A COUNTYWIDE PLANNING FRAMEWORK TO IDENTIFY CONTINUOUS AND CONNECTED MULTIMODAL ARTERIAL NETWORKS

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ABSTRACT

Over the past decade, the Complete Streets movement has revolutionized transportation planning by considering how all modes use roadways collectively. While many cities have developed roadway typology to inform design of roadway improvements, these typologies do not help agencies prioritize amongst the needs of multimodal users. Furthermore, most typologies are prepared by individual agencies ending at jurisdictional boundaries and do not offer opportunities for continuous and connected networks across jurisdictional lines. Alameda County Transportation Commission (Alameda CTC) developed a countywide planning framework for its arterial roadways based on two factors: land use context and modal function (transit, pedestrian, bicycle, auto, and goods movement). This framework prioritizes the modal users on the County’s arterial roadways based on a tiering system developed from land use context and layered modal networks. The framework applies multimodal performance measures to identify roadway segments with existing and future improvement needs for high priority modes. This needs assessment enables Alameda CTC to identify improvement areas or cross-jurisdictional corridor projects that would establish a system of continuous and connected multimodal networks across the county.

Keywords: complete streets, typology, layered network, performance measure.
INTRODUCTION
Alameda County is located at the center of the San Francisco Bay region and experiences more than 40% of
the region’s freeway congestion as measured in daily vehicle hours of delay (1). The arterial roads serve as the
backbone for regional and local traffic, and sometimes as a bypass alternative. Arterials serve various functions
across all modes with competing demands, therefore, it is important to develop a systematic framework of
identifying the different multimodal users and their needs.

The Complete Streets movement along with state and regional legislations have encouraged cities to
evaluate how multiple modes can coexist on the same streets. While many cities have developed roadway
typologies and used them to inform complete street design guidelines, there has been no effort to look at
typologies across multiple jurisdictions that could result in connected and continuous multimodal networks
across a county or regionally. There is no existing framework that ties typology to multimodal performance
objectives to identify existing and future needs that would strengthen the County’s continuous and connected
multimodal networks.

To develop this framework, Alameda CTC led a Countywide Multimodal Arterial Plan (MAP) with
the following elements:

1. Close coordination with the arterials’ owners and operators – local jurisdictions, the state DOT
(Caltrans) and the three bus agencies.
2. A typology that considers land use context and the various modes served by each roadway to develop
a system of multimodal networks.
3. A process that prioritizes the five modes (transit, pedestrian, bicycle, auto, and goods movement)
based on typology, especially since right-of-way on most of the arterials is limited.
4. Multimodal performance measures that assess how roadways would perform for the prioritized modes
and identify needs.
5. Identification of roadway improvements for each mode that would: a) allow underperforming arterials
to meet, or come as close as possible to meeting performance objectives, and b) close gaps so that each mode’s
countywide arterial network is connected and continuous.

This paper describes the framework including an evaluation of how performance measurement
outcome would improve by implementing the framework’s recommended improvements. The paper concludes
with challenges encountered during framework development and potential framework elements that can be
developed and refined in the future.

LITERATURE REVIEW
This literature review starts with national guidance and then presents exemplary local practices. Notably, all
documents are developed within the current decade and most within the last four years, demonstrating the
dynamic change within the field of arterial design.

Guidelines on System and Corridor Level Planning
In 2010, the Institute of Transportation Engineers (ITE) published a Recommended Practice on Designing
Walking Urban Thoroughfares: A Context Sensitive Approach that brought to the forefront progressive
transportation practices related to planning and design of non-auto modes in the context of major thoroughfares
(2). Its intent was to highlight the flexibility in design included in the American Association of State Highway
and Transportation Officials’ (AASHTO’s) A Policy on Geometric Design of Highways and Streets, also
known as The Green Book (3). The concept of flexibility in design has seen significant literature development
including guides for the development of bikeways, urban streets and transit streets by the National Association
of City Traffic Engineers (NACTO) (4,5,6). The Federal Highway Administration (FHWA) has taken an
active hand in promoting flexibility in design (7).

In 2014, ITE published a second Recommended Practice to more completely address network
planning issues – Planning Urban Roadway Systems (PURS) (8). PURS is the first report to formalize the
layered network concept, a series of mode-specific networks that nest within a larger grid of streets. The
layered network concept suggests that identifying complete and connected networks for autos, transit and
bicycles results in a more multimodal roadway network. The PURS report also suggested that multimodal
performance measures can assess each network’s operations and that the specific performance measures should
correspond to each street’s priority mode.

**City Level Efforts**

In recent years, cities have approached plan development with a multimodal layered networks lens. In 2013,
the Chicago Department of Transportation (CDOT) issued the Complete Streets Chicago Design Guidelines to
implement the City’s complete streets policy (9). The guidelines have four major sequential components:

1. Roadway design and operation decisions will be based on a hierarchy that ranks modes in the
   following sequence: pedestrian, transit, bicycle, and automobile.
2. Street typology based on land use, building type, and roadway form and functional characteristics
   such as right-of-way width, target speed, and traffic volume.
3. General guidance for cross-section design selection based on a roadway’s street typology and modal
   hierarchy.
4. Project delivery process that consists of six steps: project selection, scoping, design, construction,
   measurement, and maintenance.

Transportation performance measures include crash maps; multimodal volumes; and delay-based
motor vehicle and pedestrian level of service. The Guidelines do not contain the process for making design
decisions when trade-offs between modes are necessary except by defining the step-wise order of priority
modes and noting that there is no minimum vehicle level of service.

In 2014, the District of Columbia Department of Transportation (DDOT) prepared MoveDC, a long
range transportation plan (10). Among the MoveDC strategies were multimodal improvements that increase
capacity and from the downtown and improvements that increase access between neighborhoods. The plan
acknowledged that where multimodal improvements require space within existing street rights-of-way,
tradeoffs are necessary between parking, travel lanes, and providing dedicated space (and the configuration of
that space). The plan identified modal priorities for major streets as a decision-making framework.

Transportation performance measures are largely macro-scale measurements of expected mode share, capacity
to move people, transit accessibility, bicycle and pedestrian network completeness and vehicle network
operations measured with volume-to-capacity ratio.

In 2015, Pasadena, California prepared its General Plan Mobility Element with the objectives of
enhancing livability, encouraging walking, biking, transit and other alternatives to motor vehicles, and creating
a supportive climate for economic viability (11). The Mobility Element pivoted from and expanded the use of
typologies as a basis to adapt the street design to a set of strategic objectives. Pasadena has strategic objectives
and accompanying performance measures including: reduce vehicle miles traveled (VMT) per capita and
vehicle trips per capita, which can be achieved by siting development in areas with a diverse mix of land uses
and a rich set of mode choices; locating new development proximate to the bicycle and transit networks; and
siting new developments in high pedestrian accessibility areas.

**Local Alameda County Efforts**

Within Alameda County, three cities have developed typology based circulation systems: Alameda, Emeryville
and Fremont (12, 13, 14). The City of Alameda Transportation Element includes typologies, layered networks,
and multimodal performance measures, all elements that evolved further as part of the MAP. The layered
networks consist of transit and bicycle networks that are largely non-overlapping such that these modes are not
competing for space on individual streets. The City of Alameda has incorporated Highway Capacity Manual
(HCM) 2010 multimodal performance measures into its development review process (15). Application of these
performance measures has resulted in some counter-intuitive results and have proven the comfort-based HCM
performance measures to be insensitive to geometric inputs. For example, a road diet that would typically be
implemented to improve pedestrian and bicycling conditions actually degraded pedestrian and bicycle level of
service (LOS) when applying the HCM 2010 methodology (16). The MAP’s framework approach
intentionally used multimodal performance measures that largely derived from the underlying research of the
HCM and are simpler and provide more intuitive results.
FRAMEWORK APPROACH
The MAP developed a framework to identify potential improvement areas or cross-jurisdictional corridor projects that would strengthen the County’s system of continuous and connected multimodal networks. Figure 1 shows the steps of the approach:

1. Develop roadway typology: The framework developed typology based on two factors: the land use context that a road passes through and the road’s modal users – transit, pedestrian, bicycle, auto, and goods movement.
2. Identify modal priorities: Since many roadways cannot accommodate improvements for all modes, the project team has developed model priorities using a tiering system that evaluated the typology factors.
3. The framework applied performance measures and objectives to assess multimodal needs based on each roadway segment’s performance in existing and future conditions, particularly for the segment’s top priority modes.
4. Finally, the framework identified improvements that enable underperforming segments to either meet or come as closely to meeting the objectives, and improvements that close the gaps in each mode’s network to create a set of continuous and connected modal networks countywide.

Throughout these steps, Alameda CTC collaborated with the owners and operators of the arterials – local jurisdictions, the state DOT (Caltrans) and the three bus operators – to ensure that local plans and insights were incorporated.

Institutional Coordination
The framework involved collaborative stakeholder engagement throughout each step. The process built on the prior planning efforts of local agencies and Alameda CTC, such as Alameda CTC’s Countywide Transportation, Transit, Pedestrian, Bicycle and Goods Movement plans, local pedestrian, bicycle and complete streets plans and transit agencies’ major corridor strategies. Alameda CTC worked closely with the arterials’ owners and operators – the cities, the County and Caltrans – and the bus operators. There were over 65 meetings during the plan development and the project team received over 1,000 comments that leveraged local knowledge and understanding to refine inputs and conclusions of the technical processes.

The technical output generated by the subsequent steps began the conversation about reallocating available right-of-way among competing modes and particularly the needs of top priority modes. The MAP’s proposed improvements represented the product of this interaction: technical results adapted, where needed, to reflect local situations while maintaining the broader corridor- and county-level consistency. At the same time, the MAP process did not include community meetings to review specific roadway segments or proposed improvements. Therefore, jurisdictions will need to execute community-based processes to confirm and plan the individual improvements’ design.

Roadway Typology

Land Use Context
The land use context combined two sources (17):

- The Priority Development Area (PDA) land use types defined by the Regional Planning Agency – Association of Bay Area Governments (ABAG) – which are areas of higher intensity mixed-land use.
• Land use types developed in Alameda County’s Sustainability Communities Strategies (SCS) process in coordination with jurisdictions and based on their general plan designations.

These land use types were combined into 11 land use types for the framework’s street typology, and further grouped into three categories:

• Urban - Downtown/town center mixed use/education/parks
• Suburban - Mixed use/commercial/residential/rural/open space
• Industrial – Industrial land use

Modal Networks

For each mode, the project team collaborated with local jurisdictions, transit agencies and Caltrans to identify the countywide network.

Transit

The transit network consists of three levels identified by the transit operators:

• Major corridors
• Crosstown routes
• Local routes

Pedestrian

Unlike the other modes, the pedestrian network is nodal or area based, because walking is a function of proximity to land uses or destinations (such as transit stops) or by virtue of living or working within a transit-served community. Therefore, the pedestrian network included arterial segments found within:

• Priority Development Areas (PDA)
• Commercial and mixed-use areas (based on local General Plans)
• The regional metropolitan planning organization – Metropolitan Transportation Commission’s (MTC) Communities of Concern that indicates areas with disadvantaged populations
• Proximity to rail and bus facilities
• Quarter-mile buffers around activity and education centers and parks

Based on these criteria, the project team determined three levels of pedestrian emphasis areas: high, medium and low.

Bicycle

The bicycle network consists of segments from the 2012 Alameda Countywide Bicycle Plan and local updates developed by jurisdictions since 2012 (existing and proposed). The project team categorized these bike facilities based largely on the Caltrans Highway Design Manual (18):

• Class I – bicycle and multiuse path
• Class IV – cycle-tracks and similar protected bicycle facilities
• Class II enhanced – buffered bicycle lanes, and green bicycle lane
• Class II – bicycle lanes
• Class III enhanced – bike boulevards and similar enhanced bike routes
• Class III – bike routes, shared use arrows, shoulders, and curb lanes

Note that the Class IV cycle-track is intentionally out of numeric order in the above list (organized by comfort level); this is pertinent to the bicycle performance measures (as discussed later in the paper) which is based on level of bicycle comfort. The bicycle network is predominantly on arterial corridors and includes bike lanes, buffered bike lanes, bike routes, and protected bicycle lanes. It also includes parallel (arterial-adjacent) facilities including multi-use trails and bicycle boulevards.
Auto The MAP defines base street types as each arterial’s role in carrying sub-regional and local traffic. If a street is serving a high volume of vehicles that are traveling a longer distance, through movement is likely more important for drivers than access to local destinations. The typology system has four base street types (from highest to lowest order) based on trip volumes and distance:

- Throughway: At least 10,000 Average Daily Traffic (ADT) with over 50% of total traffic volume traveling more than 8 miles
- County connector: At least 10,000 ADT with a minimum of 45% of total traffic volume traveling more than 6 miles
- City/community connector: At least 50% of total volume traveling more than 4 miles
- Neighborhood/district connector: At least 50% of total volume traveling less than 4 miles

To determine these the trip distance thresholds, the project team conducted a sensitivity analysis. The analysis applied various combinations of ADT and percent of trips by travel distance, and reviewed the results for reasonableness to finalize the suitable thresholds.

Goods Movement The goods movement network consists of the Tiers 2 and 3 Goods Movement routes, as defined in the concurrently developed Alameda Countywide Goods Movement Plan. Tier 2 routes are state highways that provide intra-county and intra-city connectivity and last-mile connections to the Port of Oakland and Oakland International Airport. Tier 3 routes are arterials and collectors used in a majority of local pickup and delivery. All Tier 1 goods movement routes are on freeways, which are not a part of the County’s arterial system.

Modal Priorities Most of Alameda County’s major arterials have limited right-of-way, and many cannot accommodate improvements for all modes; therefore, the framework’s next step identifies each arterial segment’s priority modes. The project team collaborated with stakeholders to develop a tiering process that rank the arterial segments, whereby each mode’s facility types were ordered as follows:

Transit:
- Tier 1: Major corridors
- Tier 2: Crosstown routes
- Tier 3: Local routes

Pedestrian:
- Tier 1: High emphasis area
- Tier 2: Medium emphasis area
- Tier 3: Low emphasis area

Bicycle:
- Tier 1: Class IV, Class II Enhanced, Class III Enhanced
- Tier 2: Class II
- Tier 3: Class III

Automobile:
- Tier 1: Throughway
- Tier 2: County connector
- Tier 3: Community connector
- Tier 4: Neighborhood connector

Goods Movement:
- Tier 1: Tier 2 routes from Alameda CTC’s Countywide Goods Movement Plan
- Tier 2: Tier 3 routes from Alameda CTC’s Countywide Goods Movement Plan
The process of determining modal priorities differs by the aforementioned typology area type (urban, suburban, industrial). Part (a) of Table 1 contains generalized modal priorities of the three land use contexts. Part (b) of Table 1 breaks down the generalized modal priorities by applying the tiering process; this involves iterating through the first highest order facilities for each mode shown in Part (a) of Table 1, then the next highest order, and so on. Part (c) of Table 1 provides an example of this process applied to a roadway.
TABLE 1 Modal Priorities

<table>
<thead>
<tr>
<th>Land Use Context Types</th>
<th>Urban</th>
<th>Suburban</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Downtown Mixed Use</td>
<td></td>
<td>● Mixed</td>
<td></td>
</tr>
<tr>
<td>● Town Center Mixed Use</td>
<td></td>
<td>● Commercial</td>
<td></td>
</tr>
<tr>
<td>● Corridor/Neighborhood Mixed Use</td>
<td></td>
<td>● Residential</td>
<td></td>
</tr>
<tr>
<td>● Education/Public/Semi-Public</td>
<td></td>
<td>● Rural/Open Space</td>
<td></td>
</tr>
<tr>
<td>● Parks</td>
<td></td>
<td>● Other/Unknown</td>
<td></td>
</tr>
</tbody>
</table>

(a) Generalized Modal Priorities

1. Transit
2. Pedestrian
3. Bicycle
4. Auto
5. Goods Movement/Truck

(b) Specific Modal Priorities Applying the Tiering Process

1. Transit: Major Corridors
2. Pedestrian: Tier 1
3. Bicycle: Class 1, enhanced Class 2, enhanced Class 3 or Class 4
4. Auto: Throughway
5. Goods Movement: Tier 2
6. Transit: Crosstown Routes
7. Pedestrian: Tier 2
8. Bicycle: Class 2
9. Auto: County Connector
10. Pedestrian: Tier 3
11. Bicycle: Class 3
12. Transit: Local Routes
14. Auto: Community Connector
15. Auto: Neighborhood Connector

(c) Modal Priorities Identification Process for a Sample Roadway Segment

<table>
<thead>
<tr>
<th>Factor</th>
<th>Yes</th>
<th>No</th>
<th>1st Priority</th>
<th>2nd Priority</th>
<th>3rd Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is it a Major Corridor?</td>
<td>Yes</td>
<td></td>
<td>Transit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Is it a Pedestrian Tier 1?</td>
<td>Yes</td>
<td></td>
<td>Pedestrian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Is it a Bicycle Class 1, Enhanced Class 2, Enhanced Class 3 or Class 4?</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4. Is it a Throughway?</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Is it a Tier 2 Truck Route?</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Is it a Transit Crosstown Rte?</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Is it a Pedestrian Tier 2?</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Is it a Bicycle Class 2?</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Is it a County Connector?</td>
<td>Yes</td>
<td></td>
<td>Auto</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Is it a Pedestrian Tier 3?</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Is it a Bicycle Class 3?</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Is it a Transit Local Route?</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Is it a Tier 3 Truck Route?</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Is it a Neighborhood Connector?</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Needs Assessment Based on Performance Measures and Objectives

To identify improvements that would strengthen the County’s system of continuous and connected multimodal networks, the framework applies multimodal performance measures and related objectives to identify roadway segments with existing and future improvement needs. Performance objectives establish specific thresholds to which each mode is expected to function. Table 2 shows the performance measures and their respective performance objectives, and are described as follows:

- Transit travel speed: obtained from on-board GPS tracking devices, measures the average speed of buses (and shuttles) on arterial segments where service was provided in 2015. An objective that transit travel speed is at least 75 percent of the auto congested speed was identified based on recommendations by transit agencies that wanted to set a higher performance standard for themselves.

- Transit reliability: estimated by comparing peak hour transit travel speed to non-peak hour speed, assesses the predictability of buses given the influence of congestion. An objective that transit reliability should be greater than a PM peak hour-to-non-peak hour transit speed ratio of 0.7 was identified based on recommendations by transit agencies that wanted to set a higher performance standard for themselves.

- Transit infrastructure index: rates bus stops as low, medium or high on an arterial segment according to design and amenities, such as presence of bus bulbouts, bus stop length, far or near side stop location, sidewalk width, and presence of wayfinding information. An objective to achieve a medium or high rating was identified based on a similar objective applied in previous planning studies completed in Alameda County (19).

- Pedestrian comfort index: rates roadway segments as low, medium, high, or excellent based on sidewalk presence and width; presence of a buffer between sidewalk and roadway; roadway classification, number of lanes, speed limit and traffic level; and distance between crosswalks. An objective to achieve a high or excellent rating along high pedestrian priority segments was identified based on a similar objective applied in previous planning studies completed in Alameda County (19); similarly the objective to achieve a medium, high, or excellent rating for pedestrian comfort index was also identified for high transit priority segments.

- Bicycle comfort index: based on the concept of Level of Traffic Stress (LTS) that a bicyclist experiences on a road. It classifies roadway segments into one of four levels (LTS1-LTS4) ranging from an excellent rating (LTS 1) meaning most children would feel safe biking on the road to a low rating (LTS4) where a road would only be tolerated by the most experienced bikers. LTS, developed by Mineta Transportation Institute researchers, is based on the number of travel lanes, traffic speed, presence and width of bike lanes, and the presence of physical barrier between a bike facility and travel lanes (20). An objective to achieve a high” or excellent rating was identified based on a similar objective applied in previous planning studies completed in Alameda County (19).

- Auto congested speed: obtained from third party traffic data vendor, local jurisdictions or Alameda countywide travel demand model, is proportional to the quality of drivers’ experience on the roadway. An objective that PM peak period auto congested speed is at least 40 percent of the posted speed limit was identified based on the LOS D threshold set in the HCM 2000 arterial LOS methodology (21).

- Auto reliability: PM peak hour volume/capacity ratio, where volumes are from jurisdictions or the countywide model, indicate if a segment operates below, at or above its capacity. An objective that PM peak hour volume-to-capacity ratio is less than 0.8, corresponding to a reliable rating, was identified based on the LOS D threshold set in the HCM 1994 arterial LOS methodology (22).

- Truck route accommodation index: based on the curb travel lane width to accommodate truck travel. Twelve feet or greater equals a high, between 11 and 12 feet equals a medium and less than 11 feet equals a low rating. An objective that the curb lane width have high rating, was identified to minimize the probability that trucks will off-track into adjacent lane or shoulder.
### TABLE 2 Performance Measures and Objectives

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Autos</th>
<th>Transit</th>
<th>Pedestrian</th>
<th>Bicycle</th>
<th>Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit Travel Speed</td>
<td></td>
<td>Greater than 75% of the Auto Congested Speed</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Transit Reliability</td>
<td>*</td>
<td>Greater than 0.7(PM peak hour-to-non-peak hour transit speed ratio)</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Transit Infrastructure Index</td>
<td>*</td>
<td>Medium or High</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Pedestrian Comfort Index</td>
<td>*</td>
<td>Medium, High or Excellent</td>
<td>High or Excellent</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Bicycle Comfort Index</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>High or Excellent</td>
<td>*</td>
</tr>
<tr>
<td>Auto Congested Speed (volume-capacity ratio less than 0.8)</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auto Reliability</td>
<td>Reliable (volume-capacity ratio less than 0.8)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Truck Route Accommodation Index</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>High</td>
</tr>
</tbody>
</table>

Notes: The asterisk (*) indicates that a performance objective is not applicable for that specific modal priority.

To assess whether a roadway segment has existing or future needs, the framework assessed whether it met performance objectives for the top modal priorities in the existing (2015) and future (2040) conditions. The project team used the Alameda County Travel Demand Model to simulate expected growth in population and jobs to project travel demand growth, traffic volumes, and speeds to derive modal performances in existing and future conditions.

### Improvements Identification

The project team followed four steps to identify improvements on segments that are not meeting the performance objectives of their highest modal priorities. While the needs of all modes are typically considered when improving a given roadway segment; due to the scope of this countywide effort, the framework focuses on continuous and connected networks for the highest two priority modes.

**Step 1 Determine available right-of-way**

Using aerial imageries, the project team estimated available right-of-way on the arterials. This information was input into the project’s GIS tool to estimate the portion of roadway that could be repurposed to better accommodate the priority modes assuming the following NACTO minimums (5):
• 10’ travel lanes (11’ curb lanes for bus and truck routes in all jurisdictions)
• 10’ median (where provided)
• 7’ parking lanes (where provided)
• 5’ bike lanes (where provided)

Step 2 Identify Potential Improvements
For roadway segments where the priority modes’ performance objectives were not being met or not forecasted to be met in the future and where Step 1 revealed available right-of-way, the GIS tool identified potential improvements within the available right-of-way that would allow these segments to best meet the top priority modes’ performance objectives. The tool was able to suggest improvements per roadway segment with available width; however, the tool did not have the professional judgment required to iterate to, where possible, arrive at the set of improvements that provide the highest possible tier facilities of the top priority modes. Where there was no available right-of-way, other improvements that did not require right-of-way were considered, such as optimizing bus stop locations and spacing, implementing ITS improvements, and adding corner bulbs and high-visibility crosswalks for pedestrians.

Step 3 Network Connectivity Checks
The MAP identified additional improvements for lower priority modes along segments with available right-of-way to develop a complete and connected network for each mode:

• Transit: Jurisdictions proposed improvements along high priority transit segments beyond those that the transit agencies recommended for the transit Major Corridors.
• Pedestrians: Improvements were proposed to enhance pedestrian connectivity to transit around major transit hubs and along transit Major Corridors with proposed transit-only lane improvements.
• Bicycles: Improvements were identified along lower priority bicycle segments that are key to building a countywide bicycle network. The network connectivity checks also included a review of Class 1 multiuse trails and Class 3 Enhanced (Bike Boulevard) bikeways that parallel arterial network segments.
• Autos: Intelligent Transportation System (ITS) improvements were identified along segments with: 1. low auto priority but are key segments to managing traffic demand along arterial network corridors and 2. high transit priority that may have low auto priority.
• Goods Movement: Curb lane widenings were proposed along the goods movement arterial network.

Step 4 Review Proposed Improvements with Local Jurisdictions
The project team presented these improvements to local agency staff to consider them in light of local conditions and their communities’ unique issues. Through a series of meetings, these local experts reviewed the framework’s process and outcomes, and directed appropriate changes to improvements recommended by the technical process.

APPLICATIONS AND RESULTS
The project team applied the framework to recommend countywide multimodal improvements. As an example, Figure 3 walks through how transit improvements were identified for 2040 conditions:

(a) Performance Measures
The project team evaluated the County’s arterials for the three transit performance measures in 2040 – transit speed, reliability, and infrastructure index.

(b) Needs Assessment
The team identified roadway segments that had transit as one of the top two modal priorities, and identified these transit priority segments that met the objectives for the three transit performance measures in 2040. These segments are shown in green in part (b) of Figure 2 and consists of:
• 21 miles out of 150 miles meeting transit speed objective
• 56 miles out of 150 miles meeting transit reliability objective
• 27 miles out of 150 miles meeting transit infrastructure index objective

(c) Recommended Improvements
To address the needs of segments not meeting the objectives, the team identified the following improvements using the previously described four-step process:

• 39 miles of enhanced bus improvements such as bus stop consolidation, traffic signal optimization, far-side stop relocation, and minimum 80 feet of red curb at bus stops
• 82 miles of rapid bus improvements which includes the enhanced bus improvements and transit signal priority, queue jump lanes or queue bypass lanes
• 21 miles of dedicated transit lanes which include rapid bus improvements with level boarding platform, dedicated on-street transit only lanes, and supportive pedestrian enhancements

(d) Performance Measures with Recommended Improvements
The team quantified each segment’s expected benefits from the proposed improvements based on meeting the three performance objectives. These segments that meet the objectives after recommended improvements are shown in green in part (d) of Figure 2 and consists of:

• 45 miles out of 150 miles meeting transit speed objective
• 112 miles out of 150 miles meeting transit reliability objective
• 127 miles out of 150 miles meeting transit infrastructure index objective

This framework was replicated across all modes to develop a comprehensive set of multimodal improvements countywide. Figure 3 shows the recommended improvements (in green) for transit along with the baseline (existing or planned) facilities; together, these improvements and baseline facilities complete Alameda County’s continuous and connected transit network. Table 2 shows the miles of arterial segments meeting multimodal performance objectives with and without MAP’s proposed improvements.

In developing the continuous and connected network, equity measure was also considered as a metric to assess the share of improvements proposed in the MTC-defined Communities of Concerns. The framework identified improvements on 367 miles of arterial segments, of which 158 miles (43 percent) are within Communities of Concern. This is proportionally higher than the miles of arterial network within Communities of Concern (38 percent or 194 miles out of 510 miles).
FIGURE 2  Framework Application – Transit Network.
FIGURE 3 Recommended Countywide Transit Network Improvements.

TABLE 2 2040 Performance Objective Evaluation – With vs Without Proposed Improvements

<table>
<thead>
<tr>
<th>Performance Measures</th>
<th>Segment Miles That Meet Performance Objective Along High Modal Priority Arterial Network Segments - 2040 Conditions¹</th>
<th>Without Proposed Improvements (miles)</th>
<th>With Proposed Improvements (miles)</th>
<th>Net Difference (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit Travel Speed</td>
<td></td>
<td>21</td>
<td>45</td>
<td>+24</td>
</tr>
<tr>
<td>Transit Reliability</td>
<td></td>
<td>56</td>
<td>112</td>
<td>+56</td>
</tr>
<tr>
<td>Transit Infrastructure Index</td>
<td></td>
<td>27</td>
<td>127</td>
<td>+100</td>
</tr>
<tr>
<td>Pedestrian Comfort Index</td>
<td></td>
<td>133</td>
<td>188</td>
<td>+55</td>
</tr>
<tr>
<td>Bicycle Comfort Index</td>
<td></td>
<td>35</td>
<td>146</td>
<td>+111</td>
</tr>
<tr>
<td>Automobile Congested Speed</td>
<td></td>
<td>210</td>
<td>N/A²</td>
<td>N/A²</td>
</tr>
<tr>
<td>Automobile Reliability</td>
<td></td>
<td>138</td>
<td>N/A²</td>
<td>N/A²</td>
</tr>
<tr>
<td>Truck Route Accommodation Index</td>
<td></td>
<td>83</td>
<td>105</td>
<td>+22</td>
</tr>
</tbody>
</table>

Notes:
1. A mode is considered high priority if the mode is categorized in the top two prioritized mode along an Arterial Network segment. A total of 150 Arterial Network miles have high transit priority, 207 Arterial Network miles have high pedestrian priority, 268 Arterial Network miles have high bicycle priority, 250 Arterial Network miles have high automobile priority and 135 Arterial Network miles have high goods movement priority.
2. There is not enough readily-available research or data to quantify the improvements to automobile speed or reliability associated with ITS improvements.
CONCLUSIONS

The key elements of the MAP technical analysis were typologies leading to modal prioritization; adoption of a broad set of multimodal performance measures; development of performance objectives that can maintain an acceptable performance level for the highest priority modes; performing needs assessment of the arterials not meeting their performance objectives; and a robust GIS tool to automate this analysis and derive recommended improvements. Though much of this process was automated, due to the arterial network’s scale, development of continuous and connected networks, the most important outcome of this effort, required significant institutional coordination and professional judgment.

While the MAP employed a highly advanced set of methods and analysis tools, the scale of the analysis could not reflect all localized or micro level conditions. Alameda CTC employed an unprecedented level of collaboration with the 14 Alameda County cities, Alameda County, transit agencies, Caltrans, MTC, and non-agency stakeholders representing modal and issue interests. The input received through this process shaped the plan.

An important element of the project’s vision was to respect local values. The analytics developed for the MAP automated a technical process and the outcomes were adjusted based on over 1,000 comments as local inputs. This results in a set of recommendations that accomplishes two things – supporting local priorities and providing continuous and connected modal networks across jurisdictional boundaries.

With adoption of the MAP, the Alameda County Transportation Commission is proceeding with the development of multijurisdictional corridor plans. The highest priority corridors are those where improvement recommendations have the greatest potential to increase non-auto mode shares.

There were a number of challenges during the preparation of the MAP. The most substantial challenge was applying new methods and processes on over 1,200 miles of arterials to understand the basic characteristics; evaluating 510 miles of arterials of countywide significance; coordination with stakeholders; and application of innovative multimodal performance measures. Though not a feature of this paper, the Plan also included evaluation of future year scenarios considering demographic changes resulting in reduced VMT per capita and connected and autonomous vehicles; programmatic analysis and recommendations related to transportation demand management (TDM) and parking practices; and next generation traffic signals and control systems.

The important lessons learned from developing the MAP were:

- Use of current modal improvements as a basis for designating future modal priorities is limiting.
  This was most evidenced in the development of the bikeway network where arterials with current bikeways of any type received higher consideration for inclusion in the high priority bicycle network. Most of the jurisdictional bike plans and current bikeways were developed before the concept of level of traffic stress (LTS) was a consideration and before the creation of the Caltrans Class IV bikeway (separated bikeway). The MAP’s emphasis was to create a continuous and connected low stress bicycle system that tied to local and regional trail systems and bike boulevards, such as those developed in Berkeley and Emeryville. Beginning the derivation with these considerations in mind, instead of focusing on retrofitting the current streets and network, might have resulted in even better network recommendations.

- Due to the scale of the study network and coordination, and tight project schedule, the project team limited consideration of recommended improvements to the top two modal priorities for each arterial street. The team compensated for this by recommending improvements to lower priority modes when they supported another mode. For example, if dedicated transit right-of-way were recommended on a bus rapid transit route, pedestrian and other streetscape improvements were also recommended. Nonetheless, a technical process that considered all modes on all streets could have improved the multimodal nature of the recommended improvements.

As a first-of-its kind Plan, the MAP contains many elements that are transferrable to other geographies. The project team is hopeful that updates to the MAP in Alameda County will further evolve multimodal design practices and that other jurisdictions will employ and improve these practices further.
ACKNOWLEDGEMENTS
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