DIVISION OF TRAFFIC OPERATIONS
CALIFORNIA DEPARTMENT
OF TRANSPORTATION

Traffic Operations Manual

Chapter 175 Transportation Analysis

Part 2 Daily Person Hours of Delay

Calculation Guidelines

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Section 1 Introduction

The *State Highway System Management Plan* (*SHSMP*) uses objective analysis to focus investments on measured conditions and performance objectives. The historic asset-based funding approach has been replaced by a performance-driven methodology that provides greater flexibility to achieve multiple objectives within a single project. This management methodology allows the California Department of Transportation (Caltrans) to better integrate multimodal transportation facilities into projects to provide a cost-effective way to maximize the efficiency of the State Highway System (SHS) by increasing person throughput.

Operational improvement (OI) projects, which improve safety and reliability on the SHS by alleviating localized congestion, are a critical part of fulfilling Caltrans' mission, vision, and goals, specifically by enhancing the multimodal network and proactively addressing safety. Historically, daily vehicle hours of delay (DVHD) has been used as the performance measure in *SHSMP* for the OI Program. DVHD is applied to identify system deficiencies, set investment targets, and monitor the progress of the 10-year investment plan. However, the DVHD measure, focusing only on vehicular traffic delay, does not reflect the policy changes from Senate Bill (SB) 743 of 2013 and the *Climate Action Plan for Transportation Infrastructure* (*CAPTI*). Therefore, alternative measures, such as daily person hours of delay (DPHD), have been explored and evaluated. DPHD is a more adaptable measure that considers different modes of transportation, better supports Caltrans' multimodal transportation goals, and enables staff to deliver the 2023 and future *SHSMP*s more effectively. Furthermore, DPHD as a measure of effectiveness has been incorporated into Caltrans' Intersection Safety and Operational Assessment Process (ISOAP).

Implementing the DPHD supports the multimodal improvement effort and aligns with *CAPTI*, SB 743, and the current Caltrans Strategic Plan. DPHD focuses on person-based rather than vehicular-based performance, which is more inclusive. This performance measure can better capture the multimodal benefits for:

- Projects that include transit performance features such as transit signal priority.
- Intersection projects that promote bicycle and pedestrian mobility.
- New or improved bicycle lane projects.
- Improvements to existing managed-lane facilities, like increasing the minimum occupancy requirements.
- New priced managed-lanes facilities.

Additionally, the Asset Management Steering Committee suggested using the average vehicle occupancy (AVO), the average number of passengers in motor vehicles (including the driver), as an OI performance measure. As outlined in this chapter, DPHD uses AVO directly and is in alignment with those suggestions.

Note: Per the Transportation Analysis under the California Environmental Quality Act (CEQA) Technical Advisory Committee and Governor's Office of Planning and Research Technical Advisory on Evaluating Transportation Impacts in CEQA, most OI projects in the 310 Program will not lead to a measurable and substantial increase in vehicle miles traveled. These non-capacity-increasing projects have little or no impact on induced vehicle miles traveled.

Section 2 Daily Person Hours of Delay Calculation Guidelines

Traffic delays can be classified into different types, including:

- Vehicle delay – Delay associated with vehicles, which is mostly reported from simulation software or other traffic analysis tools.
- Transit delay – Delay associated with transit or bus mobility.
- Pedestrian (or bicyclist) delay – Delay experienced by someone riding or walking across an intersection or crossing a particular road location.
- Person delay – The sum of individual delays experienced by all persons in vehicles or transit in each lane, on an approach, or in each phase.

DPHD is simply the multiplication of delay saving between before and after scenarios to the benefitted demand. DPHD is an effective performance measure for OI projects. There are 15 types of OI projects defined by the Office of Mobility and System Performance, some of which are: auxiliary-lane, ramp metering, road diet, high-occupancy vehicle (HOV) lane, roundabout, and signalized intersection, among others. The DPHD calculation can be divided into two categories:

- Intersection-delay-based DPHD calculation, which is associated with interrupted-flow facilities, such as signalized or unsignalized intersections and roundabouts.
- Speed-based DPHD calculation, which can be related to segment-based or uninterrupted flow facilities.

The DPHD-saving value should be calculated and reported for the future year. The future flow can be estimated for either the project opening year or the project horizon year. The DPHD change for the opening year, the year that the project will be open to traffic, should be reported in the Caltrans Asset Management Tool for project performance benchmarking purposes. The change for the horizon year should be documented for project life cycle cost analysis or alternative selection purposes. The DPHD could also be used as a performance measure for other traffic studies, if applicable.

This section will outline the calculation process for both the intersection-delay-based and speed-based categories.

Note: Use of the equations in the following sections is dependent on data availability and can be adjusted according to conditions known at the time of analysis.

Topic 1 Interrupted-Flow Facilities (Intersection-Delay Based)

The DPHD savings calculation for intersection-delay-based facilities (those with interrupted flow) should include three components in its equation:

1. Vehicle delay savings.
2. Transit delay savings.
3. Pedestrian and bicyclist crossing delay savings.

The DPHD calculation in this case can be written in the form of Equation 175-1.

Equation 175-1

$$DPHD = DPHD_{Vehicles} + DPHD_{Transit} + DPHD_{Ped\&Bike}$$

Where:

$DPHD_{Vehicles}$ is the DPHD savings for all vehicle types (such as passenger cars, vans, recreational vehicles [RVs], and trucks). $DPHD_{Vehicles}$ is calculated based on Equation 175-2.

$DPHD_{Transit}$ is the DPHD savings for transit vehicles (such as buses). The $DPHD_{Transit}$ is calculated based on Equation 175-3.

$DPHD_{Ped\&Bike}$ is the DPHD savings for all pedestrians and bicyclists crossing the intersection. The $DPHD_{Ped\&Bike}$ is calculated based on Equation 175-4.

The $DPHD_{Vehicles}$ value can be calculated using Equation 175-2.

Equation 175-2

$$DPHD_{Vehicles} = (Average\ Projected\ Person\ Demand) * (Vehicle\ Delay\ Savings) * (\%\ Traffic\ Benefitted)$$

Where:

% Traffic Benefitted in Equation 175-2 is related to the portion of demand that is going to be benefitted with the proposed operational improvement. The *% Traffic Benefitted* is based on project location, improvement type, and the traffic characteristics of the project area. For interrupted-flow facilities, like a signalized intersection, this value is typically 100%.

Average Projected Person Demand is the average of the present and future flows (*annual average daily traffic [AADT]* multiplied by *AVO*) for the direction in which the project is implemented, or the project influence area, which is the area that has benefitted from implementation of the proposed project. The future flow can be estimated for either the project opening year or the project horizon year. The *Average Projected Person Demand* can be calculated using Equation 175-2-A.

Equation 175-2-A

$$Average\ Projected\ Person\ Demand = \frac{AADT_{present} + AADT_{future}}{2} * AVO$$

Where:

$AADT_{present}$ represents the existing traffic volume and $AADT_{future}$ represents the forecasted future traffic volume. *AVO* is the average vehicle occupancy for the current conditions. It is assumed that the *AVO* may not change significantly between current and future conditions. However, in consultation with Headquarters Division of Traffic Operations, practitioners may use projected future *AVO* estimates from other sources if the proposed project or project area is forecasted to experience a significant change in *AVO*.

The *AVO* for current conditions can be found by using the estimation guidelines developed by Caltrans at the statewide or metropolitan-area level where the project is located (refer to Section 3, "Daily Average Vehicle Occupancy Estimation").

Note: The *AVO* estimated in Section 3 already includes truck and transit modes. If *AVOs* can be estimated more accurately using alternative methods (such as using data provided by the district forecasting unit, Division of Data and Digital Services, regional metropolitan planning organizations [MPOs], transportation demand management [TDM], or count data for specific hours within the project boundaries), such methods can be used if approved by Headquarters Division of Traffic Operations.

Note: Daily *AVO* and peak-hour or peak-period *AVO* can differ significantly. While peak-hour or peak-period *AVO* data availability is extremely limited, its use in calculating DPHD is supported, especially for locations where peak-hour or peak-period delay makes up most of the daily delay. However, it is recommended to use daily *AVO* estimates provided in this chapter instead of peak-hour or peak-period *AVO* due to the lack of data availability. Refer to Section 4, Topic 3 "Example C: Daily AVO Versus Hourly AVO" for more information.

Vehicle Delay Savings used in Equation 175-2 and defined in Equation 175-2-B is the difference between *Average Vehicle Delays* before and after completing the project. It can be measured using Equation 175-2-B.

Equation 175-2-B

$$Vehicle\ Delay\ Savings = (Average\ Vehicle\ Delay)_{before} - (Average\ Vehicle\ Delay)_{after}$$

Where:

Average Vehicle Delay is the average vehicle delay of all 24 hours of a typical day for any operational scenario. This needs to be measured for the *before* (or no-build) condition and *after* (or build) condition. Traffic engineers can model or simulate the scenario for the whole 24 hours, or they can model or simulate it for just the peak-hours condition and estimate delays for the off-peak hours, and then average the delay result for the whole 24 hours.

The following equations show the process to approximately calculate the *Average Vehicle Delay* for either the before or after scenarios for the 24 hours.

Equation 175-2-C

$$Average\ Vehicle\ Delay\left(\frac{seconds}{vehicle}\right) = \frac{AM\ Peak\ Intersection\ Delay +\ PM\ Peak\ Intersection\ Delay + (Average\ Off\text{-}Peak\ Delay * 22)}{24}$$

Where:

AM Peak Intersection Delay and *PM Peak Intersection Delay* are the outputs from the simulation software (such as Synchro, VISTRO, or VISSIM) for the peak-hours volume.

Equation 175-2-D

$$Average\ Off\text{-}Peak\ Delay\ \left(\frac{seconds}{vehicle}\right) = \left(\frac{AM\ Peak\ Intersection\ Delay + PM\ Peak\ Intersection\ Delay}{2}\right) * (\%\ of\ Peak\ Delay\ in\ Average\ Off\text{-}Peak\ Hour)$$

% of Peak Delay in "Average " Off-Peak Hour is the percentage of peak-hour delay in order to estimate the average off-peak-hour delay. This percentage can be approximately estimated by taking the ratio of the average off-peak-hour volumes to the peak-hour volume, which can be measured using the following equation.

Equation 175-2-E

$$\%\ of\ Peak\ Delay\ in\ \text{Average}\ Off\text{-}Peak\ Hour = \left(\frac{AADT -\ AM\ Peak\ Volume - PM\ Peak\ Volume}{22}\right) / \left(\frac{AM\ Peak\ Volume + PM\ Hour\ Volume}{2}\right)$$

Note: If a traffic analyst has all the hourly delays available throughout the day, then the *Average Vehicle Delay* would be the average of all available hourly outputs, and Equations 175-2-C, 2-D, and 2-E can be ignored. In the following, Equations 175-3, 3-A, and 3-B show the DPHD calculation process for transit mode. Examples of transit that run mostly on the SHS are light-rail transit and buses; however, school buses and shuttle buses can also benefit from the transit priority perspectives. Some of the transit-related projects that are applicable here are transit signal priority (TSP) projects.

Note: TSP tactics like green extension, early red, phase rotation, and others are priority-in-time treatments, which are related to the signal timing category in the OI project type classification. Moreover, queue jump is another transit preferential treatment that is a priority-in-space treatment and can be categorized in the intersection-related OI project types. The benefit of utilizing transit priority, either through priority-in-time or priority-in-space, is noticeable in the $DPHD_{Transit}$ calculation, as shown in Equation 175-3.

Equation 175-3

$$DPHD_{Transit} = (Average\ Projected\ Transit\ Passenger\ Demand) * (Transit\ Delay\ Savings) * (\%\ Traffic\ Benefitted)$$

Where:

Average Projected Transit Passenger Demand is the average of the present and future passenger volumes. The *Average Projected Transit Passenger Demand* can be measured using Equation 175-3-A.

Equation 175-3-A

$$Average\ Projected\ Transit\ Passenger\ Demand = \frac{AADT_{present} * \%\ Present\ Transit\ Share * Transit\ AVO}{2} + \frac{AADT_{future} * \%\ Future\ Transit\ Share * Transit\ AVO}{2}$$

Where:

$AADT_{present}$ and $AADT_{future}$ are for the existing and future AADT conditions: *% Present Transit Share* is the existing mode share for transit (for example, 0.5% of AADT) that is passing through the proposed OI project, and *% Future Transit Share* is the future mode share for transit (for example, 1% of AADT). Transit share for present and future conditions can also be determined by the transit agency or district forecasting unit. *Transit AVO* is the average number of seating and standing passengers a form of transit or bus can accommodate, and for simplicity, the *Transit AVO* can be assumed to be half of transit capacity. The 50% usage of transit occupancy sometimes can be increased when applying to transit-oriented projects in the form of applying TSP tactics or implementing transit preferential treatments like queue jump, or both. In that case, the occupancy could rise to 60% or 70% of capacity.

Note: The *AVO* includes transit for general OI projects. For projects with high transit share, adding *Transit AVO* would make the DPHD calculation process more advanced. In this case, be aware of the minor double counting of transit occupancy.

Transit Delay Savings in Equation 175-3 is the difference between *Average Transit Delays* before and after implementing the project as shown in Equation 175-3-B.

Equation 175-3-B

$$Transit\ Delay\ Savings = (Average\ Transit\ Delay)_{before} - (Average\ Transit\ Delay)_{after}$$

Where:

The *Average Transit Delay* is the average transit delay of all 24 hours of a typical day. The calculation for transit delay should be performed for both the before (or no-build) condition and after (or build) condition.

Note: For projects where the number of transit movements is not significant, or *Transit Delay Savings* benefits are captured in the vehicle delay savings analysis, Equation 175-

3 and the associated Equations 175-3-A and 175-3-B can be skipped and the $DPHD_{Transit}$ component can be removed from Equation 175-1.

The information on the significance of transit movement can be obtained from the district transit planning unit or district traffic engineers. Approximately, when the headway of transit is more than 30 minutes, assume that the transit volume is not significant.

The $DPHD_{Ped\&Bike}$ is the DPHD for pedestrians and bicyclists crossing at an intersection. The $DPHD_{Ped\&Bike}$ is calculated using Equation 175-4.

Equation 175-4

$$DPHD_{Ped\&Bike} = (Ped\&Bike\ Delay\ Savings) * (Average\ Ped\&Bike\ Crossing\ Demand) * (\%\ Ped\&Bike\ Traffic\ Benefitted)$$

Where:

The *Average Ped Bike Crossing Demand* at intersections is the average of the existing and future pedestrian and bicyclist volumes. The existing pedestrian and bicyclist volume at an intersection can be measured by performing manual counts with a handheld counter or recorded using video camera detection. The future pedestrian and bicyclist volume can be estimated using a growth factor or obtained from the district forecasting unit.

The *% Ped&Bike Traffic Benefitted* is the portion of pedestrian and bicycle demand that is going to be benefitted with the proposed improvement. This value is typically 100%.

Note: For some OI project types, proposing a new scenario might adversely affect pedestrians and bicyclists and cause their delay to go up.

The *Average Ped&Bike Delay Savings* is the difference in delay for pedestrians and bicyclists before and after implementing the project as shown in Equation 175-4-A. The *Average Ped&Bike Delay* can be obtained from simulation tools.

Equation 175-4-A

$$Ped\&Bike\ Delay\ Savings = (Average\ Ped\&Bike\ Delay)_{before} - (Average\ Ped\&Bike\ Delay)_{after}$$

Note: If the pedestrian and bicyclist crossing volume is not significant or such data is not available, the component for pedestrians and bicyclists that includes Equation 175-4 and 175-4-A can be skipped and the $DPHD_{Ped\&Bike}$ component can be removed from Equation 175-1.

Topic 2 Uninterrupted Flow Facilities (Speed-Based)

DPHD savings calculation for speed-based analysis (those with uninterrupted flow) should include two components: *Vehicle Delay Savings* and *Transit Delay Savings*. The DPHD calculation in this case can be written based on Equation 175-5.

Equation 175-5

$$DPHD = DPHD_{Vehicles} + DPHD_{Transit}$$

Where:

$DPHD_{Vehicles}$ is the DPHD savings for all vehicle types (such as passenger cars, vans, RVs, and trucks). The $DPHD_{Vehicles}$ is calculated based on Equation 175-6.

$DPHD_{Transit}$ is the daily person (passenger) hours of delay savings for transit vehicles (such as buses). The $DPHD_{Transit}$ is calculated based on Equation 175-7.

The $DPHD_{Vehicles}$ can be calculated as follows:

Equation 175-6

$$DPHD_{Vehicles} = (Average\ Directional\ Person\ Demand) * (Vehicle\ Delay\ Savings) * (\%\ Traffic\ Benefitted)$$

Where:

The *% Traffic Benefitted* in Equation 175-6 is related to the portion of demand that will benefit from the proposed operational improvement. For speed-based analysis, calculation of the *% Traffic Benefitted* should be supported by real-world data, such as daily distribution of traffic volumes or delays.

The *Average Directional Person Demand* is the average of the present and future flows (*AADT* multiplied by *AVO*) for the direction in which the project is implemented, or the AADT of the project influence area (the area that has benefitted from implementation of the proposed project). The future values can be either for the project opening year or the project horizon year.

The *Average Directional Person Demand* can be measured using Equation 175-6-A.

Equation 175-6-A

$$Average\ Directional\ Person\ Demand = \frac{AADT_{present} + AADT_{future}}{2} * AVO$$

Where:

$AADT_{present}$ is for the existing traffic volume and $AADT_{future}$ is for the forecasted future traffic volume. *AVO* is the average vehicle occupancy for the present traffic condition. It is assumed that the *AVO* may not change significantly between current and future conditions. However, in consultation with Headquarters Division of Traffic Operations, practitioners may use projected future *AVO* estimates from other sources if the proposed project or project area is forecasted to experience a significant change in *AVO*.

The *AVO* for both present and future conditions can be obtained from Section 3, "Daily Average Vehicle Occupancy Estimation."

Note: The *AVO* estimated in Section 3 already includes truck and transit modes. If *AVOs* can be estimated more accurately using alternative methods (such as using the numbers provided by the district forecasting unit, regional MPOs, TDM, or count data for specific hours within the project boundaries) such methods can be used if properly vetted and approved by Headquarters Division of Traffic Operations.

Vehicle Delay Savings in Equation 175-6 is the difference between the travel time *(Length/Speed)* of both the before and after conditions, as shown in Equation 175-6-B:

Equation 175-6-B

$$Vehicle\ Delay\ Savings = \left(\frac{Length}{Speed}\right)_{before} - \left(\frac{Length}{Speed}\right)_{after}$$

Where:

Length is the project length for both the before and after scenarios.

Speed is the average vehicular speed during the analysis period for any operational scenario. The *Speed* value for the before (or no-build) condition can be obtained from the Performance Measurement System (PeMS) data, and the *Speed* for the after (or build) condition needs to be modeled or simulated for future scenarios for both the opening and horizon years.

Equation 175-7 shows the DPHD calculation process for transit mode, which applies to projects with high transit volume, such as a transit signal priority project.

Equation 175-7

$$DPHD_{Transit} = (Average\ Directional\ Transit\ Passenger\ Demand) * (Transit\ Delay\ Savings) * (\%\ Traffic\ Benefitted)$$

Where:

The *Average Directional Transit Passenger Demand* is the average of present and future passenger flow for the direction in which the project is implemented. The *Average Directional Transit Passenger Demand* can be measured using Equation 175-7-A.

Equation 175-7-A

$$Average\ Directional\ Transit\ Passenger\ Demand = \frac{AADT_{present} * \%\ Present\ Transit\ Share * Transit\ AVO}{2} + \frac{AADT_{future} * \%\ Future\ Transit\ Share * Transit\ AVO}{2}$$

Where:

$AADT_{present}$ and $AADT_{future}$ are for the existing and future AADT conditions. The *% Present Transit Share* is the existing mode share for transit (for example, 0.5% of AADT) that is passing through the proposed project. *% Future Transit Share* is the future mode share for transit (for example, 1% of AADT). Transit share for present and future conditions can also be determined by the transit agency or district forecasting unit. *Transit AVO* is the average number of seating and standing passengers a transit or bus can accommodate. For simplicity, the *Transit AVO* can be assumed to be half of its capacity. The 50% usage of transit occupancy can sometimes be increased when applied to a transit-oriented project such as a transit signal priority project. In that case, the occupancy could rise to 60% or 70% of capacity.

Note: The *AVO* includes transit for general OI projects. For projects with high transit share, adding *Transit AVO* would make the DPHD calculation process more advanced. In this case, be aware of the minor double counting of transit occupancy.

Transit Delay Savings in Equation 175-7 is the difference between *Average Transit Delays* before and after implementing the project as shown in Equation 175-7-B.

Equation 175-7-B

$$Transit\ Delay\ Savings = (Average\ Transit\ Delay)_{before} - (Average\ Transit\ Delay)_{after}$$
$$= \left(\frac{Length}{Transit\ Speed}\right)_{before} - \left(\frac{Length}{Transit\ Speed}\right)_{after}$$

Wnere:

Average Transit Delay is the average transit delay for a typical 24-hour day. The calculation for transit delay should be performed for both the before (or no-build) condition and after (or build) condition.

Note: For projects where the number of transit movements is not significant or *Transit Delay Savings* benefits are captured in the *Vehicle Delay Savings* analysis, Equation 175-7 and the associated Equations 175-7-A and 175-7-B can be skipped and the $DPHD_{Transit}$ component can be removed from Equation 175-5.

The information on the significance of transit movement can be obtained from the transit planning unit or district traffic engineers. Approximately, when the transit headway is more than 30 minutes, assume that the transit volume is not significant.

Section 3 Daily Average Vehicle Occupancy Estimation

AVO is a critical variable to calculate DPHD. The first step to calculate DPHD is to estimate the daily AVO at the location in which the project is located and multiply it by the vehicular volume. While AVO data collection has always been extremely difficult, using sampled survey data to estimate AVO has been an established best practice for years. To help streamline calculation methodology, Headquarters Division of Traffic Operations has developed default AVO values using the National Household Travel Survey (NHTS) database for statewide and regional uses. The steps below show the process to measure the statewide and regional use:

1. AVO data for the entire United States was downloaded for different categories from the NHTS website. These categories included: 1- HHSTATE (household state), and 2- MSASIZE (population size of the metropolitan statistical area).[1]
2. Based on the NHTS website, the AVO for the entire United States and California are 1.67 and 1.73 persons/vehicle, respectively. This suggests that the default number of AVO = 1.73 should be used statewide. Also, to estimate the AVO numbers for metropolitan areas within the state of California, the AVO numbers of the metropolitan statistical area (MSA) for the entire US were multiplied by 1.036 (1.73 / 1.67 = 1.036) to adjust this category for California. Table 175-1 shows this adjustment for metropolitan areas of different population sizes within the state of California.
3. California population data for different metropolitan areas was downloaded from usa.com.
4. The adjusted AVO categories in Step 2 were applied to the downloaded California data in Step 3 to estimate the AVO for the different metropolitan areas of California. This suggests that the AVO can now be estimated based on the location of the project (for example, which metropolitan area it is located in).
5. This process (Steps 1-4) should be repeated for future NHTS updates.

Footnote: [1] Federal Highway Administration, National Household Travel Survey, https://nhts.ornl.gov/.

Table 175-1 Average Vehicle Occupancy for Different Population Size Categories of the Metropolitan Statistical Area

Population size category of the Metropolitan Statistical Area	Average Vehicle Occupancy Nationwide	Average Vehicle Occupancy Adjusted for California
In an MSA of Less than 250,000	1.69	1.75
In an MSA of 250,000 – 499,999	1.68	1.74
In an MSA of 500,000 – 999,999	1.67	1.73
In an MSA or CMSA of 1,000,000 – 2,999,999	1.61	1.67
In an MSA or CMSA of 3 million or more	1.69	1.75
Not in MSA or CMSA	1.69	1.75
All	1.67	1.73

Based on NHTS, use the daily AVO value of 1.73 persons per vehicle for California. In addition to the default state value, AVO values can be estimated for the area in which the project is located based on the surrounding metropolitan area population. Table 175-2 illustrates the AVO values for different metropolitan areas of California.

Note: The daily AVO values listed in Table 175-2 include *Transit AVO*. The latest AVO values for each metropolitan area can be found on the Mobility and System Performance Onramp web page.

Table 175-2. Average Vehicle Occupancy for Different Metropolitan Areas of California

	Area	Population	Average Vehicle Occupancy
1	Los Angeles-Long Beach-Santa Ana	12,828,837	1.75
2	San Francisco-Oakland-Fremont	4,466,251	1.75
3	San Jose-Sunnyvale-Santa Clara	1,898,457	1.67
4	San Diego-Carlsbad-San Marcos	3,183,143	1.75
5	Stockton	701,050	1.73
6	Vallejo-Fairfield	421,624	1.74
7	Santa Cruz-Watsonville	267,203	1.74
8	Sacramento-Arden-Arcade-Roseville	2,197,422	1.67
9	Oxnard-Thousand Oaks-Ventura	835,790	1.73

	Area	Population	Average Vehicle Occupancy
10	Modesto	522,794	1.73
11	Santa Rosa-Petaluma	491,790	1.74
12	Napa	139,253	1.75
13	Riverside-San Bernardino-Ontario	4,345,485	1.75
14	Fresno	948,844	1.73
15	Yuba City	168,126	1.75
16	Merced	261,609	1.74
17	Chico	221,578	1.75
18	Salinas	424,927	1.74
19	Santa Barbara-Santa Maria-Goleta	423,895	1.74
20	Hanford-Corcoran	151,390	1.75
21	Bakersfield-Delano	857,730	1.73
22	Truckee-Grass Valley	98,606	1.75
23	Visalia-Porterville	451,108	1.74
24	San Luis Obispo-Paso Robles	274,184	1.74
25	Madera	152,452	1.75
26	Clearlake	64,209	1.75
27	Redding	178,520	1.75
28	El Centro	177,026	1.75
29	Eureka-Arcata-Fortuna	134,876	1.75
30	Phoenix Lake-Cedar Ridge	55,365	1.75
31	Crescent City	28,066	1.75
32	Ukiah	87,612	1.75
33	Red Bluff	63,284	1.75
34	Susanville	33,356	1.75
35	Bishop	18,546	1.75

Based on available data, Headquarters Division of Traffic Operations recommends using 1.73 for the daily AVO in an OI project analysis or one of the daily AVO values listed in Table 175-2 for specific geographical areas. Headquarters Division of Traffic Operations also supports the use of other data sources that are available for project areas, such as occupancy count data.

Note: Peak-hour or peak-period AVO can differ from daily AVO and should be taken into account if used to calculate DPHD.

As a last resort, AVO information is available in travel demand models and may be used if it is properly vetted, and if the AVOs at the project level are different from the default values provided in Table 175-2.

Note: Travel demand models may use AVOs that are estimated and projected based on other needs, such as air quality conformity requirements. Therefore, for project-level analysis, the DPHD formula will be flexible enough to incorporate transit delay and pedestrian and bicyclist delay, and to convert vehicular delay to person delay. Multimodal delay analysis requirements will be based on project type and data availability.

Section 4 Empirical Examples

This section illustrates two examples employing the DPHD measurement. One example is related to intersection-delay-based interrupted facilities, and the other example is related to speed-based facilities.

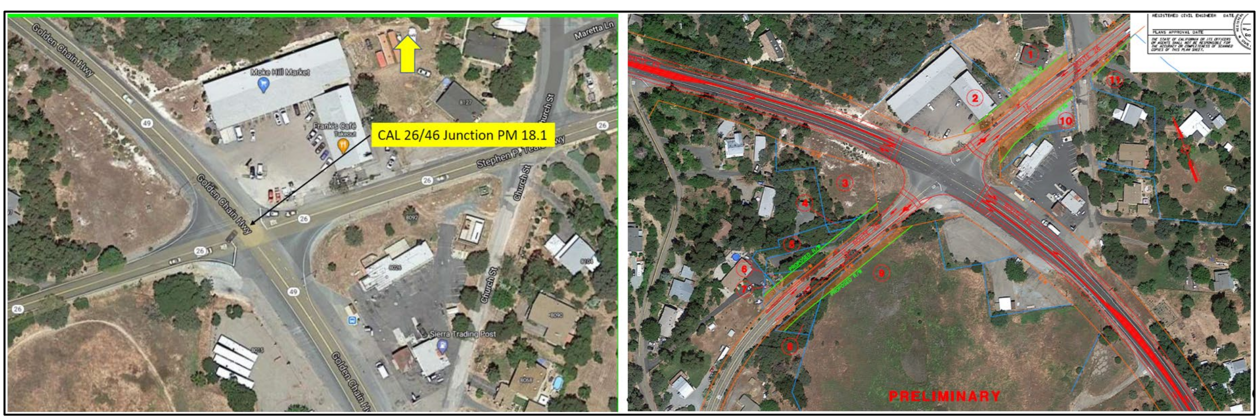
Topic 1 Example A: Daily Person Hours of Delay for Signalized Intersection (Interrupted Facility)

To demonstrate calculating the DPHD of an interrupted facility, Example A uses an isolated signalized intersection as one of the OI categories for the *SHSMP*. The sample project for Example A is the intersection of the Golden Chain Highway and Stephen P. Teale Highway located in Calaveras County (District 10). The existing operational condition of this intersection is an all-way stop-control (AWSC). The proposed alternative is to consider a signalized intersection for this location.

Example A compares the isolated signalized intersection as a proposed alternative to the AWSC as the existing or "do-nothing" alternative. This comparison of traffic operational alternatives will be applied by calculating the DPHD and measuring how much the DPHD will be reduced. Figure 175-1 shows the location of this intersection with the AWSC condition and the proposed layout with signal control.

Note: Intersection alternative analysis would need to conform to ISOAP requirements. In other words, the selection for the type of intersection, such as signalized intersection, stop-controlled intersection, or roundabout, is part of the ISOAP process and the DPHD savings value is one of the criteria in this alternative selection process.

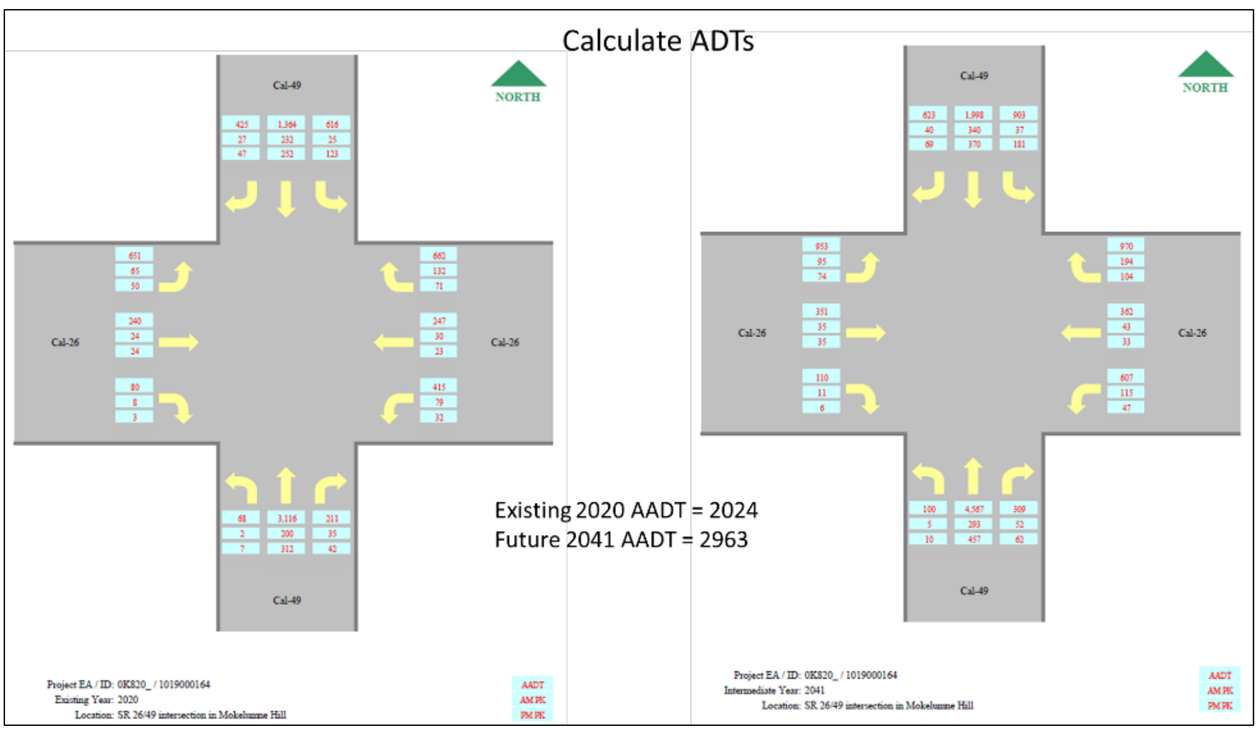
Figure 175-1 Existing Intersection with AWSC (Left) and Alternative with Signal Control (Right)



DPHD savings is measured for the future demand. To calculate the DPHD, the future AADT needs to be projected for every intersection's movement and approach for the defined future year. The existing and future intersection AADT can be calculated as the average of all involved streets' AADTs. The future traffic demand can be calculated through growth factor models in coordination with regional MPOs as well as the district's travel forecasting and modeling group.

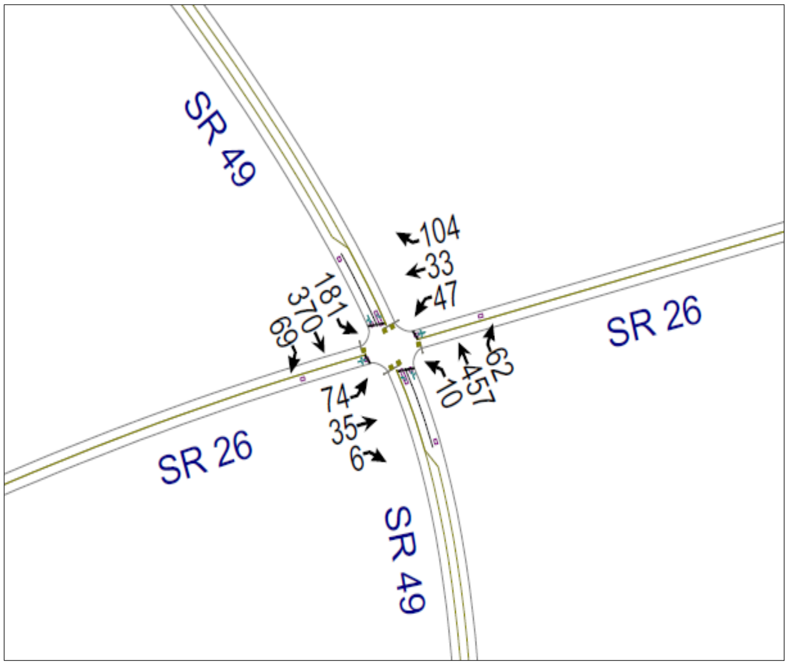
Note: Forecasting volumes should be calculated using the appropriate methodology. Figure 175-2 displays two intersection layouts and their turning movement counts for the example District 10 project. The layout on the left shows the average daily traffic values (ADTs) of all the intersection's movement volumes for the existing 2020 condition, and the layout on the right shows the projected demand for the future horizon year 2041 (20 years after the project is open to traffic). The three volumes on each approach movement are AADT and the a.m. and p.m. peak volumes. The existing 2020 AADT for this intersection is 2,024 vehicles (veh)/day, which is the average of all four AADTs. The future 2041 AADT is 2,963 veh/day, calculated by projecting growth and in coordination with the regional MPO. For the future AADT, all directional movements of the four approaches can be calculated accordingly. As seen in Figure 175-2, the most critical movement for the future 2041 demand is northbound through with 4,567 AADT, which includes 293 veh/hour (hr) for the a.m. peak and 457 veh/hr for the p.m. peak.

Figure 175-2 Intersection Layouts of the Example Project for the Existing 2020 Condition (Left) and the Future 2041 Condition (Right)



With the availability of AADT at each approach, the delay of each approach as well as the delay of the entire intersection can be calculated. This can be done through hand calculations following the *Highway Capacity Manual* (*HCM*), or it can be obtained by utilizing an appropriate simulation software such as Synchro, VISSIM, or VISTRO. In practice, the simulation is done for the peak hour. Figure 175-3 shows the layout of this intersection with hourly volumes of all entry approaches in the Synchro software.

Figure 175-3 Intersection Layouts in Synchro With Hourly Volumes (PM Peak) for the Future Year (2041)



DPHD is a measurement that considers the average of all 24 hours of a day. If a traffic analyst can model the project for all hours of a day, the average hourly delay will be an input to the DPHD calculation. However, in practice, the scenario analysis is mostly applied to the peak-hours condition. Thus, in this example, the project is only modeled for the p.m. peak.

Note: It is extremely important to use data-backed analysis and reasonable assumptions when translating peak-hour or peak-period traffic benefits to daily traffic benefits.

Figures 175-4 and 175-5 show the calculated control delay result during peak hours for an AWSC intersection and an isolated signal from Synchro software. As highlighted, the average intersection delay is 155.5 seconds for AWSC and 31.0 seconds for isolated signalized intersections. The delay outputs of both scenarios are for the p.m. peak, as the peak-hour volume for this intersection is one hour during p.m. time. These intersection delay outputs will be the inputs for calculating the DPHD.

Figure 175-4 Intersection Summary for the AWSC Alternative in Synchro

Design Year 2041 PM Peak
AWSC (No Build) 2/21/2021

Intersection	
Intersection Delay, s/veh	155.5
Intersection LOS	F

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	74	35	6	47	33	104	10	457	62	181	370	69
Future Vol, veh/h	74	35	6	47	33	104	10	457	62	181	370	69
Peak Hour Factor	0.85	0.58	0.50	0.54	0.83	0.86	0.50	0.91	0.77	0.71	0.84	0.78
Heavy Vehicles, %	4	4	4	4	4	4	4	4	4	4	4	4
Mvmt Flow	87	60	12	87	40	121	20	502	81	255	440	88
Number of Lanes	0	1	0	0	1	0	0	1	0	0	1	0

Approach	EB	WB	NB	SB
Opposing Approach	WB	EB	SB	NB
Opposing Lanes	1	1	1	1
Conflicting Approach Left	SB	NB	EB	WB
Conflicting Lanes Left	1	1	1	1
Conflicting Approach Right	NB	SB	WB	EB
Conflicting Lanes Right	1	1	1	1
HCM Control Delay	18.9	21.8	114.8	256.9
HCM LOS	C	C	F	F

Lane	NBLn1	EBLn1	WBLn1	SBLn1
Vol Left, %	2%	64%	26%	29%
Vol Thru, %	86%	30%	18%	60%
Vol Right, %	12%	5%	57%	11%
Sign Control	Stop	Stop	Stop	Stop
Traffic Vol by Lane	529	115	184	620
LT Vol	10	74	47	181
Through Vol	457	35	33	370
RT Vol	62	6	104	69
Lane Flow Rate	603	159	248	784
Geometry Grp	1	1	1	1
Degree of Util (X)	1.147	0.376	0.53	1.504
Departure Headway (Hd)	7.674	10.007	9.043	7.227
Convergence, Y/N	Yes	Yes	Yes	Yes
Cap	476	362	401	510
Service Time	5.674	8.007	7.043	5.227
HCM Lane V/C Ratio	1.267	0.439	0.618	1.537
HCM Control Delay	114.8	18.9	21.8	256.9
HCM Lane LOS	F	C	C	F
HCM 95th-tile Q	19.2	1.7	3	38.7

Figure 175-5 Intersection Summary for the Isolated Signal Alternative in Synchro

Design Year 2041 PM Peak
Traffic Design 3/23/2021

3: SR 49 & SR 26 Performance by movement

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Denied Delay (hr)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
Denied Del/Veh (s)	0.2	0.2	0.3	0.3	0.2	0.1	3.1	0.5	0.8	3.3	0.8	1.0
Total Delay (hr)	0.6	0.3	0.0	0.3	0.2	0.3	0.0	4.0	0.4	2.0	1.4	0.2
Total Del/Veh (s)	37.0	33.0	21.5	28.9	36.8	17.4	40.5	39.3	25.7	47.5	16.9	15.7
Stop Delay (hr)	0.5	0.3	0.0	0.2	0.2	0.3	0.0	2.6	0.3	1.7	0.6	0.1
Stop Del/Veh (s)	33.1	27.3	20.1	25.3	31.4	15.7	35.3	25.9	17.7	40.9	7.6	9.9
Travel Dist (mi)	12.7	7.7	1.9	10.0	7.2	22.0	0.7	83.9	12.2	30.4	61.8	7.4
Travel Time (hr)	1.0	0.5	0.1	0.6	0.5	1.0	0.1	5.9	0.8	3.0	2.8	0.4
Avg Speed (mph)	13	14	17	17	16	21	13	14	16	11	22	19
Fuel Used (gal)	0.5	0.3	0.1	0.3	0.2	0.7	0.0	2.9	0.4	1.3	1.8	0.2
Fuel Eff. (mpg)	25.7	26.6	29.7	30.5	29.7	32.7	36.0	28.7	32.4	23.1	33.4	41.1
HC Emissions (g)	9	6	0	1	1	14	0	68	6	22	39	3
CO Emissions (g)	224	146	14	67	54	310	6	1850	192	725	1207	84
NOx Emissions (g)	26	17	1	6	4	38	0	171	17	59	112	8
Density (ft/veh)												

3: SR 49 & SR 26 Performance by movement

Movement	All
Denied Delay (hr)	0.3
Denied Del/Veh (s)	0.9
Total Delay (hr)	9.8
Total Del/Veh (s)	31.0
Stop Delay (hr)	7.0
Stop Del/Veh (s)	22.1
Travel Dist (mi)	258.0
Travel Time (hr)	16.7
Avg Speed (mph)	16
Fuel Used (gal)	8.8
Fuel Eff. (mpg)	29.4
HC Emissions (g)	171
CO Emissions (g)	4878
NOx Emissions (g)	462
Density (ft/veh)	345

Considering that there are transit/bus lines along the eastbound (EB) and westbound (WB) directions, it is assumed that the present transit share is 0.05% of the AADT and the future transit share is estimated to be 1% of the AADT. It is assumed that the average daily transit hours of delay (the average of 24 hours of delays) reported from the simulation software are 60 seconds per vehicle (sec/veh) for the before (no-build) scenario and 30 sec/veh for the after (build) scenario. The average transit delay is the average of EB and WB directions used to obtain the average intersection delay for transit.

Moreover, the pedestrian and bicyclist volumes were counted as well as projected for the future year. It is assumed that the present volume of pedestrians and bicyclists is 140, and the future volume is 430. Subsequently, the average daily pedestrian and bicyclist delays (the average of 24 hourly delays) that are reported by simulation software are 20 seconds for the before (no-build), and 15 seconds for the after (build) scenarios.

Priority Index Number and Daily Person Hours of Delay Calculation

The goal of the OI program is to reduce traffic congestion through treatments that do not increase capacity. One of the factors utilized in programming a project is the benefit-cost ratio determined by calculating the priority index number (PIN). The PIN is determined by taking the ratio of the discounted delay savings over the life of the project and the total project costs. For more information, please refer to Chapter 7 of the *Highway Operational Improvement Program Guidelines*.

The intersection-delay based DPHD calculation can also be used for project analysis in determining DVHD and DPHD reduced values by inputting the needed traffic parameters into the fields highlighted blue in the DPHD spreadsheet shown in Figures 175-6 and 175-7. The present and future AADT of an intersection are input parameters and are 2,024 and 2,963 veh/day, respectively. The p.m. peak vehicular hours of delay for the future demand (design year) for the AWSC and signalized intersection scenarios are 155.5 seconds and 31.0 seconds, respectively. Also, the a.m. peak vehicular hours of delay for the future demand (design year) for the AWSC and signalized intersection scenarios are 135 seconds and 25 seconds, respectively. With this information in hand, apply the following procedure to calculate DPHD and DVHD.

Figure 175-6 Intersection-Delay Based DPHD Calculation Spreadsheet Used to Determine Average Delay Savings

DAILY PERSONS HOURS OF DELAY (DPHD) SA'

LOCATION / DESCRIPTION: **SR 26/49, in Mokelumne, Calaveras County**
Traffic Signal Alternative

INSTRUCTIONS: Fill in the areas that are marked in blue or with an asterisk.

NOTE: For certain parameters that are in the blue boxes or have asterisks, if there is no valid data, districts can place zero or use en

NOTE: For reference to the parameters used in this DPHD spreadsheet, please refer to the DPHD guideline here:

FACTORS			
"L1" BEFORE MILES		*	0.20
"L2" AFTER MILES		*	0.20
PRESENT AADT	(YR 2020)	*	2024
FUTURE AADT	(YR 2041)	*	2963
AVERAGE AADT			2493.5
% TRAFFIC BENEFITED		*	100
AVE. AADT BENEFITED			2493.5
% TRUCKS		*	4.0
% RV'S		*	2.0
ALTITUDE (FEET)		*	3000
DIRECTIONAL SPLIT			
Ave Vehicle Occupancy (AVO)			1.73
Ave Persons Beneffited			4313.8
Present Transit Volume			10.1
Future Transit Volume			29.6
Transit Capacity			40
Ave Transit Pax Volume			397.5
Present Ped/Bike Volume			140
Future Ped/Bike Volume			430
Ave Ped/Bike Benefitted			285

CALCULATIONS

Daily Delay Calculation (Design Year 2041)

Inputs - to measure off peak variation[1]		
Key Movement		CAL 26-49
ADT		4567
AM Peak Hour Vol	(VPH)	293
PM Peak Hour Vol	(VPH)	457

1. Vehicle count

Existing Configuration AWSC (Design Year 2041)		
AM Peak Hr Intersection Delay (vehicular)	(sec/veh)	135
PM Peak Hr Intersection Delay (vehicular)	(sec/veh)	155.5
Ave Off Peak Delay (vehicular)	(sec/veh)	67.20
Ave Vehicular Hours of Delay (vehicular)	(sec/veh)	73.7
Ave Transit Delay	(sec/veh)	60.0
Ave Ped/Bike Delay	(sec/person)	20.0

W/ Proposed Improvement Traffic Signal (Design Year 2041)		
AM Peak Hr Intrsn Delay (vehicular)	(sec/veh)	25.0
PM Peak Hr Intrsn Delay (vehicular)	(sec/veh)	31.0
Ave Off Peak Delay (vehicular)	(sec/veh)	12.95
Ave Vehicular Hours of Delay (vehicular)	(sec/veh)	14.2
Ave Transit Delay	(sec/veh)	30.0
Ave Daily Ped/Bike Delay	(sec/person)	15.0

Figure 175-7 Intersection-Delay-Based DPHD Calculation Spreadsheet Used to Determine Average Delay Savings

SAVINGS WORK SHEET (Intersection-Delay Based)

COUNTY-RTE :	*	CAL 26-49
P.M. LIMITS :	*	18.1
EA :	*	10-1k820
R/W+CONST $:	*	$ 3,819,543
CALC. BY :	*	Vu H Nguyen
DATE:	*	5/4/2021
PHONE NO. :	*	(209) 603-5126

gineering judgment.

DPHD OUTPUT

Delay Outputs			
Average off-peak hourly vol	(vph)	174	
% of peak delay in "average" off-peak hour		0.46	
Delay without improvement (vehicular)	(min/veh)	1.228	
Delay with improvement (vehicular)	(min/veh)	0.237	
Delay Savings (vehicular)	(min/veh)	0.992	
Ave Daily Vehicular Delay Savings	(minutes)	2472.6	DVHD = 41.2
DPHD (Vehicles)	(minutes)	4277.7	
Ave Transit Delay Savings	(min/veh)	0.500	
DPHD (Transit)	(minutes)	198.8	
Ave Ped/Bike Delay Savings	(min per ped/bike)	0.083	
DPHD (Ped/Bike)	(minutes)	23.8	
DPHD (Total)	(minutes)	**4500.2**	**DPHD = 75.0**

The vehicular data used in Figure 175-7 is for the peak hours (one hour during a.m. and one hour during p.m.) and the off-peak hours will be the remaining hours of the day (22 hours). Thus, in the following calculations, the vehicular average off-peak-hour data and outputs have been averaged out over 22 hours. Delay without improvement is the delay measurement for the existing AWSC condition, and the delay with improvement is the delay measurement for the built signalized alternative. To calculate the average vehicular delay of 24 hours for both AWSC (before) and isolated signal intersection (after) scenarios, use Equations 175-2-C, 2-D, and 2-E as follows.

All-Way Stop-Controlled

$$A.M.\ Peak\text{-}Hour\ Intersection\ Vehicular\ Delay\ =\ 135\ sec/veh$$

$$P.M.\ Peak\text{-}Hour\ Intersection\ Vehicular\ Delay\ = 155.5\ sec/veh$$

$$Ave\ Off\text{-}Peak\ Vehicular\ Delay\ = 0.46\left(\frac{135 + 155.5}{2}\right) = 67.2\ sec/veh$$

$$Where\ 0.46\ is\ Calculated\ Through:\ \left(\frac{4{,}567-457-293}{22}\right)\Big/\left(\frac{457+293}{2}\right)=0.46$$

$$Average\ Vehicular\ Delay\ =\frac{135+155.5+67.2*22}{24}=73.7\ sec/veh$$

$$Delay\ without\ Improvement\ (Vehicular)=\frac{64.7}{60}=1.228\ min/veh$$

Isolated Signalized Intersection

$$A.M.\ Peak\text{-}Hour\ Intersection\ Vehicular\ Delay\ =\ 25\ sec/veh$$

$$P.M.\ Peak\text{-}Hour\ Intersection\ Vehicular\ Delay\ =31\ sec/veh$$

$$Ave\ Off\text{-}Peak\ Delay\ =0.46\left(\frac{25+31}{2}\right)=12.95\ sec/veh$$

$$Average\ Vehicular\ Delay\ =\frac{25+31+12.95*22}{24}=14.2\ sec/veh$$

$$Delay\ with\ Improvement\ (Vehicular)=\frac{14.2}{60}=0.237\ min/veh$$

$$\begin{aligned}&Vehicular\ Delay\ Savings\\&\quad=(Average\ Delay\ without\ Improvement-\ Average\ Delay\ with\ Improvement)\\&\quad=1.228-0.237=0.992\ min/veh\end{aligned}$$

$$Average\ Benefited\ AADT\ =\left(\frac{2{,}024+2{,}963}{2}\right)\left(\frac{100}{100}\right)=2{,}493.5\ veh/day$$

$$DVHD\ =\frac{Vehicular\ Delay\ Saving\ *\ Average\ Benefited\ AADT}{60}=\frac{0.992*2{,}493.5}{60}$$
$$=41.2\ veh\text{-}hr/day$$

$$The\ DVHD\ (daily\ vehicular\ hours\ of\ delay\ savings)\ for\ this\ project\ is\ 41.2.$$

Note: The DVHD calculation is based on vehicle minutes of delay, for which the input will be 2,472.6 (or 41.2 * 60).

To calculate the total value of DPHD, the *AVO* factor needs to be included in the calculation process. Moreover, the transit and pedestrian and bicyclist delays are also going to be included.

The $DPHD_{Vehicles}$ value can be measured by using Equations 175-2, 2-A, and 2-B. The input values for the average *AVO* are 1.73 for both present and future scenarios. Also, it is assumed that 100% of traffic volume will benefit from the proposed scenario. Thus, the $DPHD_{Vehicles}$ equation will be as follows:

$$Vehicle\ Delay\ Savings\ =\ 21.228-0.237=0.992\ min/veh$$

$$Average\ Projected\ Person\ Demand\ =\frac{2{,}024*1.73}{2}+\frac{2{,}963*1.73}{2}=4{,}313.8\ person/day$$

$$DPHD_{Vehicles}\ =\ 0.992*4{,}313.8*\left(\frac{100}{100}\right)=4{,}277.7\ person\text{-}min/day=71.29\ person\text{-}hr/day$$

To calculate the $DPHD_{Transit}$, obtain the input values for transit. The average transit delays, reported from the simulation software, are 60 sec/veh for the existing scenario and 30 sec/veh for the proposed scenarios. The present transit share is assumed to be 0.5% of the AADT and the future transit share is estimated to be 1% of the AADT. Also, the transit capacity is 40 passengers (pax)/veh for this project; and by default, it is suggested to use the half capacity value (0.5 * 40 = 20 pax). The 50% usage of occupancy sometimes can be increased when applying it to a transit-oriented project like TSP, thus the occupancy could rise to 60% or 70% of capacity. Moreover, it is assumed that 100% of the transit will benefit from the proposed scenario. Thus, following Equation 175-3, 175-3-A, and 175-3-B, $DPHD_{Transit}$ will be calculated as follows:

$$Average\ Transit\ Passenger\ Volume = \frac{0.005 * 2{,}024 * 0.5 * 40}{2} + \frac{0.01 * 2{,}963 * .05 * 40}{2} = 397.5\ pax$$

$$Transit\ Delay\ Savings = \frac{60 - 30}{60} = 0.5\ min/veh$$

$$DPHD_{Transit} = 397.5 * 0.5 * \left(\frac{100}{100}\right) = 198.8\ pax\text{-}min/day = 3.31\ pax\text{-}hr/day$$

To calculate *DPHD* for peds&bikes, measure the pedestrian and bicyclist input values for $DPHD_{Ped\&Bike}$. It is assumed that the pedestrian and bicyclist volumes for the present and future conditions are 140 and 430 people, respectively. Also, the average pedestrian and bicyclist delays that are reported by simulation software are 20 seconds and 15 seconds for the before (no-build) and after (build) scenarios, respectively.

$$Average\ Ped\&Bike\ Delay\ Savings = \frac{20 - 15}{60} = 0.083\ min/ped\&bike$$

$$Average\ Ped\&Bike\ Demand\ Benefitted = \frac{140 + 430}{2} = 285\ ped\&bike$$

$$DPHD_{Ped\&Bike} = 0.083 * 285 = 23.8\ ped\&bike\text{-}min/day = 0.4\ ped\&bike\text{-}hr/day$$

Finally, the total DPHD will be the summation of all three person delay components including *vehicles*, *transit*, and *ped&bike*.

$$DPHD = DPHD_{Vehicles} + DPHD_{Transit} + DPHD_{Ped\&Bike}$$

$$DPHD = 4{,}277.7 + 198.8 + 23.8 = 4{,}500.2\ person\text{-}min/day = 75.0\ person\text{-}hr/day$$

$$\mathbf{DPHD} = 71.3 + 3.3 + 0.4 = \mathbf{75.0\ person\text{-}hr/day}$$

Note: If the data for transit or pedestrians and bicyclists are not available or are not significant, the delay part of transit or pedestrians and bicyclists can be skipped. In this situation, the total DPHD would just be the $DPHD_{Vehicles}$ value, which would be 71.3 person-hr/day.

The DPHD reduced value as the performance measure should be reported for all OI projects. In this case study, and considering all modes of travel, the performance measure value that should be reported is 75.0 person-hr/day. The same process should be calculated for the opening year and its performance measure should be reported using the Caltrans Asset Management Tool. The DPHD change for the opening year shall be reported in the Caltrans Asset Management Tool for project performance benchmarking purposes, while the change for the horizon year should be documented for project life cycle cost analysis or alternative selection purposes. Accurate performance reporting is critical as this performance evaluation process has significant impacts on project funding, scheduling, and overall efficiency of the SHS.

Note: General instructions for using the DPHD spreadsheet can be found in Appendix 175 A. This section is likely to provide guidance on data input procedures and other relevant information necessary for effectively utilizing the spreadsheet.

Topic 2 Example B: Daily Person Hours of Delay for Freeway Improvement (Uninterrupted Facility)

To calculate the DPHD for uninterrupted flow facilities, review the following example in which an auxiliary lane was added on Interstate 10 (I-10) WB in Los Angeles County (District 7). In the section under study, I-10 contains three 12-foot lanes in each direction with 20-foot inside shoulders and a median concrete barrier separating the travel directions. The overall purpose of this project is to construct an auxiliary lane on I-10 WB, from the El Monte toll road and bus on-ramp to the Mission Road off-ramp.

Currently, the significant number of vehicles entering from the bus/toll lane on-ramp during peak hours disrupts the mainline traffic flow and creates congestion on I-10 WB. The introduction of an auxiliary lane will create a continuous, uninterrupted lane from the on-ramp to the Mission Road off-ramp and improve the merging maneuvers. Furthermore, the availability of sufficient cross-sectional width for adding the auxiliary lane suggests that the cost for this short segment will remain low. The proposed alternative for the I-10 WB is shown in Figure 175-8.

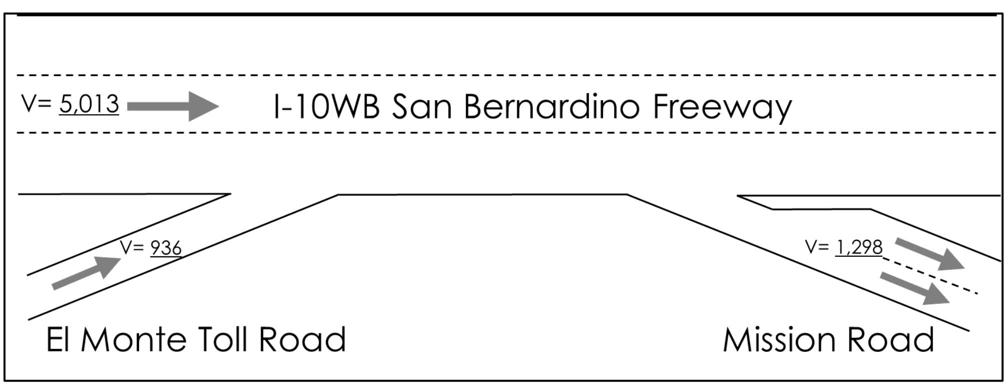
To illustrate an example of DPHD calculation, the original model calculations (submitted by District 7) have been altered, and some hypothetical assumptions have been added to the example.

Figure 175-8 I-10 WB Near Mission Road

To calculate the DPHD savings, first, the directional AADT needs to be estimated for the existing year and then projected to the future for the horizon year. The AADT for the existing year can be obtained from the Traffic Census Program website, PeMs, or any other valid source.

For the WB direction of the I-10 freeway, the existing (2022) AADT (obtained from PeMS) is found to be 70,888 veh/day. Also, the mainline, on-ramp, and off-ramp peak-hour volumes are found to be 5,013 veh/hr, 936 veh/hr, and 1,298 veh/hr, respectively. Other geometric features of the facility for the existing conditions are shown in Figure 175-9.

Figure 175-9 I-10 WB Existing Condition (2022)



Once the existing AADT and peak-hour volumes are calculated, the future volumes can be estimated for the following:

- Opening year (2030) under no-build scenario.
- Opening year (2030) under build scenario.
- Horizon year (2050) under no-build scenario.
- Horizon year (2050) under build scenario.

AADT projections for the future years should either be calculated using growth factor models or obtained from the district forecasting unit or regional MPOs. Since the project is not capacity-increasing for both the build and no-build scenarios, the future AADTs for the opening (2030) and horizon (2050) years are forecasted to be 72,320 veh/day and 75,920 veh/day, respectively.

Figures 175-10 and 175-11 show geometric features of the facility along with the peak-hour demand volumes for the opening year (2030) as well as the horizon year (2050) under the build scenario. As shown in the figures, the build alternative considers adding an auxiliary lane (shown in green) between the entrance from El Monte Toll Road and the exit ramps of Mission Road. The entire length of the auxiliary lane between the two segments is 0.33 miles.

Note: The length of the impacted area may extend beyond the actual project boundaries, which can be taken into consideration based on the project area and its type.

Figure 175-10 I-10 WB Opening Year (2030) Under the Build Scenario

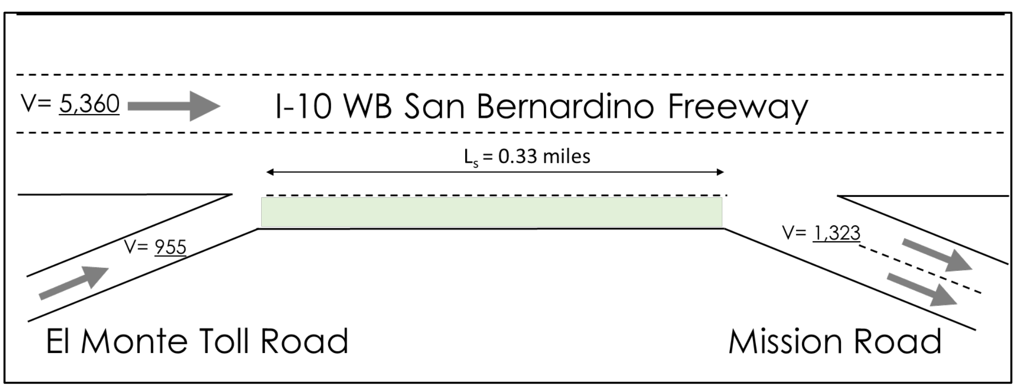
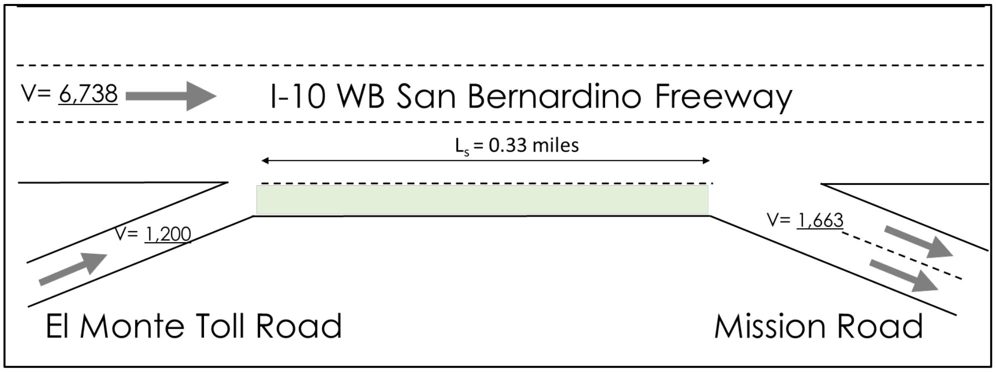


Figure 175-11 I-10 WB Horizon Year (2050) Under the Build Scenario



The geometric features of the facility along with the peak-hour demand volumes shown in Figures 175-9, 175-10, and 175-11, are all fed to an appropriate software (such as Highway Capacity Software in this example) to estimate the operating speed of the facility during the peak hour. Once the geometric and demand features are coded into HCS, they need to be calibrated to replicate the real-world conditions. To achieve this, download traffic speeds from PeMS for the segments under study and compare them with the speeds calculated by HCS. Slight changes are made to different parameters, such as capacity adjustment factor and speed adjustment factor, to bring the software's speeds as close to real-world speeds as possible. Once the software is calibrated to replicate the existing conditions, the build and no-build scenarios for the future (opening and horizon) years can also be modeled. Thus, it is crucial to avoid over-calibration of the software to obtain realistic results when introducing future alternatives.

Note: An ideal traffic analysis considers the entire 24 hours of operation and applies the hourly demand volumes for the entire day (for example, AADT * demand distribution curve) to estimate operating speeds of the facility during a full day. In the absence of a model for the entire day, it is acceptable to do the analysis for the peak hours as shown in this example and use a *% Traffic Benefitted* value based on project area traffic conditions and data.

Figures 175-12, 175-13, and 175-14 show the calculated overall facility speed results reported from HCS during peak hour for the existing condition, as well as the opening year (2030) no build and build scenarios. As is highlighted in Figures 175-13 and 175-14, the average freeway speed for the opening year (2030) no-build and build scenarios is 44.9 miles per hour (mph) and 59.2 mph, respectively. The speed outputs of both scenarios are for the a.m. peak hour. These speed outputs will be the inputs for DPHD calculations for speed-based facilities.

Figure 175-12 HCS Results for the I-10 WB Existing Condition (2022)

Facility Segment Data

Segment 1: Basic

AP	PHF	fHV	Flow Rate (pc/h)	Capacity (pc/h)	d/c Ratio	Speed (mi/h)	Density (pc/mi/ln)	LOS
1	0.94	0.952	5097	7200	0.78	35.8	47.5	F

Segment 2: Merge

AP	PHF		fHV		Flow Rate (pc/h)		Capacity (pc/h)		d/c Ratio		Speed (mi/h)		Density (pc/mi/ln)		LOS
	F	R	F	R	Freeway	Ramp	Freeway	Ramp	F	R	F	R Infl.	F	R Infl.	
1	0.94	0.94	0.952	0.667	6280	1493	7200	1936	0.99	0.77	33.4	53.6	62.7	45.0	F

Segment 3: Overlap

AP	PHF	fHV	Flow Rate (pc/h)	Capacity (pc/h)	d/c Ratio	Speed (mi/h)	Density (pc/mi/ln)	LOS
1	0.94	0.952	6255	7200	0.92	33.4	62.7	F

Segment 4: Diverge

AP	PHF		fHV		Flow Rate (pc/h)		Capacity (pc/h)		d/c Ratio		Speed (mi/h)		Density (pc/mi/ln)		LOS
	F	R	F	R	Freeway	Ramp	Freeway	Ramp	F	R	F	R Infl.	F	R Infl.	
1	0.94	0.94	0.952	0.667	6255	2070	6718	1936	0.99	1.07	60.6	54.5	34.4	36.7	F

Segment 5: Basic

AP	PHF	fHV	Flow Rate (pc/h)	Capacity (pc/h)	d/c Ratio	Speed (mi/h)	Density (pc/mi/ln)	LOS
1	0.94	0.952	4185	7200	0.72	73.5	19.0	C

Facility Analysis Results

AP	VMT veh-mi/AP	VMT-Demand veh-mi/AP	VHD veh-h/AP	Total Delay Cost $/AP	Speed mi/h	Density pc/mi/ln	Density veh/mi/ln	TT min	LOS
1	2915	3076	26.13	653.21	45.0	36.7	34.9	3.30	F

Facility Overall Results

Space Mean Speed, mi/h	45.0	Average Density, veh/mi/ln	34.9
Average Travel Time, min	3.30	Average Density, pc/mi/ln	36.7
Total VMT, veh-mi	2915	Total VHD, veh-h	26.13
Vehicle Value of Time (VOT), $/h	25.00	Total Delay Cost, $	653.21

Figure 175-13 HCS Results for the Opening Year (2030) Under the No-Build Scenario

Facility Segment Data

No.	Coded	Analyzed	Name	Length, ft	Lanes
1	Basic	Basic	I-10 Westbound	5280	3
2	Merge	Merge	El Monte Toll/Bus on-ramp	1000	3
3	Overlap	Overlap	I-10 Westbound	500	3
4	Diverge	Diverge	Mission off-ramp	1000	3
5	Basic	Basic	I-10 Westbound	5280	3

Facility Segment Data

Segment 1: Basic

AP	PHF	fHV	Flow Rate (pc/h)	Capacity (pc/h)	d/c Ratio	Speed (mi/h)	Density (pc/mi/ln)	LOS
1	0.94	0.952	5422	7200	0.83	33.9	53.4	F

Segment 2: Merge

AP	PHF		fHV		Flow Rate (pc/h)		Capacity (pc/h)		d/c Ratio		Speed (mi/h)		Density (pc/mi/ln)		LOS
	F	R	F	R	Freeway	Ramp	Freeway	Ramp	F	R	F	R Infl.	F	R Infl.	
1	0.94	0.94	0.952	0.667	6589	1523	7200	1936	1.04	0.79	39.2	53.6	56.0	47.7	F

Segment 3: Overlap

AP	PHF	fHV	Flow Rate (pc/h)	Capacity (pc/h)	d/c Ratio	Speed (mi/h)	Density (pc/mi/ln)	LOS
1	0.94	0.952	6574	7200	0.98	39.2	56.0	F

Segment 4: Diverge

AP	PHF		fHV		Flow Rate (pc/h)		Capacity (pc/h)		d/c Ratio		Speed (mi/h)		Density (pc/mi/ln)		LOS
	F	R	F	R	Freeway	Ramp	Freeway	Ramp	F	R	F	R Infl.	F	R Infl.	
1	0.94	0.94	0.952	0.667	6574	2110	7060	1936	1.00	1.09	60.6	54.4	36.2	38.0	F

Segment 5: Basic

AP	PHF	fHV	Flow Rate (pc/h)	Capacity (pc/h)	d/c Ratio	Speed (mi/h)	Density (pc/mi/ln)	LOS
1	0.94	0.952	4464	7200	0.77	72.6	20.5	C

Facility Analysis Results

AP	VMT veh-mi/AP	VMT-Demand veh-mi/AP	VHD veh-h/AP	Total Delay Cost $/AP	Speed mi/h	Density pc/mi/ln	Density veh/mi/ln	TT min	LOS
1	3094	3290	27.95	698.82	44.9	39.1	37.2	3.30	F

Facility Overall Results

Space Mean Speed, mi/h	44.9	Average Density, veh/mi/ln	37.2
Average Travel Time, min	3.30	Average Density, pc/mi/ln	39.1
Total VMT, veh-mi	3094	Total VHD, veh-h	27.95
Vehicle Value of Time (VOT), $/h	25.00	Total Delay Cost, $	698.82

Figure 175-14 HCS Results for the Opening Year (2030) Under the Build Scenario

Facility Segment Data

Segment 1: Basic								
AP	PHF	fHV	Flow Rate (pc/h)	Capacity (pc/h)	d/c Ratio	Speed (mi/h)	Density (pc/mi/ln)	LOS
1	0.94	0.952	5990	7200	0.83	64.1	31.2	D
Segment 2: Weaving								
AP	PHF	fHV	Flow Rate (pc/h)	Capacity (pc/h)	d/c Ratio	Speed (mi/h)	Density (pc/mi/ln)	LOS
1	0.94	0.952	7512	8180	0.92	51.0	36.8	E
Segment 3: Basic								
AP	PHF	fHV	Flow Rate (pc/h)	Capacity (pc/h)	d/c Ratio	Speed (mi/h)	Density (pc/mi/ln)	LOS
1	0.94	0.952	4832	7200	0.67	60.3	26.7	D

Facility Analysis Results

AP	VMT veh-mi/AP	VMT-Demand veh-mi/AP	VHD veh-h/AP	Total Delay Cost $/AP	Speed mi/h	Density pc/mi/ln	Density veh/mi/ln	TT min	LOS
1	3371	3055	8.38	209.60	59.2	30.8	28.8	2.50	D

Facility Overall Results

Space Mean Speed, mi/h	59.2	Average Density, veh/mi/ln	28.8
Average Travel Time, min	2.50	Average Density, pc/mi/ln	30.8
Total VMT, veh-mi	3371	Total VHD, veh-h	8.38
Vehicle Value of Time (VOT), $/h	25.00	Total Delay Cost, $	209.60

Daily Person Hours of Delay Calculation for Speed-Based Facilities

The freeway-speed-based DPHD calculation can also be used for project analysis to determine DPHD reduced values by inputting the needed traffic parameters into the fields highlighted in blue in the DPHD spreadsheet shown in Figure 175-15.

Figure 175-15 Speed-Based DPHD Calculation Spreadsheet to Determine Average Delay Savings

LOCATION /PROJECT DESCRIPTION:	Adding Aux Lanes to I-10 WB to connet El Monte Toll/Bus Lane onramp with Mission Road offramp
INSTRUCTIONS: FILL IN AREAS THAT ARE MARKED IN BLUE OR WITH AN ASTERISK.	

CALCULATIONS

INPUT

PASSENGER VEHICLES INPUT		
"L1" BEFORE MILES	*	0.33
"L2" AFTER MILES	*	0.33
"S1" BEFORE MPH	*	44.9
"S2" AFTER MPH	*	59.2
PRESENT AADT	*	71,000
FUTURE AADT	*	72,320
AVERAGE AADT	*	71,660
% TRAFFIC BENEFITED	*	31.5
AVO	*	1.75
% TRUCKS	*	5
AVE. AADT BENEFITED		39,503
TRANSIT INPUT		
TRANSIRT CAPACITY PERSON	*	40
"S1" TRANSIT BEFORE MPH	*	44.9
"S2" TRANSIT AFTER MPH	*	59.2
% PRESENT TRANSIT SHARES	*	1
% FUTURE TRANSIT SHARES	*	1.5
PRESENT TRANSIT AADT		710
FUTURE TRANSIT AADT		1,085
AVERAGE TRANSIT AADT		897
AVE. TRANSIRT AADT BENEFITED		5,654

COUNTY-RTE :	*	LA-10, LA-101
P.M. LIMITS :	*	Rte 10 0.4/Rte 1010.37
EA :	*	10-1k820
R/W+CONST $:	*	$ 10,000,000
CALC. BY :	*	ANALYST'S NAME
DATE:	*	1/1/2023
PHONE NO. :	*	(...)...-....

The directional *AADT* for present and future conditions of the freeway facility are input parameters for the DPHD calculation sheet. In this example, the directional AADTs are 71,000 and 72,320 veh/day, respectively. Since the project is implemented near Los Angeles, the input values for the *AVO* can be considered 1.75 based on the values provided in Section 3, "Daily Average Vehicle Occupancy Estimation." Notice that the value of 1.75 persons/vehicle is not very different from the statewide *AVO* of 1.73 persons/vehicle. Based on the *AVO* and the directional AADTs, the *Average Directional Person Demand* can be calculated using Equation 175-6-A:

$$Average\ Directional\ Person\ Demand\ = 1.75\left(\frac{71{,}000 + 72{,}320}{2}\right) = 125{,}405\ person/day$$

Calculation of *Vehicle Delay Savings* for the interrupted flow facilities in Section 4, Topic 1 "Example A: Daily Person Hours of Delay for Signalized Intersection (Interrupted Facility) assumed that delay during the off-peak hours is a proportion of the peak-hour delay and, consequently, extrapolated the delay for other off-peak hours and estimated the delay for the entire day. However, for speed-based facilities, this calculation is not possible because establishing a relationship between the delay of the vehicles during the peak hours and off-peak hours is not easy due to the non-linear relationship between delay and speed experienced by the drivers under the two conditions and in absence of the control delay. Therefore, for speed-based facilities, it is assumed that the delay during the peak hour lasts for the entire day but the percentage of traffic that benefits from this improvement is reduced (from 100%) to represent the portion of drivers traveling during the peak periods. This estimation methodology replaces the need for hourly analysis for each hour of the day, which would be infeasible because of the data collection and level of effort requirements.

The average speed of the facility for no-build and build scenarios (which are outputs of simulation software), as well as the *Lengths* of the facility, are inserted into Equation 175-6-B to calculate *Vehicle Delay Savings*.

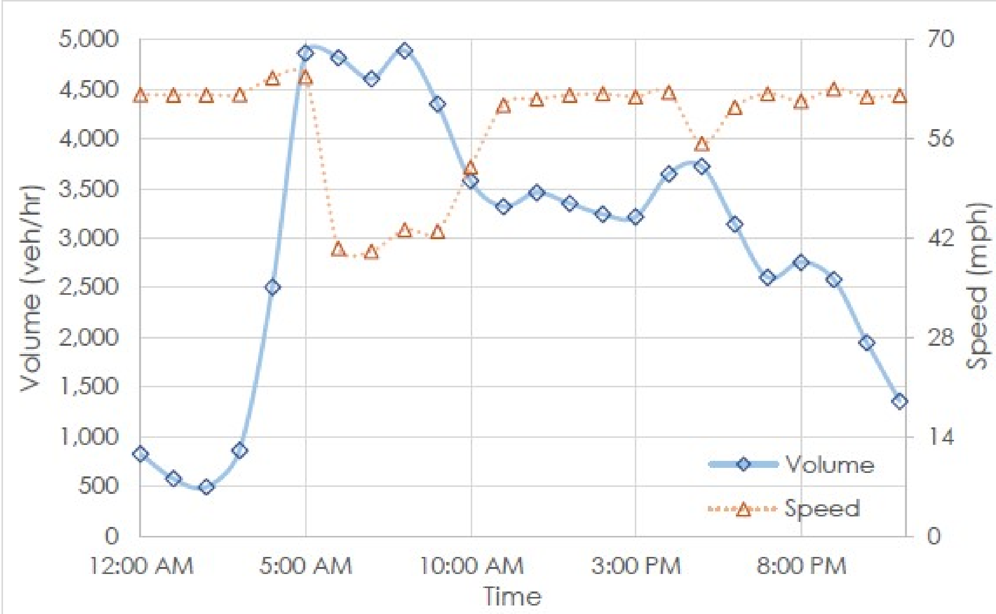
$$Vehicle\ Delay\ Savings = \left(\frac{0.33}{44.9}\right) - \left(\frac{0.33}{59.2}\right) = 0.00178\frac{hr}{veh} * 60\frac{min}{hr} = 0.107\ min/veh$$

Note: The before (no-build) and after (build) project speeds are to be developed using appropriate modeling applications and best practices for data collection. Before and after project speeds should be based on data and analysis, not on assumptions. Consult with Headquarters Division of Traffic Operations if you experience any issues with data collection or project modeling analysis.

To estimate the percentage of vehicles that will benefit from the implementation of the build scenario, it is useful to estimate what percentage of the vehicles passing through the segment during the entire day will experience a delay that will be removed after the implementation of the build scenario. For instance, using Figure 175-16 for the segment under study, traffic congestion starts at 6 a.m. and ends near 11 a.m. Approximately 22,000 vehicles pass through this segment during this period and will be impacted by the congestion. This suggests that (22,000 / 71,000) = 31.5% of the traffic will benefit from improvements (such as the build scenario) that help reduce congestion.

Note: More detailed analysis can be conducted for *% Traffic Benefitted* to produce a more accurate estimation. This includes using lane-by-lane data, *HCM* methodologies for determining which lanes are impacted, microsimulation modeling of future conditions to estimate delay growth, and other appropriate methodologies in collaboration with Headquarters Division of Traffic Operations.

Figure 175-16 Speed and Volume of the Freeway Segment Under Study



Assuming that 31.5% of traffic has benefitted from the implementation of the build scenario in this example, the DPHD saving value for the vehicles can be calculated based on Equation 175-6 as:

$$\boldsymbol{DPHD_{Vehicles}} = 0.107 * 125{,}405 * 31.5\% = 4{,}221\, person\text{-}min/day$$

$$\frac{4{,}221 \frac{person\text{-}min}{day}}{60 \frac{min}{hr}} = \boldsymbol{70\, person\text{-}hr/day}$$

In the absence of volume data, peak-period durations can be considered to calculate the percentage of vehicles benefitted. For instance, if a segment experiences major delays for 3 hours during the morning peak period and 3 hours during the afternoon peak period, then (3 + 3) / 24 = 25% of the travelers will benefit from the improvement.

To calculate the DPHD for transit, obtain the input values for transit volume. Like passenger vehicles, the average transit speed reported by the simulation software can be used to estimate the *Transit Delay Savings*. However, since for the present example, HCS does not analyze transit for freeway facilities, the speed of transit for vehicles is assumed to be the same as passenger vehicles (for example, 44.9 mph and 59.2 mph for no-build and build scenarios). It is also assumed that the present transit share is 1% of the AADT and the future transit share is 1.5% of the AADT. Also, transit capacity is 40 pax/veh; and by default, half of transit capacity is recommended to be used in the calculation (0.5 * 40). Moreover, it is assumed that 31.5% of the transit will benefit from the proposed scenario. Thus, following Equations 175-7, 7-A, and 7-B, $DPHD_{Transit}$ will be calculated as follows:

$$Average\ Directional\ Person\ Demand = \frac{71{,}000 * 1\% * 0.5 * 40}{2} + \frac{72{,}320 * 1.5\% * 0.5 * 40}{2}$$
$$= 17{,}948$$

$$Vehicle\ Delay\ Savings\ = \left(\frac{0.33}{44.9}\right) - \left(\frac{0.33}{59.2}\right) = 0.00178\frac{hr}{veh} * 60\frac{min}{hr} = 0.107\,min/veh$$

$$\boldsymbol{DPHD_{Transit}} = 0.107 * 17{,}948 * 31.5\% = 604.9\,person\text{-}min/day$$

$$\frac{604.9\frac{person\text{-}min}{day}}{60\frac{min}{hr}} = \mathbf{10}\,\boldsymbol{person\text{-}hr/day}$$

Finally, the total DPHD as the summations of the $DPHD_{Transit}$ and $DPHD_{Vehicles}$ is calculated based on Equation 175-5.

$$\boldsymbol{DPHD} = DPHD_{Vehicles} + DPHD_{Transit} = 70.1 + 10 = \mathbf{80}\,\boldsymbol{person\text{-}hr/day}$$

Note: If the data for transit is not available or it is not significant, the delay portion for transit can be skipped. In this situation, the total DPHD would be equal to $DPHD_{Vehicles}$.

The DHPD value calculated for the opening year (2030) shall be submitted to the Caltrans Asset Management Tool. Similar DPHD calculations should also be provided to the Headquarters Division of Traffic Operations for the horizon (2050) year.

Note: General instructions for using the DPHD spreadsheet can be found in Appendix 175 A. This section is likely to provide guidance on data input procedures and other relevant information necessary for effectively utilizing the spreadsheet.

Topic 3 Example C: Daily Versus Hourly Average Vehicle Occupancy

To better clarify the use of daily AVO versus hourly AVO, review the following two hypothetical examples. Table 175-3 shows traffic data and performance measurement features of an OI project that includes count volume, speed, and AVO data throughout 24 hours of a typical day. It is assumed that the traffic does not grow at the project site, so the average of the present and future demand would be equal.

When reviewing Table 175-3, note the following:

- The first row, titled "HOUR (A.M.)," shows 24 hours divided into two sections: a.m. and p.m.
- The second row, titled "COUNT," shows the passenger vehicle volumes distributed throughout 24 hours.
    - The sum of all 24-hour volumes would be roughly the AADT value.
- The third row is the AVO value throughout 24 hours.
    - The AVO value is not equal throughout the day and deviates from the average value, specifically during peak hours (a.m. or p.m.). The average of all 24 AVO values would be the Daily AVO of the OI project, which can get close to 1.73, the California Daily AVO.

- The fourth row is the delay savings value. It is the difference between the before (no-build) and after (build) scenarios.
- The fifth row referring to person hours of delay (PHD) calculates the DPHD by multiplying the second, third, and fourth rows. In other words, the fifth row is the multiplication of hourly count, hourly AVO, and hourly delay-saving values. The DPHD is the summation of the PHD values of all contributing hours.

Table 175-3 Traffic Data and Performance Measure of the First Hypothetical Example

HOUR (A.M.)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
COUNT	100	100	100	100	100	100	800	800	800	800	800	400
AVO	1	1	1	1	1	1	1.15	1.15	1.15	1.15	1.15	3
DELAY SAVINGS	0.001	0.001	0.001	0.001	0.001	0.001	0.005	0.005	0.005	0.005	0.005	0.002
PERSON-HOURS DELAY (PHD)	0.1	0.1	0.1	0.1	0.1	0.1	4.6	4.6	4.6	4.6	4.6	2.4

HOUR (P.M.)	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
COUNT	400	400	400	400	900	900	900	900	500	500	500	500
AVO	3	3	3.2	3	1.15	1.15	1.15	1.15	3	3	3	1
DELAY SAVINGS	0.002	0.002	0.002	0.002	0.009	0.009	0.009	0.009	0.001	0.001	0.001	0.001
PERSON-HOURS DELAY (PHD)	2.4	2.4	2.56	2.4	9.315	9.315	9.315	9.315	1.5	1.5	1.5	0.5
DPHD: SUM OF PHD	**78.02**											

The following are two cases that demonstrate how to calculate DPHD:

Case I Daily Average Vehicle Occupancy

For case I, the example shown in Table 175-3 has been considered. It is assumed that the district can obtain or estimate the volume and calculate the delay throughout all 24 hours of a day. In this example, the traffic demand would benefit from the OI project throughout all 24 hours. Recall that the PHD is the multiplication of *hourly count, AVO,* and *delay savings* values, and the DPHD can be the summation of all 24 PHD values.

$$This\ results\ in\ the\ DPHD\ value\ of\ \mathbf{78.02\ Person\text{-}Hours\ Delay\ Daily\ (person\text{-}hrs\text{-}delay/day)}.$$

Another way to calculate DPHD, similar to the intersection project explained in Section 4, Topic 1 Example A: DPHD for Signalized Intersection (Interrupted Facility), is to multiply the *AADT* value with the average daily *AVO* and average daily delay saving. The average delay saving throughout 24 hours is 0.0034. The average of all *AVOs* in this example is around 1.73. Recall that in the absence of an hourly *AVO*, it is acceptable to use California's or the district's *AVO*. Thus, the DPHD value would be the multiplication of *AADT*, the *average daily AVO*, and the *average daily delay savings*, as follows:

$$12{,}200 * 1.73 * 0.0034 = \mathbf{71.28\ person\text{-}hrs\text{-}delay/day}$$

Both calculated DPHD values are close together. The first calculated DPHD savings of 78.02 is more accurate and recommended because the district can access the data and can measure or estimate the delay savings for all 24 hours. The second calculated DPHD of 71.28 is a more approximated measure.

Case II Hourly Average Vehicle Occupancy

In the second hypothetical example, as shown in Table 175-4, the delay savings is only pronounced during a.m. and p.m. peaks, and the delay savings is zero during off-peak hours. In this case, it is assumed that the OI project is only effective during certain hours of the day. For example, transportation system management and operations (TSMO) ramp metering can be placed in this category, where the ramps are functional only during peak hours. In other cases, the effect of an OI project could be significant only during peak hours. For these types of projects, only the peak-hour *AVO* should be considered, not the daily *AVO*. Thus, the DPHD performance measurement would be the summation of all PHD values for the active operational hours. Considering the example in Table 175-4, the DPHD would be the summation of all PHD values during the a.m. peak (hours 6, 7, 8, 9, and 10) and the p.m. peak (hours 16, 17, 18, and 19).

$$The\ DPHD\ would\ result\ in\ \mathbf{64.4\ person\text{-}hrs\text{-}delay/day}.$$

Table 175-4 Traffic Data and Performance Measure of the Second Hypothetical Example

HOUR (A.M.)	0	1	2	3	4	5	6	7	8	9	10	11
COUNT	-	-	-	-	-	-	800	800	800	800	800	-
AVO	-	-	-	-	-	-	1.15	1.15	1.15	1.15	1.15	-
DELAY SAVINGS	0	0	0	0	0	0	0.005	0.005	0.005	0.005	0.005	0
PHD	0	0	0	0	0	0	4.6	4.6	4.6	4.6	4.6	0

HOUR (P.M.)	12	13	14	15	16	17	18	19	20	21	22	23
COUNT	-	-	-	-	900	900	900	900	-	-	-	-
AVO	-	-	-	-	1.15	1.15	1.15	1.15	-	-	-	-
DELAY SAVING	0	0	0	0	0.01	0.01	0.01	0.01	0	0	0	0
PHD	0	0	0	0	10.35	10.35	10.35	10.35	0	0	0	0
DPHD: SUM OF PHD	**64.4**											

Another approximate approach, in this case, would be to multiply ADDT with a specific portion of a day (peak operational hours / 24), which can be referred to as *% Traffic Benefitted* in the DPHD calculation sheet. Then, multiply the calculated portion of traffic volume by the average peak-hour *AVO* as well as the average hourly delay savings. In this DPHD, it can be interpreted that only a portion of daily traffic volume contributes to this performance measure, and the rest of the daily traffic does not benefit from the OI project.

Section 5 Special Considerations

This chapter has introduced DPHD as the new performance measurement for the OI Program that will replace DVHD. DPHD is a more flexible measure that better aligns with Caltrans' multimodal transportation goals and enables delivery of the *SHSMP*. The DPHD will also be used to inventory systemwide deficiencies, set investment targets, and monitor the progress of the 10-year investment plan. The DPHD calculation methodologies explained in this chapter are the baseline approach with consideration for some practical assumptions. However, Headquarters Division of Traffic Operations encourages practitioners to propose better analysis methodologies and use best practices with reliable data sources while limiting assumptions wherever possible. Any new DPHD calculation methodology needs to be defensible and should be conducted in coordination with Headquarters Division of Traffic Operations.

With advances in intelligent transportation systems and connected and autonomous vehicles, the Division will encounter more diverse datasets. These datasets will assist with modeling and calibrating each OI project utilizing traffic simulation tools or big data analysis and modeling. Headquarters Division of Traffic Operations encourages practitioners and modelers to view each OI problem or project through a wider modeling perspective.

The DPHD guidelines in this chapter are the result of developing and modifying guidelines for different OI projects, each with unique features and complexities. For example:

- When completing a project with high truck mobility, the truck can be defined as a new mode in the DPHD calculation process.
- When calculating DPHD for a project with high freight mobility, the process would be similar to what was discussed in this chapter, however, new parameters such as truck delay, speed, volume, and AVO would need to be added.
- The method to calculate DPHD for an HOV-type project would also need to be adjusted. For instance, the AVO value for the general-purpose lane and HOV lane are different. The method for how to include these two values in the DPHD calculation process would need a more elaborate modification.

In the future, additional information will be made available that addresses how to calculate the DPHD value in more types of OI projects.