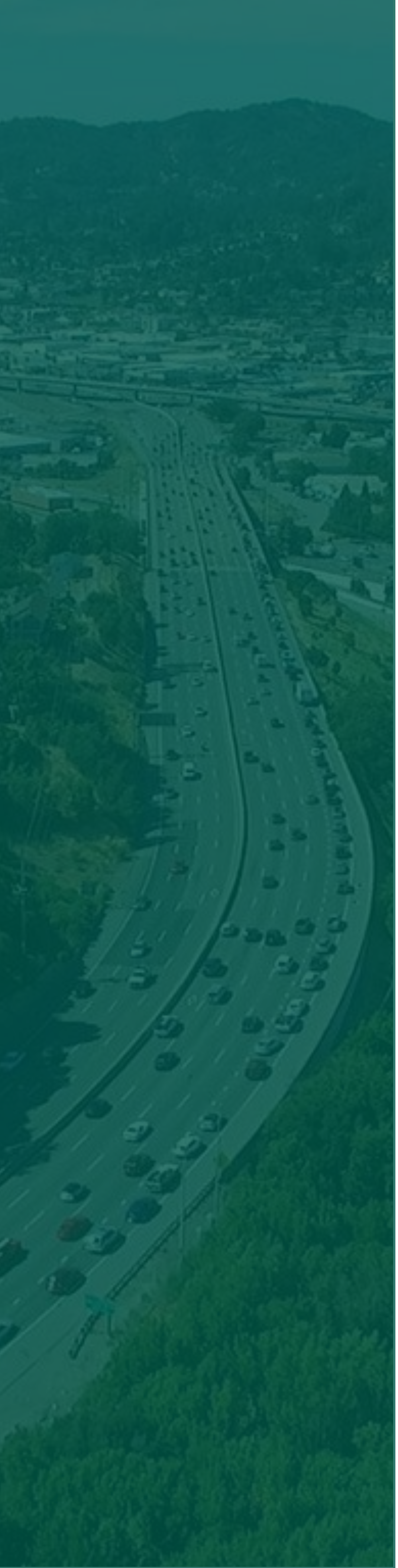

Transportation Authority of Marin Demand Model Update

Development Report

Submitted to:

Transportation Authority of Marin

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Introduction

This Development Report is one of three documents prepared to chronicle the 2025 second-generation update of the Transportation Authority of Marin Demand Model (TAMDM), an activity-based model (ABM) that builds on prior versions of the Metropolitan Transportation Commission's (MTC) regional model with additional network and land use refinements in Marin County. The other documents are a Model User's Guide and an MTC Consistency Memo. **These updated documents are important for model users as they describe significant changes to the model scripts that update the software packages to the latest versions and the development of two new model scenarios (2022 and 2050).** The new 2050 horizon year includes land use changes that reflect recent updates to agency housing elements that incorporate 2023-2031 Regional Housing Needs Allocation[1] (RHNA) housing allocations as well as revised work from home forecasts consistent with recent MTC model updates.

In 2020, the Transportation Authority of Marin (TAM) capitalized on MTC's investment in the Travel Model Two (TM2) system—leveraging its networks, zonal structure, land use datasets, custom software, and scripting framework—to develop the first generation of the TAMDM ABM.

Building on this foundation, TAM made further investments in 2024 and 2025 to enhance and update TAMDM. These updates were designed to ensure the model utilized the latest software versions, had built-in post-processors for generating common model outputs, better captured evolving travel demand patterns in the post-COVID context, reflected the latest regional land use forecasts, and incorporated technical improvements that streamline model deployment for new users. For detailed documentation on installing and running the model, please refer to the Model User's Guide. For a comprehensive explanation of how TAMDM aligns with MTC's travel forecasting guidelines, please consult the MTC Consistency Memo.

This report is intended to provide TAMDM users with an overview of the model, details regarding the model design, a summary of data sources used, comparisons of model outputs to observed data, validation measures for the new 2022 horizon year, and future year (2050) scenario inputs and forecasts. This report also documents the new 2022 and 2050 scenario land use inputs as well as refinements to the work from home module to align with updated work from home assumptions developed by MTC.

Model Overview

TAMDM was initially developed in 2016, using MTC's TM2 as its foundational framework. TM2 itself incorporated all enhancements made to MTC's Travel Model One (TM1) during its evolution, serving as a robust starting point for TAMDM. The model is a member of the Coordinated Travel – Regional Activity-based Modeling Platform (CT-RAMP) family of models, implemented in a number of large metropolitan areas including Atlanta, San Diego, Miami, and Chicago. TAMDM features a very detailed spatial system including an all-streets transportation network with 4,800 Transportation Analysis Zones (TAZs) and almost 40,000 Micro-Analysis Zones (MAZs) for precise measurements of walking and biking time. The model also utilizes 6,200 Transit Access Points (TAPs) for transit stop-to-stop level-of-service. TAMDM simulates 2.9 million households and 7.9 million persons in 2022.

[1] https://www.hcd.ca.gov/rhna

Model Design

This chapter describes MTC TM2, including the general model design, spatial and temporal units, and refinements made for Marin County implementation.

MTC Travel Model Two

MTC TM2 is based on the CT-RAMP (Coordinated Travel Regional Activity-Based Modeling Platform) family of ABMs. This model system is an advanced, but operational, ABM that fits the needs and planning processes of MTC and Marin County. The CT-RAMP model, which is fully described in the following section, adheres to the following basic principles:

- The CT-RAMP design attempts to model individual travel choices with behavioral realism. It addresses both household-level and person-level travel choices including intra-household interactions between household members.
- Operates at a detailed temporal (half-hourly) level and considers congestion and pricing effects on travel time-of-day and peak spreading of traffic volume.
- Reflects and responds to detailed demographic information, including household structure, aging, changes in wealth, and other key attributes.
- Offers sensitivity to demographic and socio-economic changes observed or expected in the dynamic San Francisco Bay region. This is ensured by the enhanced and flexible population synthesis procedures as well as by the fine level of model segmentation.
- Accounts for the full set of travel modes including non-motorized travel and transit.
- Responds to accessibilities throughout the model system including effects of accessibility on auto ownership and frequency of travel.

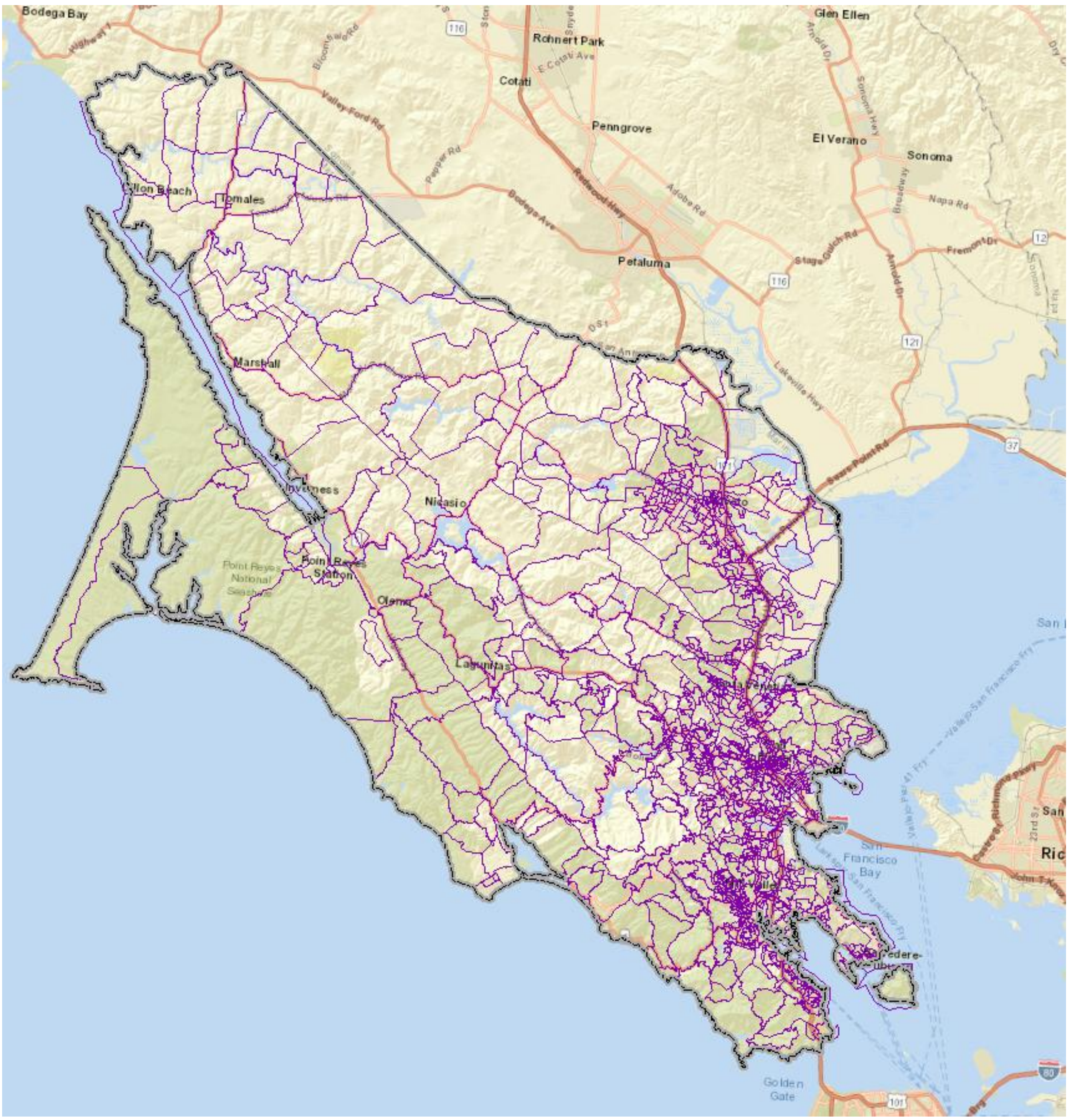
General Model Design

TM2 has its roots in a wide array of analytical developments. They include discrete choice forms (multinomial and nested logit), activity duration models, time-use models, models of individual micro-simulation with constraints, entropy-maximization models, etc. These advanced modeling tools are combined in the ABM design to ensure maximum behavioral realism, replication of the observed activity-travel patterns, and ensure model sensitivity to key projects and policies. The model is implemented in a micro-simulation framework. Micro-simulation methods capture aggregate behavior through the representation of the behavior of individual decision-makers. In travel demand modeling these decision-makers are typically households and persons. The following sections describe the basic conceptual framework at which the model operates.

Treatment of Space

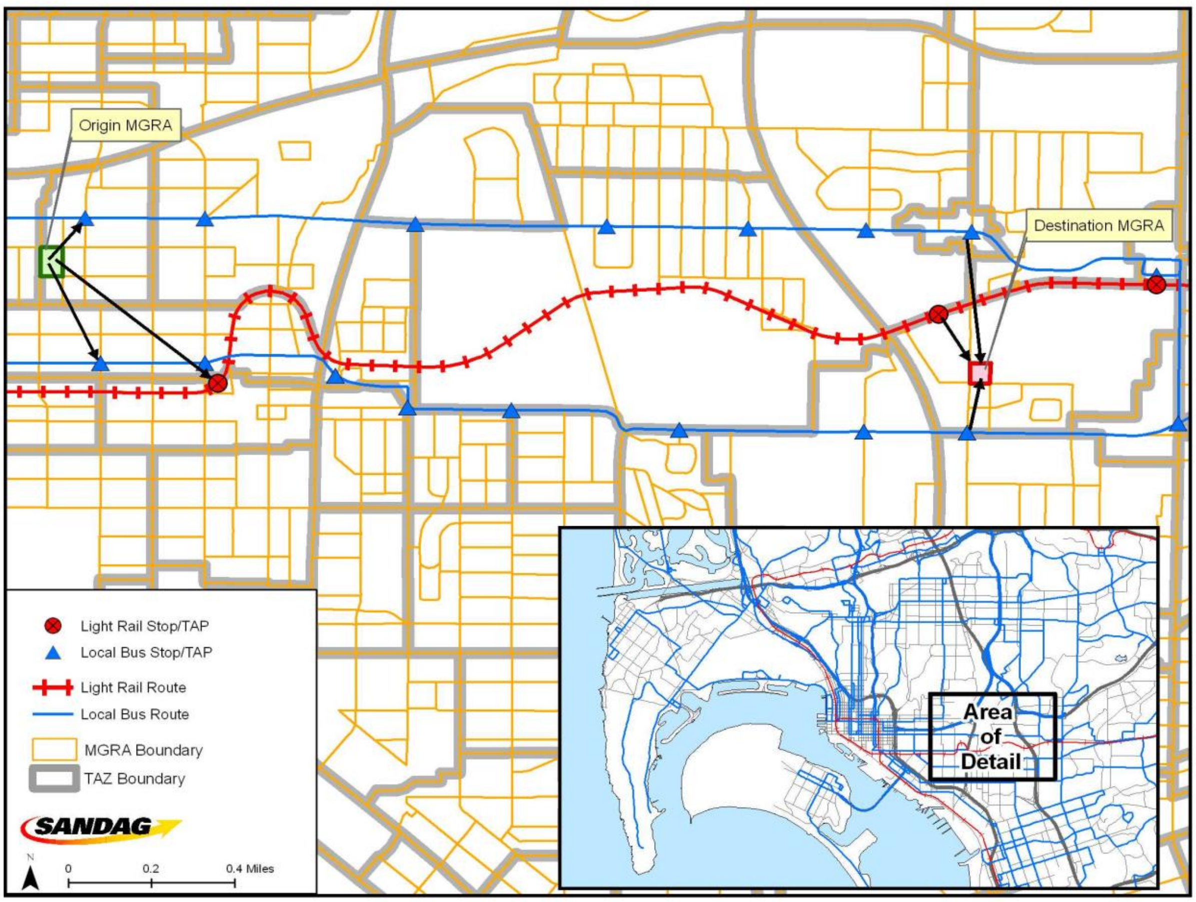
Activity-based and tour-based models can exploit fine-scale spatial data, but the advantages of additional spatial detail must be balanced against the additional efforts required to develop zone and associated network information at this level of detail. TM2 takes advantage of a new MAZ system in addition to a TAZ system. MTC's MAZ system consists of approximately 40,000 zones, which are roughly equivalent to Census block groups. MAZs are used for non-motorized times, including walk and bike times and transit walk access and egress times. To reduce computational burden, TAMDM collapsed MAZs outside of Marin County to the TAZ level, resulting in approximately 5,900 MAZs in TAMDM. The TAMDM MAZ system within Marin County is shown in **Figure 1.**

Figure 1: TAMDM MAZ System within Marin County



The TAZ system is used for highway skims and trip assignment, but transit route choice is calculated at the MAZ level. This is accomplished by generalizing transit stops into pseudo-TAZs called TAPs (Transit Access Points), and relying on Cube to generate TAP-TAP level-of-service matrices (also known as "skims") including characteristics such as in-vehicle time, first wait, transfer wait, and fare. All access and egress calculations, as well as paths following the Origin MAZ to Boarding TAP to Alighting TAP to Destination MAZ, are computed within custom-built software. These calculations rely upon detailed geographic information regarding MAZ to TAP distances and accessibilities. A graphical depiction of the MAZ to TAP transit calculations is shown in **Figure 2.** The figure illustrates potential walk paths from an origin MAZ, through three potential boarding TAPs (two of which are local bus and one of which is rail), with three potential alighting TAPs at the destination end.

Figure 2: MAZ to TAP Transit Accessibility Illustration



A highway trip assignment modification was also made to TAMDM which assigns intra-TAZ or 'intra-zonal' auto trips between MAZs using the shortest path along an all-streets network, while relying on the TAZ system and a planning-level network that excludes roadways below an arterial designation for non-intra-TAZ trips. This approach was developed to reduce 'intra-zonal' bias for large TAZs and force more vehicle trips onto the street network to improve VMT reporting.

Table 1 provides the number of MTC TM2 and TAMDM TAZs, MAZs, and TAPs by county.

Table 1: MTC TM2 and TAMDM TAZs, MAZs, and TAPs by County

County	MTC TM2 TAZs	TAMDM TAZs	MTC TM2 MAZs	TAMDM MAZs	MTC TM2 TAPs	TAMDM TAPs
San Francisco	633	633	4,148	633	775	775
San Mateo	410	410	4,458	410	782	782
Santa Clara	1,011	1,011	8,519	1,011	1,299	1,299
Alameda	1,093	1,093	8,635	1,093	1,439	1,439
Contra Costa	621	621	5,921	621	826	826
Solano	268	268	2,823	268	303	303
Napa	99	99	963	99	113	113
Sonoma	351	351	2,894	351	480	480
Marin	202	202	1,424	1,424	197	197
Total	**4,688**	**4,688**	**39,785**	**5,910**	**6,214**	**6,214**

Source: Fehr & Peers, RSG

Synthetic Population

Decision-makers in the model system include both persons and households. These decision-makers are created (synthesized) for each simulation year based on tables of households and persons from census data and forecasted TAZ-level distributions of households and persons by key socio-economic categories. These decision-makers are used in the subsequent discrete-choice models to select a single alternative from a list of available alternatives according to a probability distribution. The probability distribution is generated from a logit model which takes into account the attributes of the decision-maker and the attributes of the various alternatives. The decision-making unit is an important element of model estimation and implementation, and is explicitly identified for each model specified (long-term, mobility, travel pattern, stop-level, and trip-level) in the following sections.

In order to reduce runtime and increase the stability of model predictions for Marin County residents, a sampling methodology was developed for TAMDM that maximizes the representation of travel for residents of Marin County and neighboring counties that exhibit the greatest interaction with Marin County, and reduces the sample rate for residents of other counties based upon level of interaction and distance to Marin County. To aide in the level of interaction determination, Marin County trip distribution and journey to work patterns from the TAM Origin and Destination Study were used.

Households in Marin County are sampled at a rate three times higher (300 percent) than their representation in the synthetic population, in order to reduce Monte Carlo[2] variation. Their generated travel is then factored down by three (one third) before assigning their trips to networks. This would be equivalent to running the model three times for Marin County residents, but offers reduced time for input/output and skimming/assignment procedures. For households outside Marin County, a sampling rate is applied based upon level of interaction and distance to the nearest Marin County zone. The sample rate for these households range from 50 percent (one of two households) to 5 percent (one in twenty households).

For the purpose of calculating distance to Marin County, four TAZs in Marin County were used:

- TAZ 4616, at the north end of the Golden Gate Bridge
- TAZ 4681, at the east end of the Richmond/San Rafael Bridge
- TAZ 4562, near Highway 1 at the Marin/Sonoma county line
- TAZ 4253, near Highway 101 at the Marin/Sonoma county line

The distance to Marin County for each non-Marin County TAZ is calculated as the minimum distance from the TAZ to any of these four TAZs.

Table 2 provides the minimum, mean, and maximum distance to Marin County from other Bay Area counties.

Table 2: Distance to Marin County

County	Distance to Marin County (Miles)		
	Minimum	Mean	Maximum
San Francisco	4.4	8.9	14.5
San Mateo	11.3	26.6	50.3
Santa Clara	39.2	56.8	88.9
Alameda	11.6	29.4	56.5
Contra Costa	6.4	31.2	63.7
Solano	22.5	37.8	62.9
Napa	19.7	29.4	56.2
Sonoma	0.3	16.6	58.3

Source: Fehr & Peers, RSG

[2] https://en.wikipedia.org/wiki/Monte_Carlo_method

Table 3 provides the sample rates used for the initial implementation of TAMDM. As described above, the rates assume a 300 percent sample for Marin County resident households. For non-Marin County resident households, the sample rate starts at 50 percent at a range of 0 to 5 miles and decreases to 5 percent over 40 miles from Marin. The sample rates reduce the number of simulated households in 2015 from 2.7 million to approximately 681,000, a 75 percent reduction with a 200 percent gain in accuracy for Marin County. The sample rate calculations are provided as a tabular input to TAMDM, so that alternative weighting schemes can be quickly analyzed.

Table 3: Sample Rates for Bay Area Households based on Distance to Marin County

Distance to Marin (miles)		Total Households	Total Population	Sample Rate	Sample Households	Sample Population
0	3	22,287	58,173	50%	11,144	29,087
3	5	2,607	5,767	50%	1,304	2,884
5	10	305,699	688,315	40%	122,280	275,326
10	15	212,816	577,672	30%	63,845	173,302
15	20	234,863	586,827	20%	46,973	117,365
20	30	385,399	1,043,574	10%	38,540	104,357
30	40	402,924	1,132,612	10%	40,292	113,261
40	50	379,713	1,041,735	5%	18,986	52,087
50	60	373,566	1,078,749	5%	18,678	53,937
Over 60 miles		184,937	590,313	5%	9,247	29,516
Marin County		103,205	245,610	300%	309,615	736,830
Total		**2,711,221**	**7,294,957**	**25%**	**680,902**	**1,687,951**

Source: Fehr & Peers, RSG

Person-Type Segmentation

TM2 is implemented in a micro-simulation framework. A key advantage of using the micro-simulation approach is that there are essentially no computational constraints on the number of explanatory variables that can be included in a model specification. However, even with this flexibility, the model system will include some segmentation of decision-makers. Segmentation is a useful tool to both structure models, such that each person-type segment could have their own model for certain choices, and to characterize person roles within a household. Segments can be created for persons as well as households.

A total of eight segments of person-types, shown in **Table 4**, are used for the TM2 model system. The person-types are mutually exclusive with respect to age, work status, and school status.

Table 4: Model Person Types

Number	Person Type	Age	Work Status	School Status
1	Full-time worker	18+	Full-time	None
2	Part-time worker	18+	Part-time	None
3	College student	18+	Any	College +
4	Non-working adult	18 to 64	Unemployed	None
5	Non-working senior	65+	Unemployed	None
6	Driving age student	16 to 17	Any	Pre-college
7	Non-driving student	6 to 15	None	Pre-college
8	Pre-school	0-5	None	None

Source: Fehr & Peers, RSG

Further, workers are stratified by their occupation, shown in **Table 5**. These are used to segment destination choice size terms for work location choice, based on the occupation of the worker.

Table 5: Model Occupation Types

Number	Occupation Type
1	Management
2	Professional
3	Services
4	Retail
5	Manual
6	Military

Source: Fehr & Peers, RSG

Activity Type Segmentation

The set of activity types considered by the model system is shown in **Table 6**. The activity types are grouped according to whether the activity is mandatory, maintenance, or discretionary. Eligibility requirements are assigned to determine which person-types can be used for generating each activity type. The classification scheme of each activity type reflects the relative importance or natural hierarchy of the activity, where work and school activities are typically the most inflexible in terms of generation, scheduling and location, whereas discretionary activities are typically the most flexible on each of these dimensions. When generating and scheduling activities, this hierarchy is not rigid and is informed by both activity-type and activity-duration. Each out-of-home location that a person travels to in the simulation is then assigned one of the activity types.

Table 6: Model Activity Types

Number	Activity Type	Description	Classification	Eligibility
1	Work	Working at regular workplace or work-related activities outside the home.	Mandatory	Workers and students
2	University	College +	Mandatory	Age 18+
3	High School	Grades 9-12	Mandatory	Age 14-17
4	Grade School	Grades K-8	Mandatory	Age 5-13
5	Escorting	Pick-up/drop-off passengers	Maintenance	Age 16+
6	Shopping	Shopping away from home.	Maintenance	5+
7	Other Maintenance	Personal business/services, and medical appointments.	Maintenance	5+
8	Social/Recreational	Recreation, visiting friends/family.	Discretionary	5+
9	Eat Out	Eating outside of home.	Discretionary	5+
10	Other Discretionary	Volunteer work, religious activities.	Discretionary	5+

Source: Fehr & Peers, RSG

Treatment of Time

The model system functions at a temporal resolution of one-half hour. These one-half hour increments begin with 3 AM and end with 3 AM the next day. However, the hours between 3 AM and 5 AM are aggregated into one time period and hours between 12 AM and 3 AM the next day are aggregated into another time period to reduce computational burden and because there are very few observed travelers during these periods. Temporal integrity is ensured so that no activities are scheduled with conflicting time windows, with the exception of short activities/tours that are completed within a one-half hour increment.

A critical aspect of the model system is the relationship between the temporal resolution used for scheduling activities and the temporal resolution of the network simulation periods. Although each activity generated by the model system is identified with a start time and end time in one-half hour increments, level-of-service skim and origin-destination trip matrices are only created for five aggregate time periods – early AM, AM peak period, midday, PM peak period, and evening. The trips occurring in each time period reference the appropriate transport network depending on their trip mode and the mid-point trip time. The definition of time periods for level-of-service matrices is provide in **Table 7.**

Table 7: Model Time Periods

Number	Description	Begin Time	End Time
1	Early	3:00 AM	5:59 AM
2	AM Peak Period	6:00 AM	9:59 AM
3	Midday	10:00 AM	3:00 PM
4	PM Peak Period	3:00 PM	6:59 PM
5	Evening	7:00 PM	2:59 AM

Source: Fehr & Peers, RSG

Trip Modes

There are 23 trip modes in TAMDM, including auto by occupancy and toll/non-toll choice, walk and bike non-motorized modes, and walk and drive access to three types of transit service. Pay modes are those that involve paying a choice or "value" toll. Tolls on bridges are counted as a travel cost with the trip mode being considered "free" or non-toll.

The TNC modes were added to the model to provide functionality for potential scenario tests in which it is envisioned that TNC mode shares would increase significantly beyond their current levels. The model also provides capabilities around private AV ownership; if a household owns at least one AV, it is possible that some portion of their trips will be made by the autonomous vehicle, in which case time and cost sensitivities can be altered in the mode choice model. If an AV is selected for the trip, the trip is tracked in a separate trip table and can be assigned using AV-specific travel time functions.

The 23 trip modes in MTC TM2 and TAMDM are provided in **Table 8**.

Table 8: TAMDM Trip Modes

Number	Trip Mode
1	Auto SOV (Non-Toll)
2	Auto SOV (Toll)
3	Auto 2 Person (Non-Toll, HOV)
4	Auto 2 Person (Toll, HOV)
5	Auto 3+ Person (Non-Toll, HOV)
6	Auto 3+ Person (Toll, HOV)
7	Walk
8	Bike
9	Walk-Local Transit
10	Walk-Premium Transit
11	Walk-Local+Premium
12	PNR-Local Transit
13	PNR -Premium Transit
14	PNR -Local+Premium
15	KNR-Local Transit
16	KNR -Premium Transit
17	KNR -Local+Premium
18	TNC-Local Transit
19	TNC -Premium Transit
20	TNC -Local+Premium
21	Taxi
22	TNC
23	School Bus (only available for school purpose)

Source: Fehr & Peers, RSG

CT-RAMP Design

The basic sequence of CT-RAMP sub-models and associated travel choices is outlined in **Table 9**.

Table 9: CT-RAMP Design Outline

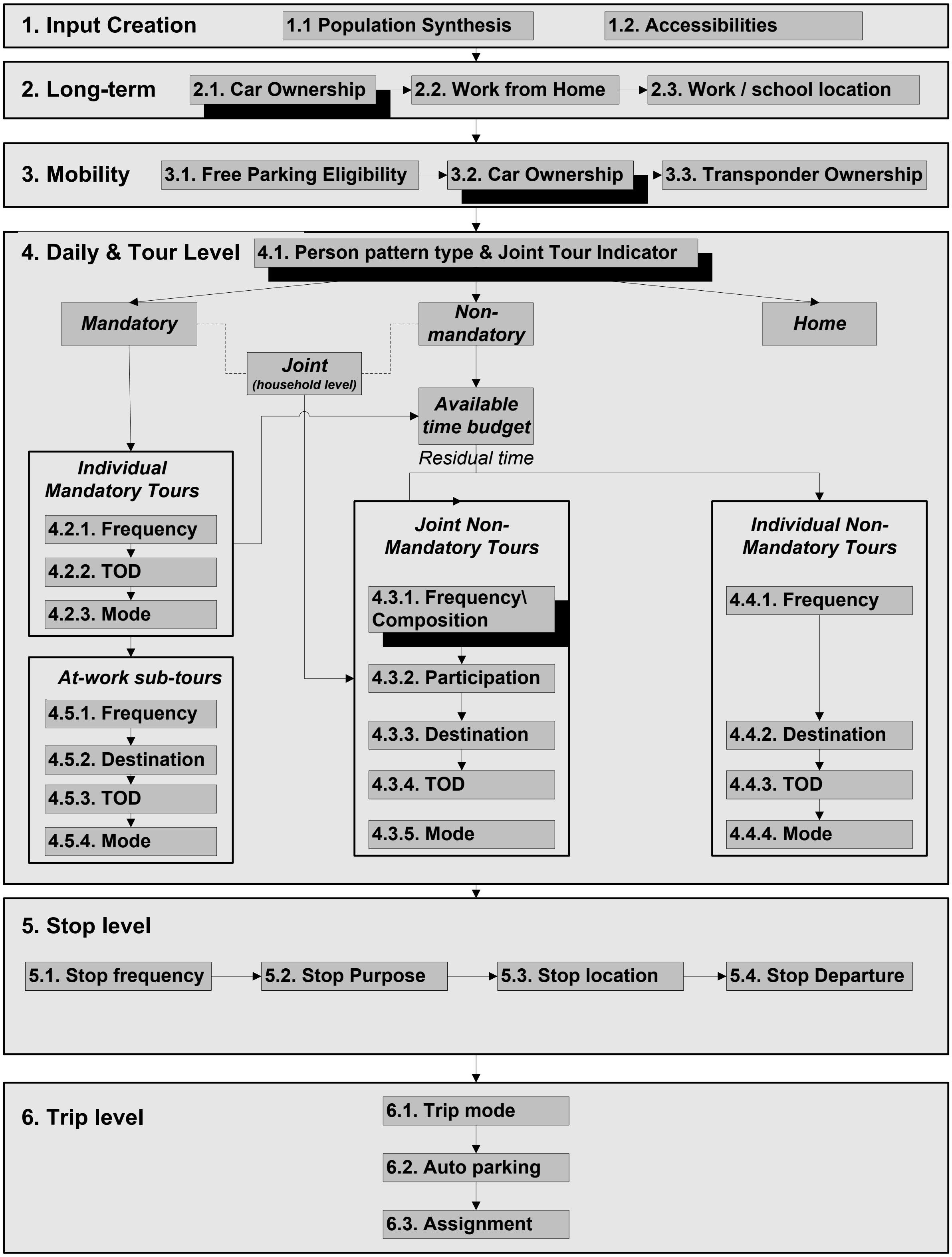
Step	Description
Step 1: Input Creation	
1.1	**Synthetic population and household** databases are synthesized based on based on tables of households and persons from census data at the MAZ-level
1.2	**Destination-choice accessibilities** for use in mobility models and tour generation are created
Step 2: Long-Term Choice Models	
2.1	Preliminary **household car ownership** is forecasted based on household/person attributes and household accessibilities
2.2	**Work from home** model is run to forecast whether a worker's regular workplace is their home
2.3	**Mandatory activity locations** for each household member are determined (workplace/university/school)
Step 3: Mobility Choice Models	
3.1	**Parking cost** is used to determine whether workers pay to park at their workplace MAZ
3.2	Final **household car ownership** is forecasted based on household/person attributes and household accessibilities
3.3	**Transponder ownership** is determined for use of toll lanes
Step 4: Daily Travel Pattern/Schedule Models	
4.1	**Daily travel pattern type** for each household member (main activity combination, at home versus on tour) with a linkage of choices across various person categories, and generation of a joint tour indicator at the household level.
4.2	**Individual mandatory activities/tours** for each household member are forecasted (note that locations of mandatory tours have already been determined in long-term choice model)
4.2.1	Frequency of mandatory tours is determined
4.2.2	Mandatory tour time of day (departure/arrival time combination) is determined
4.2.3	Mandatory tour mode choice is determined
4.3	**Joint travel tours** for each household member are forecasted (conditional upon the available time window left for each person after the scheduling of mandatory activities, and the presence of a joint tour indicated from Model 4.1)
4.3.1	Joint tour frequency/composition, which predicts the exact number of joint tours (1 or 2), the purpose of each tour, and the composition of each tour (adults, children, or mixed)
4.3.2	Person participation in each joint tour
4.3.3	Primary destination for each joint tour
4.3.4	Joint tour time of day (departure/arrival time combination)
4.3.5	Joint tour mode choice
4.4	**Individual non-mandatory tours** for each household member are forecasted (conditional upon the available time window left for each person after the scheduling of mandatory and joint non-mandatory activities)

4.4.1	Individual non-mandatory tour frequency, applied for each person
4.4.2	Individual non-mandatory tour primary destination
4.4.3	Individual non-mandatory tour departure/arrival time
4.4.4	Individual non-mandatory tour mode choice
4.5	**At-work sub-tours** for each household member are forecasted (conditional upon the available time window within the work tour duration)
4.5.1	At-work sub-tour frequency, applied for each work tour
4.5.2	At-work sub-tour primary destination
4.5.3	At-work sub-tour departure/arrival time
4.5.4	At-work sub-tour mode choice
Step 5: Stop-Level Model	
5.1	**Frequency of secondary stops**
5.2	**Intermediate stop purpose**
5.3	**Intermediate stop location choice**
5.4	**Intermediate stop departure time choice**
Step 6: Trip-Level Model	
6.1	**Trip mode choice** conditional upon the tour mode
6.2	**Auto trip parking location** choice for parking constrained areas
6.3	**Trip assignment** of origin-destination tables at the TAZ-level

Source: Fehr & Peers, RSG

The general design of the CT-RAMP model is illustrated in a flow chart format in **Figure 3** and discussed in detail below. Shadowed boxes indicate choices that relate to the entire household or a group of household members and assume explicit modeling of intra-household interactions (sub-models 2.1, 3.2, 4.1, and 4.3.1). The other models are applied to individuals, though they may consider household-level influences on choices.

Figure 3: CT-RAMP General Design Flow Chart



Input Creation

The model system uses synthetic household population as a base input (sub-model 1.1). Certain models also utilize destination-choice logsums, which are represented as MAZ variables (sub-model 1.2). Once these inputs are created, the travel model simulation begins.

Long-Term Choice Models

An auto ownership model is run before workplace/university/school location choice in order to select a preliminary auto ownership level for calculation of accessibilities for location choice (sub-model 2.1). The model uses the same variables as the full auto ownership model, with the exception of the work/university/school-specific accessibilities that are used in the full model. It is followed by long-term choices that relate to the workplace/university/school for each worker and student (sub-models 2.2 and 2.3).

Mobility Choice Models

Medium-term mobility choices relate to free parking eligibility for workers (sub-model 3.1), household car ownership (sub-model 3.2), and transponder ownership (sub-model 3.3) are determined.

Daily Travel Pattern/Schedule Models

The daily activity pattern type of each household member (sub-model 4.1) is the first travel-related sub-model in the modeling hierarchy. This model classifies daily patterns by three types: 1) mandatory (that includes at least one out-of-home mandatory activity), 2) non-mandatory (that includes at least one out-of-home non-mandatory activity, but does not include out-of-home mandatory activities), and 3) home (that does not include any out-of-home activity and travel).

The pattern type model also predicts whether any joint tours will be undertaken by two or more household members on the simulated day. However, the exact number of tours, their composition, and other details are left to subsequent models. The pattern choice set contains a non-travel option in which the person can be engaged in in-home activity only (purposely or because of being sick) or can be out of town. In the model system application, a person who chooses a non-travel pattern is not considered further in the modeling stream, except that they can make an internal-external trip. Daily pattern-type choices of the household members are linked in such a way that decisions made by some members are reflected in the decisions made by the other members.

The next set of sub-models (4.2.1 to 4.2.3) define the frequency, time-of-day, and mode for each mandatory tour. The scheduling of mandatory activities is generally considered a higher priority decision than any decision regarding non-mandatory activities for either the same person or for the other household members. "Residual time windows," or periods of time with no person-level activity, are calculated as the time remaining after mandatory tours have been scheduled. The temporal overlap of residual time windows among household members are estimated after mandatory tours have been generated and scheduled. Time window overlaps, which are left in the daily schedule after the mandatory commitment of the household members has been made, affect the frequency of joint and individual non-mandatory tours, and the probability of participation in joint tours. At-work sub-tours are modeled next, taking into account the time-window constraints imposed by their parent work tours (sub-models 4.5.1-4.5.4).

The next major model component relates to joint household travel. Joint tours are tours taken together by two or more members of the same household. This component predicts the exact number of joint tours by travel purpose and party composition (adults only, children only, or mixed) for the entire household (sub-model 4.3.1), and then defines the participation of each household member in each joint household tour (sub-model 4.3.2). It is followed by choice of destination (sub-model 4.3.3), time-of-day (sub-model 4.3.4), and mode (sub-model 4.3.5).

The next stage relates to individual maintenance (escort, shopping and other household-related errands) and discretionary (eating out, social/recreation, and other discretionary) tours. All of these tours are generated by person in sub-model 4.4.1. Their destination, time of day, and mode are chosen next (sub-models 4.4.2, 4.4.3, and 4.4.4).

Stop-Level Model

The next set of sub-models relate to the stop-level details for each tour. They include the frequency of stops in each direction (sub-model 5.2), the purpose of each stop (sub-model 5.2), the location of each stop (sub-model 5.3) and the stop departure time (sub-model 5.4).

Trip-Level Model

The stop-level model is followed by the last set of sub-models that add details for each individual trip including trip mode (sub-model 6.1) and parking location for auto trips (sub-model 6.2). The trips are then assigned to highway and transit networks depending on trip mode and time period (sub-model 6.3).

Model Data

This section describes the data sets used in the update, calibration and validation for the second-generation update of TAMDM. The base year for TAMDM was updated to 2022, and therefore, all the data sets used for calibration and validation are from around fall 2022 or later. **Table 10** presents a list of all the TAMDM input, calibration and validation datasets used for the second-generation update.

Table 10: TAMDM Input, Calibration and Validation Datasets

Dataset	Year	Source	Purpose
Land Use Data	2022	ABAG	Land Use Inputs
Traffic Count Data	2022	Caltrans Freeway Performance Monitoring System (PeMS)	Highway Validation
Transit Ridership Data	2022	MTC Statistical Summary of Bay Area Transit Operators, Ridership Reports of Bay Area Transit Operators	Transit Validation
Origin-Destination Data	2022	StreetLight Data	Trip Distribution Calibration
Work from Home Data	2022, 2050	MTC	Work Location Choice Calibration

Source: Fehr & Peers, RSG

Land Use Data

Base year (2022) land use input data was obtained from the Association of Bay Area Governments (ABAG). **Table 11** presents the household data and **Table 12** presents the employment data inputs.

Table 11: TAMDM 2022 Household Data

Area	2015	2022	Growth	% Per Year
Bay Area	2,768,377	2,956,964	188,587	1.0%
Marin County	106,829	109,741	2,912	0.4%
Belvedere	919	919	0	0.0%
Corte Madera	3,727	3,762	35	0.1%
Fairfax	3,229	3,304	75	0.3%
Larkspur	5,938	6,027	89	0.2%
Mill Valley	6,052	6,056	4	0.0%
Novato	22,078	22,593	515	0.3%
Ross	815	858	43	0.8%
San Anselmo	5,338	5,236	-102	-0.3%
San Rafael	23,808	25,031	1,223	0.7%
Sausalito	4,169	4,195	26	0.1%
Tiburon	3,788	3,793	5	0.0%
Marin County Unincorporated	26,968	27,967	999	0.5%

Source: Fehr & Peers, RSG

Table 12: TAMDM 2022 Employment Data

Area	2015	2022	Growth	% Per Year
Bay Area	3,519,517	3,684,963	165,446	0.7%
Marin County	119,139	127,054	7,915	0.9%
Belvedere	489	493	4	0.1%
Corte Madera	7,703	8,111	408	0.8%
Fairfax	1,444	1,575	131	1.3%
Larkspur	6,629	7,009	380	0.8%
Mill Valley	6,544	7,179	635	1.4%
Novato	23,059	24,783	1,724	1.1%
Ross	449	613	164	5.2%
San Anselmo	3,250	3,474	224	1.0%
San Rafael	41,069	43,488	2,419	0.8%
Sausalito	6,966	6,778	-188	-0.4%
Tiburon	2,886	3,075	189	0.9%
Marin County Unincorporated	18,651	20,476	1,825	1.4%

Source: Fehr & Peers, RSG

The base year (2022) land use input summary tables also provide comparisons to the previous TAMDM base year (2015) land use inputs and indicate that household growth was estimated at 0.4% per year and employment growth was estimated at 0.9% per year in Marin County from 2015 to 2022.

Traffic Count Data

Traffic count data was obtained for 10 directional highway segment locations within Marin County from the Caltrans Freeway Performance Monitoring System (PeMS) and the Bay Area Toll Authority (BATA). The traffic count data used for highway validation is summarized by roadway direction in **Table 13.**

Table 13: Traffic Count Data

Direction	Location	AM Peak Period (6-10 AM)	PM Peak Period (3-7 PM)	Daily
NB	US 101 at the Sonoma/Marin County Line	7,300	13,700	45,200
NB	US 101 North of San Rafael	13,800	27,600	88,500
NB	US 101 at San Rafael Creek	16,932	27,566	89,419
EB	SR 37 at the Sonoma/Marin County Line	3,400	6,200	20,400
EB	I-580 at the Contra Costa/Marin County Line	5,853	14,482	41,355
SB	US 101 at the Sonoma/Marin County Line	12,441	8,614	40,460
SB	US 101 North of San Rafael	24,600	19,900	87,200
SB	US 101 at the San Francisco/Marin County Line	14,613	12,567	48,683
WB	SR 37 at the Sonoma/Marin County Line	6,600	4,000	19,100
WB	I-580 at the Contra Costa/Marin County Line	12,500	7,200	36,700

Source: Fehr & Peers, RSG

Transit Ridership Data

Table 14 presents the transit operator-level transit ridership data sources used to obtain daily transit boardings for the purposes of transit ridership validation.

Table 14: Transit Ridership data by Operator

Operator	Year	Source
Golden Gate Transit Bus & Ferry	2022	https://www.goldengate.org/bus/history-research/statistics-ridership/ https://www.goldengate.org/ferry/history-research/statistics-ridership/
Marin Transit	2022	FY22 Ridership Report
SMART	2022	https://www.sonomamarintrain.org/RidershipReports

Source: Fehr & Peers, RSG

Origin-Destination Data

In 2015 Fehr & Peers analyzed data from cellular and GPS-enabled mobile devices to provide an understanding of Marin County travel patterns and to support the development of TAMDM. Origin-destination data was obtained passively and anonymously from mobile devices, providing a very large sample of empirical data that included the origins and destination of individual trips as well as the home and work locations associated with individual devices.

As part of the TAMDM update, Fehr & Peers collected origin-destination data from connected vehicles in 2022 to assess changes in travel behavior. It is important to note that the two datasets differ in nature: mobile device data primarily represents person trips, while connected vehicle data (CVD) reflects vehicle trips. Due to these fundamental differences in data sources and representation, the 2022 dataset is not intended to be directly compared with the 2015 dataset.

The CVD points were tagged to the same geographic layer of zones based on the MTC TAZ system that was used in 2015. The zone system within Marin County is shown in **Figure 4** and the zone system outside Marin County is shown in **Figure 5**. Analysis of this data provided an understanding of inter-Marin County travel patterns as well as local travel behaviors generated from communities and towns within Marin County.

Figure 4: Marin County Connected Vehicle Data Zone System

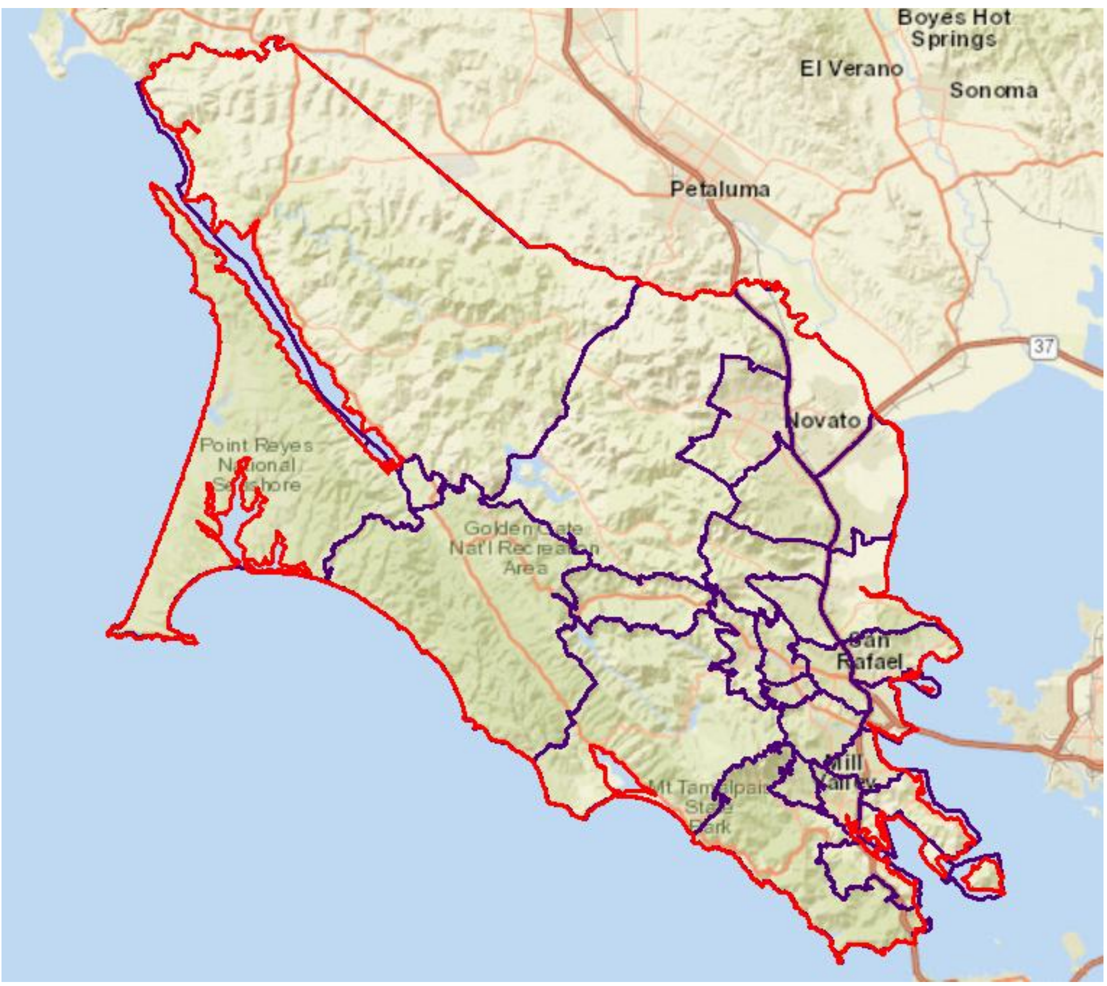


Figure 5: Outside Marin County Connected Vehicle Data Zone System

The tables in this section summarize the connected vehicle origin-destination data used for the purposes of trip distribution model calibration. The focus of the connected vehicle calibration data was on the AM peak period (6 AM to 10 AM) as trip and workplace destination as well as modal decisions made during this period typically control decisions made throughout the day.

Table 15 presents the distribution of inter-Marin County trips generated by Marin County that travel to other Bay Area counties in the AM peak period. **Table 16** presets the distribution of inter-Marin County trips generated by other Bay Area counties that come into Marin County in the AM peak period. Contra Costa County was divided into two zones, one for the western portion and one for the eastern portion, while Alameda County was also divided into two zones, one for the northern portion and one for the southern portion, as shown in Figure 5.

The data indicates that trips out of Marin County in the AM peak period primarily travel to San Francisco County (37%), Sonoma County (27%), Alameda County (10%), and Contra Costa County (8%), while trips into Marin County in the AM peak period primarily travel from Sonoma County (44%), Contra Costa County (16%), San Francisco County (14%), and Alameda County (9%).

Table 15: Connected Vehicle Data AM Peak Period Trips out of Marin County

Destination County	Percent of Trips
Sonoma	**27%**
Napa	3%
Solano	4%
West Contra Costa	6%
East Contra Costa	2%
North Alameda	8%
San Francisco	**37%**
San Mateo	9%
South Alameda	2%
Santa Clara	2%

Source: Fehr & Peers, RSG, StreetLight Data

Table 16: Connected Vehicle Data AM Peak Period Trips into Marin County

Origin County	Percent of Trips
Sonoma	**44%**
Napa	3%
Solano	8%
West Contra Costa	12%
East Contra Costa	4%
North Alameda	7%
San Francisco	**14%**
San Mateo	4%
South Alameda	2%
Santa Clara	1%

Source: Fehr & Peers, RSG, StreetLight Data

Work from Home Data

The work from home percentage used to calibrate the work location choice model was derived from estimates published by MTC in the Plan Bay Area 2050 Final Blueprint Documents[3]. **Table 17** presents the work from assumptions for the second-generation update of TAMDM.

Table 17: Work from Home Assumptions

Scenario	Work from Home Percentage
2022	33%
2050	30%

Source: Fehr & Peers, RSG, MTC

[3] https://planbayarea.org/2050-plan/plan-bay-area-2050-blueprint/plan-bay-area-2050-final-blueprint-documents

Base Year (2022) Model Validation

After a model is calibrated to produce demand that reasonably predicts observed travel behavior in the region, the model is validated to test the model's predictive capabilities before it is used to produce forecasts. The validation process compares outputs from base year model components to observed data and iteratively adjusts model parameters until the model outputs fall within an acceptable range of error.

The traditional approach to the validation of travel demand models is to compare the roadway segment volumes for the model's base year to actual traffic counts collected in the same year. This approach provides information on a model's ability to reproduce a static condition. As part of this model update, static validation was conducted for the highway, transit, trip distribution, and work location choice components. This section builds on the extensive static and dynamic validation efforts completed during the development of the first generation of TAMDM.

Static Model Validation

Static model validation measures how well the model's base year demand forecasts replicate observed data. The observed databases used for TAMDM static model validation are described in the Data Chapter. The TAMDM update static model validation process includes the following:

- Highway Validation – compares model-estimated traffic volumes with traffic count data
- Transit Validation - compares model-estimated transit boardings with transit ridership data
- Trip Distribution Validation - compares vehicle origin-destination data from the model with vehicular travel patterns from connected vehicle data
- Work Location Choice Validation - compares work location choice data from the model to work from home data from MTC

Highway Validation

For the updated TAMDM highway validation, forecasted 2022 model volumes were compared to traffic count data collected for 2022 conditions from the PeMS system at 10 available bi-directional roadway segment locations. The results of the highway validation which was conducted using the guidelines and thresholds from the 2024 California RTP Guidelines[4] are presented in **Table 18** and indicate that the updated TAMDM 2022 base year meets all recommend validation measures.

Table 18: Highway Validation by 2024 California RTP Model Validation Standards

Validation Measure	AM Peak Period	PM Peak Period	Daily	Threshold
Volume-to-Count Ratio	1.04	1.05	1.04	+/- 10%
Percent Root Mean Square Error	19%	20%	18%	Below 30%
Correlation Coefficient	0.93	0.95	0.99	At Least 0.90

Source: Fehr & Peers, RSG

[4] https://dot.ca.gov/programs/transportation-planning/division-of-transportation-planning/regional-and-community-planning/rtp-guidelines-update

Table 19, **Table 20**, and **Table 21** present a comparison of bi-directional 2022 model volumes to 2022 traffic count data at locations where PeMS or BATA data was available for AM peak period, PM peak period, and daily conditions, respectively. The tables indicate that 2015 TAMDM highway volumes reasonably replicate traffic count data compiled at six key bi-directional roadway segment locations.

Table 19: AM Peak Period Highway Validation at Key Roadway Facilities

Traffic Count Location	Count	Model	Model/ Count Ratio
US 101 at the Sonoma/Marin County Line	19,700	22,200	1.13
US 101 North of San Rafael	38,400	40,200	1.05
US 101 at San Rafael Creek	31,500	32,400	1.03
US 101 at the Golden Gate Bridge (Southbound Only)	14,600	14,700	1.01
SR 37 at the Sonoma/Marin County Line	10,000	11,900	1.19
I-580 at the Contra Costa/Marin County Line	18,400	19,000	1.03

Source: Fehr & Peers, RSG

Table 20: PM Peak Period Highway Validation at Key Roadway Facilities

Traffic Count Location	Count	Model	Model/ Count Ratio
US 101 at the Sonoma/Marin County Line	22,300	23,100	1.04
US 101 North of San Rafael	47,500	49,200	1.04
US 101 at San Rafael Creek	40,100	36,300	0.91
US 101 at the Golden Gate Bridge (Southbound Only)	12,600	13,200	1.05
SR 37 at the Sonoma/Marin County Line	10,200	15,700	1.54
I-580 at the Contra Costa/Marin County Line	21,700	25,800	1.19

Source: Fehr & Peers, RSG

Table 21: Daily Highway Validation at Key Roadway Facilities

Traffic Count Location	Count	Model	Model/ Count Ratio
US 101 at the Sonoma/Marin County Line	85,700	91,000	1.06
US 101 North of San Rafael	175,700	173,400	0.99
US 101 at San Rafael Creek	138,100	133,100	0.96
US 101 at the Golden Gate Bridge (Southbound Only)	48,700	53,300	1.09
SR 37 at the Sonoma/Marin County Line	39,500	44,600	1.13
I-580 at the Contra Costa/Marin County Line	78,100	91,200	1.17

Source: Fehr & Peers, RSG

Transit Validation

For the updated TAMDM transit validation, forecasted model boardings were compared to transit operator-level transit ridership data obtained from transit operators for the purposes of transit ridership validation. The results of the transit validation are presented in **Table 22** and indicate that the updated TAMDM 2022 base year total transit ridership forecast is within 25% of observed ridership.

Table 22: Daily Transit Validation by Transit Operator

Operator	2022/2023 Ridrship Data	2022 TAMDM	Delta	% Difference
Golden Gate Transit Bus	4,514	6,671	2,157	48%
Golden Gate Transit Ferry	5,349	6,680	1,331	25%
Marin Transit	8,203	8,563	361	4%
SMART Rail	2,750	3,832	1,082	39%
Total	**20,816**	**25,746**	**4,930**	**24%**

Source: Fehr & Peers, RSG

Trip Distribution Validation

For the updated TAMDM trip distribution validation, forecasted vehicle origin-destination data from the model was compared to vehicular travel patterns from 2022 connected vehicle data. The focus of the mobile device data validation effort was on the AM peak period (6 AM to 10 AM) as trip and workplace destination as well as modal decisions made during this time period typically control decisions made throughout the day. **Table 23** presents a comparison of the relative distribution pattern of inter-Marin County trips generated by Marin County that travel to other Bay Area counties in the AM peak period. **Table 24** presents a comparison of the distribution pattern of inter-Marin County trips generated by other Bay Area counties that come to Marin County in the AM peak period.

Table 23: Connected Vehicle Data AM Peak Period Trips out of Marin County

Destination County	Connected Vehicle Data	2022 TAMDM	Delta
Sonoma	27%	32%	5%
Napa	3%	2%	-1%
Solano	4%	3%	-1%
West Contra Costa	6%	8%	2%
East Contra Costa	2%	1%	-1%
North Alameda	8%	10%	2%
San Francisco	37%	32%	-5%
San Mateo	9%	8%	-1%
South Alameda	2%	2%	0%
Santa Clara	2%	2%	0%

Source: Fehr & Peers, RSG, StreetLight Data

Table 24: Connected Vehicle Data AM Peak Period Trips into Marin County

Origin County	Connected Vehicle Data	2022 TAMDM	Delta
Sonoma	44%	40%	-4%
Napa	3%	1%	-2%
Solano	8%	3%	-5%
West Contra Costa	12%	15%	3%
East Contra Costa	4%	7%	3%
North Alameda	7%	15%	8%
San Francisco	14%	12%	-2%
San Mateo	4%	2%	-2%
South Alameda	2%	4%	2%
Santa Clara	1%	1%	0%

Source: Fehr & Peers, RSG, StreetLight Data

The relative inter-county trip distribution pattern comparisons presented above indicate that the updated TAMDM 2022 base year inter-county trip distribution patterns are all within 10% of observed patterns from 2022 connected vehicle data.

Work Location Choice Validation

For the updated TAMDM work location choice validation, the model incorporates research findings from MTC as documented in the Plan Bay Area 2050 Final Blueprint Documents. These documents provide county-level telecommuting trends for Bay Area counties, which informed the model's calibration for Marin County residents. According to the documents, the share of Marin County workers telecommuting was 33% in 2022, with a projected decline to 30% by 2050. These telecommuting shares served as the basis for calibration and validation of the work location choice models to ensure the updated TAMDM reflected current and anticipated shifts in work location choice over time.

Table 25 presents a comparison of the 2022 telecommuting percentage from MTC to the updated 2022 TAMDM scenario and indicates that the second-generation update of TAMDM closely matches the published research findings from MTC.

Table 25: Work from Home Assumptions

Origin County	MTC Data	2022 TAMDM	Delta
2022	33%	32.4%	-0.6%

Source: Fehr & Peers, RSG

Future Year (2050) Scenario

Following validation of the new base year (2022) scenario, modifications were made to the model's roadway network, transit network, land use, and work location choice inputs to develop a new future year (2050) scenario consistent with MTC's Plan Bay Area 2050+ and the Regional Transportation Plan (RTP). This chapter provides an overview of the new future year (2050) scenario development, including a summary of future year transportation network and land use assumptions, followed by a discussion of the resulting future year (2050) forecasts.

Roadway Network

The future year (2050) roadway network improvements within Marin County were coded based on input provided by TAM staff and are summarized in **Table 26**. Roadway network improvements outside Marin County were limited to major highway improvements included in MTC's Travel Model One within Bay Area counties that interact with Marin County.

Table 26: Future Year Roadway Network Improvements within Marin County

Facility Type	Roadway Network Improvement
Highway Facility	US 101/Tiburon Blvd. northbound on-ramp widened from one lane to two lanes
	Northbound US 101 to eastbound I-580 direct connector
	Eastbound I-580/Bellam Blvd. off-ramp widened from three lanes to four lanes immediately west of the ramp terminal intersection
	SR 37 widened to provide two lanes of travel in each direction through existing two-lane section with a toll facility
	Marin-Sonoma Narrows: widen 17 miles of US 101 from four to six lanes by adding one high occupancy vehicle lane in each direction
Local Facility	Novato Blvd. widened to provide two lanes of travel in each direction between Grant Ave. and Diablo Ave.

Source: Fehr & Peers, RSG

Transit Network

The future year (2050) transit network improvements within Marin County were limited to the inclusion of additional planned SMART stations. SMART stations included in the future year (2050) scenario are listed in **Table 27**. Base year (2022) bus and ferry service were left unmodified for the future year (2050) scenario. Transit network improvement outside Marin County were limited to BART and Caltrain projects included in MTC's Travel Model One.

Table 27: Future Year SMART Stations

County	Station
Sonoma	Cloverdale
	Healdsburg
	Windsor
	Sonoma County Airport
	Santa Rosa North
	Santa Rosa Downtown
	Rohnert Park
	Cotati
	Petaluma North
	Petaluma Downtown
Marin	Novato San Marin
	Novato Downtown
	Novato Hamilton
	Marin Civic Center
	San Rafael
	Larkspur

Source: Fehr & Peers, RSG

Land Use

As discussed in the Model Data chapter, Fehr & Peers received 2022 land use data from MTC to serve as the basis for the new base year (2022) scenario land use inputs. The future year (2050) scenario land use inputs were also developed based on land use data provided by MTC to ensure consistency with the most recent land use and socio-economic database of ABAG and assumptions of MTC's latest TM1.

The ABAG projections served as a starting point and were then updated to ensure the 2050 horizon year included land use changes that reflect recent updates to agency housing elements that incorporate 2023-2031 RHNA housing allocations. The 2050 scenario was updated to reflect the implementation of three full rounds of RHNA housing allocations.

The final 2022 and 2050 TAMDM land use inputs are summarized in **Table 28** and indicate that the average growth per year in population plus employment in Marin County is roughly 0.6% for the 2050 horizon year. Household and population growth is assumed to grow at a faster rate (0.9%) than employment growth (0.2% based on the inclusion of multiple rounds of RHNA housing allocations.

Table 28: TAMDM Land Use Data Summary

Scenario	Population	Households	Employees	Jobs-to-Housing Ratio	Population + Employment
2022	261,751	109,741	127,054	1.16	388,805
2050	323,084	136,543	133,768	0.98	456,852
Growth Per Year					
2050	0.8%	0.9%	0.2%	--	0.6%

Source: Fehr & Peers, RSG

As discussed in the Origin-Destination Data section, empirical connected vehicle data indicates that trips out of Marin County in the AM peak period primarily travel to San Francisco County (37%), Sonoma County (27%), Alameda County (10%), and Contra Costa County (8%). These inter-county flows are directly influenced by the jobs-to-housing ratio within Marin County as well as job availability and growth in nearby counties. Therefore, it is important to understand the growth in employment in these nearby counties projected by ABAG when setting expectations and checking the reasonableness of the updated TAMDM horizon year forecasts.

Table 29 presents the 2022 and 2050 employment assumptions for the top four destination counties for inter-Marin County travel and indicates that over 300,000 additional jobs are assumed in San Francisco and over 400,000 additional jobs are assumed in Alameda County by 2050, while Table 28 indicates that less than 7,000 additional jobs are assumed in Marin County and that the jobs-to-housing ratio in Marin County is projected to fall below 1.00 by 2050 with the addition of over 60,000 residents. According to the Building Industry Association[5], experts say that a healthy jobs-to-housing balance is roughly 1.5.

These data points suggest that Marin County will likely export a higher proportion of trips in 2050 than in 2022 to meet the employment demand of Marin County residents. San Francisco and Alameda counties are likely destinations given their proximity, direct access via major freeways, and large projected growth in employment.

Table 29: TAMDM External County Employment Data

External County	2022 Employees	2050 Employees	Employment Growth	% Growth	% Growth Per Year
San Francisco	601,163	918,465	317,302	53%	1.9%
Alameda	773,375	1,182,349	408,974	53%	1.9%
Contra Costa	392,214	533,786	141,572	36%	1.3%
Sonoma	224,082	251,635	27,553	12%	0.4%

Source: Fehr & Peers, RSG

[5] https://www.biabayarea.org/bay-area-jobs-housing-imbalance-continues

The final 2022 and 2050 TAMDM land use inputs by jurisdiction for households, population, and employment are summarized in **Table 30, Table 31,** and **Table 32,** respectively.

Table 30: TAMDM Household Data

Area	2022	2050
Bay Area	2,956,964	4,033,846
Marin County	109,741	136,543
Belvedere	919	1,345
Corte Madera	3,762	5,433
Fairfax	3,304	4,449
Larkspur	6,027	8,910
Mill Valley	6,056	7,978
Novato	22,593	26,968
Ross	858	994
San Anselmo	5,236	6,225
San Rafael	25,031	30,912
Sausalito	4,195	5,926
Tiburon	3,793	4,879
Marin County Unincorporated	27,967	32,524

Source: Fehr & Peers, RSG

Table 31: TAMDM Population Data

Area	2022	2050
Bay Area	7,892,157	10,304,366
Marin County	261,751	323,084
Belvedere	2,222	3,015
Corte Madera	9,816	12,964
Fairfax	7,406	9,450
Larkspur	12,913	19,516
Mill Valley	14,555	18,107
Novato	55,552	66,707
Ross	2,543	2,661
San Anselmo	12,698	14,347
San Rafael	59,738	76,483
Sausalito	7,403	10,785
Tiburon	9,536	11,376
Marin County Unincorporated	67,369	77,673

Source: Fehr & Peers, RSG

Table 32: TAMDM Employment Data

Area	2022	2050
Bay Area	3,684,963	5,426,365
Marin County	127,054	133,768
Belvedere	493	489
Corte Madera	8,111	8,745
Fairfax	1,575	1,764
Larkspur	7,009	7,233
Mill Valley	7,179	7,237
Novato	24,783	26,965
Ross	613	449
San Anselmo	3,474	3,518
San Rafael	43,488	46,112
Sausalito	6,778	7,498
Tiburon	3,075	3,294
Marin County Unincorporated	20,476	20,464

Source: Fehr & Peers, RSG

Work Location Choice

The work from home percentages used to calibrate the work location choice models were derived from estimates published by MTC in the Plan Bay Area 2050 Final Blueprint Documents. **Table 33** presents the calibrated work from percentages for the second-generation update of TAMDM and indicates that all three scenarios closely match the published research findings from MTC.

Table 33: Work from Home Assumptions

Origin County	MTC Data	TAMDM	Delta
2022	33%	32.6%	-0.4%
2050	30%	29.7%	-0.3%

Source: Fehr & Peers, RSG

Future Year (2050) Forecasts

This section summarizes the future year (2050) roadway link, vehicle miles travelled (VMT), transit boarding, work location choice, and vehicle origin-destination forecasts.

Roadway Link Forecasts

Table 34 presents a summary of bi-directional growth at the six count locations where PeMS or BATA traffic count data was available for AM peak period, PM peak period, and daily conditions for the future year (2050) scenario.

Table 34: 2050 Growth at Key Roadway Facilities

Traffic Count Location	AM Peak Period	PM Peak Period	Daily
US 101 at the Sonoma/Marin County Line	-7%	19%	9%
US 101 North of San Rafael	23%	29%	18%
US 101 at San Rafael Creek	-8%	40%	16%
US 101 at the Golden Gate Bridge (Southbound Only)	117%	7%	35%
SR 37 at the Sonoma/Marin County Line	51%	41%	26%
I-580 at the Contra Costa/Marin County Line	14%	36%	22%

Source: Fehr & Peers, RSG

As shown in Table 34, future year (2050) roadway link forecasted growth is generally in line with the 0.6 percent annual growth in population plus employment from the ABAG land use projections. Significant growth in AM peak period travel southbound across the Golden Gate Bridge can be attributed to the relatively high household growth in Marin County coupled with the relatively low employment growth in Marin County, which increases the number of residents that need to leave Marin County for work. San Francisco is a logical choice for employment given the proximity, direct access via US 101, and over 300,000 jobs assumed to be added in San Francisco by 2050. Growth on the Richmond-San Rafael Bridge can also be attributed to these factors as Alameda County is also a logical choice for employment given the proximity, direct access via I-580, and over 400,000 jobs assumed to be added in Alameda County by 2050. Reductions in traffic on US 101 can be attributed to the expansion of SMART, while the significant growth on SR 37 can be attributed to the SR 37 widening project.

Vehicle Miles Travelled Forecasts

Table 35 presents a summary of resident-based VMT per resident and employee-based VMT per employee for Marin County for the new 2022 and 2050 scenarios, as well as data for the previous 2015 and 2040 scenarios for comparison purposes. The resident-based VMT includes home-based personal auto trips generated by residents, while employee-based VMT includes home-based work and work-based personal auto trips generated by employees within Marin County.

Table 35: Marin County Vehicle Miles Travelled Forecasts

Model Scenario	Work from Home %	Resident-Based VMT per Resident		Employee-Based VMT per Employee	
Previous 2015	11%	4,081,169	15.7	2,649,623	20.8
2022	33%	4,044,738	15.5	2,206,512	17.4
Previous 2040	12%	4,101,886	15.0	2,706,854	19.9
2050	30%	4,517,456	14.0	1,836,067	13.7

Source: Fehr & Peers, RSG

Table 36 presents a summary of resident-based VMT per resident and employee-based VMT per employee for the Bay Area, Marin County, and by Marin County jurisdiction for the new 2022 and 2050 scenarios. The table indicates that the VMT per capita for Marin County as well as for Marin County jurisdictions is generally higher than the Bay Area average.

Table 36: Jurisdiction-Level Vehicle Miles Travelled Forecasts

Jurisdiction	Resident-Based VMT per Resident		Employee-Based VMT per Employee	
	2022	2050	2022	2050
Bay Area	12.1	10.9	13.1	10.5
Marin	15.5	14.0	17.4	13.7
Belvedere	23.7	15.8	23.0	18.0
Corte Madera	14.3	12.2	15.6	13.5
Fairfax	13.1	13.4	16.6	12.4
Larkspur	14.0	13.6	17.7	12.1
Mill Valley	14.4	12.8	18.5	14.7
Novato	16.6	15.0	18.1	12.5
Ross	10.8	9.7	15.6	15.4
San Anselmo	12.5	12.2	16.4	14.2
San Rafael	12.1	10.6	15.4	11.8
Sausalito	14.5	12.2	21.3	16.1
Tiburon	15.6	16.8	19.0	20.8
Unincorporated	19.0	17.3	19.4	17.8

Source: Fehr & Peers, RSG

Transit Boarding Forecasts

Table 37 presents a summary of 2050 daily transit boarding forecasts by transit operator compared to 2022/2023 ridership data obtained from the transit operators. The table indicates that 2050 TAMDM forecasts roughly an additional 17,600 transit boardings between 2022 and 2050, an annual growth of roughly 4.7 percent, representing a significant increase over the 0.6 percent annual growth in population plus employment forecast by ABAG.

Table 37: 2050 Daily Transit Boarding Forecasts by Transit Operator

Operator	2022/2023 Ridrship Data	2050 Forecast	Growth	% Growth	% Growth Per Year
Golden Gate Transit Bus	4,514	8,800	4,286	95%	5.3%
Golden Gate Transit Ferry	5,349	8,100	2,751	51%	2.9%
Marin Transit	8,203	10,900	2,697	33%	1.8%
SMART Rail	2,750	10,600	7,850	285%	15.9%
Total	**20,816**	**38,400**	**17,584**	**84%**	**4.7%**

Source: Fehr & Peers, RSG

Work Location Choice Forecasts

Table 38 presents the modeled distribution of Marin County workers by work location choice, including both in-county and inter-county destinations, for the 2022 and 2050 scenarios. As discussed in the future year Land Use section, it was anticipated that TAMDM would forecast a reduction in commute share within Marin County and a significant growth in commute share to other Bay Area counties, especially San Francisco and Alameda Counties.

Table 38: 2022 & 2050 TAMDM Marin County Work Location Choice

Work Location	2022 Workers	2022 Share	2050 Workers	2050 Share
Alameda	**1,860**	**1.5%**	**4,930**	**3.0%**
Contra Costa	83	0.1%	223	0.1%
Marin	**56,677**	**45.7%**	**65,422**	**40.3%**
Napa	653	0.5%	1,276	0.8%
San Francisco	**11,980**	**9.7%**	**24,899**	**15.3%**
San Mateo	3,431	2.8%	4,430	2.7%
Santa Clara	851	0.7%	1,047	0.6%
Solano	713	0.6%	1,423	0.9%
Sonoma	7,612	6.1%	10,417	6.4%

Source: Fehr & Peers, RSG

Vehicle Origin-Destination Forecasts

Table 39 presents a summary of the forecasted growth in vehicle trips for the types of vehicle trips that are occurring within Marin County in the AM peak period for the 2050 scenario. As discussed in the future year Land Use section, it was anticipated that TAMDM would forecast a significant growth in commute share out of Marin County to other Bay Area counties, which is indicated by a forecasted growth of 56% by 2050. Total trips were forecasted to grow by 18% in 2050, an annual growth rate of roughly 0.6% per year. The annual growth rates is in line with the 0.6 percent annual growth in population plus employment forecast by ABAG.

Table 39: 2050 AM Peak Period Vehicle Origin-Destination Forecasts

Trip Type	2022	2050	Growth	% Growth
Marin County Pass-Through Trips	12,100	16,900	4,800	40%
Trips into Marin County	32,900	28,900	-4,000	-12%
Trips out of Marin County	**28,500**	**44,500**	**16,000**	**56%**
Intra-Marin County Trips	137,300	158,100	20,800	15%
Total Trips	210,800	248,400	37,600	18%

Source: Fehr & Peers, RSG

Table 40 presents a summary of growth for the key inter-Marin County origin-destination pairs in the AM peak period for the 2050 scenario. The table indicates that 2050 TAMDM forecasts significant growth in vehicle travel from Sonoma County to San Francisco County (85% growth), which can be attributed to widening of the Marin-Sonoma Narrows and the projected increase in employment growth in San Francisco. Significant growth in travel from Marin County to San Francisco (48% growth) and Alameda & Contra Costa counties (126% growth) is also forecasted due to projected changes in land use patterns discussed in the future year Land Use section. Travel into Marin County is also generally projected to decline even further by 2050 due to the low levels of employment projected to be added in Marin County and the high levels of employment projected to be added elsewhere.

Table 40: 2050 AM Peak Period Vehicle Origin-Destination Forecasts

Origin-Destination Pair	2022	2050	Growth	% Growth
Sonoma County to Marin County	13,200	13,300	100	1%
Sonoma County to San Francisco	3,400	7,200	3,800	112%
San Francisco to Sonoma	2,500	1,300	-1,200	-48%
Marin County to Sonoma County	9,100	10,400	1,300	14%
Marin County to San Francisco	9,100	15,300	6,200	68%
San Francisco to Marin County	3,900	4,200	300	8%
Marin County to Napa or Solano County	1,400	1,600	200	14%
Solano or Napa County to Marin County	1,400	1,100	-300	-21%
Marin County to Alameda or Contra Costa County	6,100	11,300	5,200	85%
Alameda or Contra Costa County to Marin County	13,300	9,500	-3,800	-29%

Source: Fehr & Peers, RSG

Conclusions and Recommended Practices

As discussed in the Base Year (2022) Model Validation chapter, the new base year (2022) TAMDM meets all validation criteria developed by Caltrans and the California Transportation Commission for the highway and transit networks within Marin County. Additionally, Fehr & Peers feels the model calibration and validation comparisons indicate the model is suitable for use in the development of future year and alternative traffic forecasts on the highway and transit networks. However, Fehr & Peers developed TAMDM as a starting point for project-level applications within Marin County, and recommends additional, more localized subarea validation efforts be undertaken to improve the accuracy of the model within each project's study area to ensure confidence and defensibility of the resulting demand forecasts.

Recommended Practices

TAMDM is designed for use in evaluating the potential impacts to the transportation system of proposed land use development and infrastructure improvements. This section provides an overview of the recommended practices when using the model in this role.

Local Calibration

TAMDM was calibrated to meet the validation criteria developed by Caltrans and the CTC for roadway segments of highest significance within Marin County. Because the model includes a highly detailed roadway network and TAZ structure, it can be adapted for more localized studies. We recommend that this adaption include additional local calibration to ensure the model is able to replicate traffic conditions on the roadway segments or at the intersections of most interest to the particular project under study, as well as to ensure that the model responds in the correct direction and magnitude when making changes to land use and the roadway network in the vicinity of the project. Performing a local calibration should be standard practice prior to using any travel demand model, not just TAMDM.

A local calibration typically involves the following:

- Collecting multi-day field counts at key locations in the project study area, and checking the model's base year traffic volumes against those field counts.
- Checking the roadway network coding for roadways affected by the project, including determining whether the centroid connectors are loading at the proper locations in the roadway network.
- Checking that the base year land uses and SED are correct for zones affected by the project.
- Running the model and iteratively adjusting model parameters until all validation criteria established by Caltrans and the CTC are met or exceeded.

Scenario Input Data

Once the local calibration is complete, the next step is to input the data for the scenario being tested. The mechanics of inputting scenario data are very similar to the steps in the local calibration.

- Modify the roadway network if the scenario includes changes such as the creation of new roadways or intersections or the addition of travel lanes.
- Edit the land use and SED if the scenario includes changes such as the addition of households or employment.
- Run the model with the modified roadway network and land use inputs and compare the outputs to the outputs from the locally calibrated model.

Adjusting Model Outputs

Travel demand models such as TAMDM provide volume outputs that need to be adjusted in order to develop volume forecasts for the scenario being tested. Raw volume outputs from a travel demand model should rarely be applied directly in analysis, only being used after adjustments are made. The rationale for adjusting raw model volume outputs is that observed travel behavior is the result of a highly complex mixture of variables, only some of which are included in any given travel demand model, and so an adjustment is needed to capture the variables not captured by the model itself. The adjustment takes the form of changing the model outputs to correct for discrepancies between the base year field counts and the base year model volumes identified during the local calibration process, as it is assumed that the discrepancy will likely affect all scenarios in the same order of magnitude. This can be done several ways, as defined in the *National Cooperative Highway Research Program Report 255: Highway Traffic Data for Urbanized Area Project Planning and Design*, Transportation Research Board, December 1982[6]. The three most common industry-standard procedures for adjusting model traffic forecasts for both link and turning movement volumes are described below.

DIFFERENCE METHOD

The difference between the base year field count and the base year model volume is added to the output model volume to develop the forecasted volume for the scenario being tested. For example, if the base year model volume for a roadway segment was 650 ADT while the field count was 700 ADT, then the difference method would suggest the output model volume on that roadway segment should be increased by 50 ADT to develop the forecasted volume for the scenario being tested. The difference method adjustment is summarized in the formula below.

Scenario Forecast = Output Model Volume + (Field Count – Base Year Model Volume)

[6] http://teachamerica.com/tih/PDF/nchrp255.pdf

RATIO METHOD

The ratio method is similar, except that it uses the ratio of the base year field count and the base year model volume to make the adjustment. For example, if the base year model volume for a roadway segment was 650 ADT while the field count was 700 ADT, then the ratio method would suggest the output model volume should be increased by 7.7% (700 / 650 = 1.077) to develop the forecasted volume for the scenario being tested. The ratio method adjustment is summarized in the formula below.

Scenario Forecast = Output Model Volume * (Field Count / Base Year Model Volume)

BLENDED METHOD

The blended method takes the average of the ratio method and the difference method scenario forecasts. The blended method adjustment is summarized in the formula below.

Scenario Forecast = (Difference Method Scenario Forecast + Ratio Method Scenario Forecast) / 2

The most appropriate adjustment method is left to the judgment of the engineer for each project. However, there are guidelines that the Transportation Research Board has published based on the difference between base year field counts and base year model volumes: use the ratio method if the difference is less than 50%, use the difference method if the difference is greater than 150%, otherwise use the blended method. No matter which method is selected, the reasonableness of the scenario forecast should always be checked based on knowledge of the area, comparisons to forecasts at adjacent locations, off-model calculations of the trip generation, distribution, and assignment of adjacent land use, or other methodologies, as deemed appropriate.