include only Tuesdays, Wednesdays, and Thursdays between March 1 and May 31, 2024, excluding holidays. Data was extracted for three analysis time periods: (1) Morning peak-period: 7:00 – 9:00 AM; (2) Afternoon peak-period: 4:00 –6:00 PM; and (3) Off-peak-period: 10:00 AM – 12:00 PM. Data was further screened to include transit trunk routes only, as defined by Alameda CTC as specific transit routes of interest along CMP network segments within various jurisdictions in Alameda County.

The AVL and Running Time data was cleaned up by removing inaccurate data points. There are many factors that could affect the quality of GPS readings. For example, trees, buildings, and clouds could block satellite's line of sight in some portions of the road and result in poor GPS reading. No matter what the cause of the suspect GPS reading, a data point was considered inaccurate whenever one or two of the following criteria had not been met.

- The recorded points must be inside the roadway boundary. A point outside the roadway boundary means GPS triangulation reading has a significant error and must be removed. For example, a data point that falls on top of a building would be considered inaccurate and removed.
- The GPS heading must be along the general direction of movement. Consecutive points must show forward movement. In other words, it is expected that the bus distance from the very first bus stop (for a specific route) increases by time. If a location point indicates that this distance has decreased, it means the bus moved backward which is not possible in normal service conditions and therefore indicates an erroneous GPS reading that must be removed.

Using the AC Transit and LAVTA data, midweek average peak-period and off-peak transit speeds were then calculated for the monitored CMP arterial roadways. In the process of developing the methodology for transit performance monitoring, three measures were identified and used:

- Average bus speed during peak-periods
- Average bus speed to average auto speed ratio
- Peak-to-off-peak bus speed ratio

Given that the format of transit data differed by operator, separate data analysis procedures were developed to derive comparable metrics or performance measures from both AC Transit and LAVTA data.

A.2.2a Average Transit Speed for Peak-Periods

After cleaning the AVL data based on geospatial criteria and monitoring periods, the data points (snapshots) were mapped on the corresponding bus routes. Next, speeds were estimated for the CMP segments by inserting new data points at the CMP segment end-points, and then interpolating or extrapolating the date/time stamp at the CMP end-points. For each bus run, it was assumed that buses would operate in a safe manner within the roadway speed limits. To produce the final results, the results for all of the monitored routes were consolidated and aggregated using the weighted average method with the weights set equal to sample sizes.

A similar approach was taken to calculate speeds for LAVTA bus routes using the Running Time database. However, given that the Running Time database only contains highly aggregated records for each period, only one speed could be calculated without knowledge of speed variations within peak-periods.

A.2.2b Average Bus Speed to Average Auto Speed Ratio

The ratio of average bus speed to average auto speed, or the transit-to-auto speed ratio, compares speeds at the same time, on the same CMP segment, with typical values between 0.5 and 1. Higher values indicate where transit is more competitive. If the ratio is closer to 1, then the transit speed is nearing auto speeds. The Transit Capacity and Quality of Service Manual[4] identified transit-to-auto-travel time ratio as a primary factor affecting passengers' decision to use transit on a regular basis. The manual acknowledged that transit travel time might be longer than personal vehicle trips, but the time on transit can be used for more productive activities without the hassles of driving during peak-period congestion. If transit-to-auto-travel-time is 1.5 or below, which translates to a transit-to-auto speed ratio of 0.65 or above, transit is considered as a viable choice by users.

A.2.2c Peak-to-Off-Peak Bus Speed Ratio

Another measure of transit network performance is the peak-to-off-peak-period bus speed ratio. This compares service on the same route at different times of day and measures the difference in service during peak-period congestion and uncongested mid-day service between 10 AM and 12 PM. A peak-to-off-peak speed ratio closer to one indicates the peak-period speeds are unimpaired by congestion.

A.3 Active Transportation

A.3.1 Active Transportation Count Program

Alameda CTC has regularly collected manual counts to monitor active transportation activity throughout the county in some form since 2002. As of 2018, Alameda CTC's Active Transportation Count Program takes place every other year between September and early November. Alameda CTC counts bicycles, pedestrians, and scooters at 150 intersections and collects data on bicyclist and scooter user behaviors. Active transportation counts are conducted by paid professionals who use the National Pedestrian and Bicycle Documentation Project methodology.

[4] Transit Capacity and Quality of Service Manual, Third Edition, Transportation Research Board, Washington, D.C., 2013.

Each location is surveyed once per monitoring cycle during a midweek PM peak period (Tuesdays-Thursdays, 4:00 p.m.–6:00 p.m.) between September and early November. Selected locations also have data collected either at midday (12:00 p.m.–2:00 p.m.) or after school hours (2:00 p.m.–4:00 p.m.).

A.3.1a Public Holidays and Special Events

No public holidays occurred on midweek days during the 2024 data collection period. The following days were excluded due to potentially unusual active transportation conditions.

- Wednesday, October 2, 2024: International Walk to School Day
- Wednesday, October 9, 2024: Walk and Roll to School Day
- Tuesday, October 15, 2024: Day after Columbus Day

A.3.1b Air Quality

No counts are conducted on days when the local air quality index (AQI) exceeds 80, as poor air quality can reduce outdoor activity and alter bicycle travel patterns. However, this did not impact the 2024 count program, as all data collection dates had an AQI of 80 or below.

A.3.1c Active Transportation Users

The following active transportation users and their behaviors were collected:

- **Bicycle counts** were collected in the form of turning movement counts at each intersection. The data collection notes included helmet usage, wrong-way riding, and sidewalk riding. In the 2024 Multimodal Monitoring Cycle, electric bicycles were counted separately.
- **Pedestrian counts** were collected in the form of intersection crossing and tabulated by each leg of the intersection.
- **Scooter counts** were collected as turning movement counts at each intersection. The data collection notes included helmet usage, wrong-way riding, and sidewalk riding. In the 2024 Multimodal Monitoring Cycle, electric scooters were counted separately.

A time series analysis was conducted to examine bicycle, pedestrian, and scooter counts over time, identifying trends and changes in travel patterns. Bicycle and scooter travel behaviors were analyzed over time as well. The percentages of e-bikes and e-scooters were calculated and compared across different time periods.