Caltrans TDDC | Report on Transit Technology Ecosystem

Subsection Transit Signal Priority

Thoughts, comments, and opinions.

Paul Hoekstra – 1 April 2025

Introduction

- The document's authors have identified several significant obstacles to using technology to make material improvements to Transit service levels.
    - Measurability of Transit performance and benefits of TSP solutions
    - Standardized communication protocols
    - Solution pricing, match to needs
- The approach seems to originate from surveys and evaluates current technologies and vendors.
- The report concludes that over the last 45 years (since 1980), the industry has failed to measure the benefits achieved with TSP and has not established a common language for the technology's components to communicate with each other.
- With the introduction of new technologies and service delivery, California has the opportunity to adapt the paradigm and lead the mobility/transit transformation.
- The comments on the following slides are provided from a multi-modal, citizen-centric service perspective.
- Pulling from adjacent industries and building on proven next-generation technology and approaches, tension is created to challenge the status quo.
- A remark regarding the CalTrans signal controllers. AB3418 is the communication protocol and Caltrans is currently evaluating controller software options for their traffic signals throughout the state. This could enable NTCIP without the need to replace the hardware (CPU upgrade might be required).

Planning and Operational Excellence requires predictability

Intersection Performance

Rank	ID	STREET1	STREET2	PREEMPT_PR		Mean (mph)	Median (mph)	stddev	cv
1	14864	HAYES	VAN NESS	TSP		23.95	23.59	5.58	23%
2	14820	GROVE	VAN NESS	TSP		23.93	24.13	7.25	30%
3	14797	CALIFORNIA	VAN NESS	TSP		21.82	23.02	7.44	34%
4	15349	GREENWICH	VAN NESS	TSP		20.64	20.67	3.83	19%
5	15389	TURK	VAN NESS	TSP		20.18	20.98	7.95	39%
6	14786	CLAY	VAN NESS	TSP		19.87	20.63	7.64	38%
7	15459	PINE	VAN NESS	TSP		19.76	21.29	8.28	42%
8	14863	FELL	VAN NESS	TSP		19.67	22.08	9.65	49%
9	14770	VAN NESS	WASHINGTON	TSP		19.30	21.68	8.45	44%
10	14751	FRANCISCO	VAN NESS	TSP		19.24	20.04	7.00	36%
68	14517	EXCELSIOR	MISSION	TSP		6.69	5.01	6.54	98%
69	14819	MCALLISTER	VAN NESS	TSP		6.66	2.01	7.84	118%
70	14785	SUTTER	VAN NESS	TSP		6.48	2.16	7.43	115%
71	14787	SACRAMENTO	VAN NESS	TSP		6.47	1.65	7.59	117%
72	14593	MARKET	SOUTH VAN NESS	None		6.32	1.40	7.53	119%
73	14816	EDDY	VAN NESS	None		5.84	0.99	7.30	125%
74	14749	CHESTNUT	VAN NESS	TSP		5.78	1.81	6.74	116%
75	15007	12TH ST	MISSION	None		5.45	3.05	5.79	106%
76	15388	O'FARRELL	VAN NESS	TSP		5.33	0.86	7.09	133%
77	15677	FRIDA KAHLO	CITY COLLEGE TERMINAL	None		2.58	0.86	3.77	146%

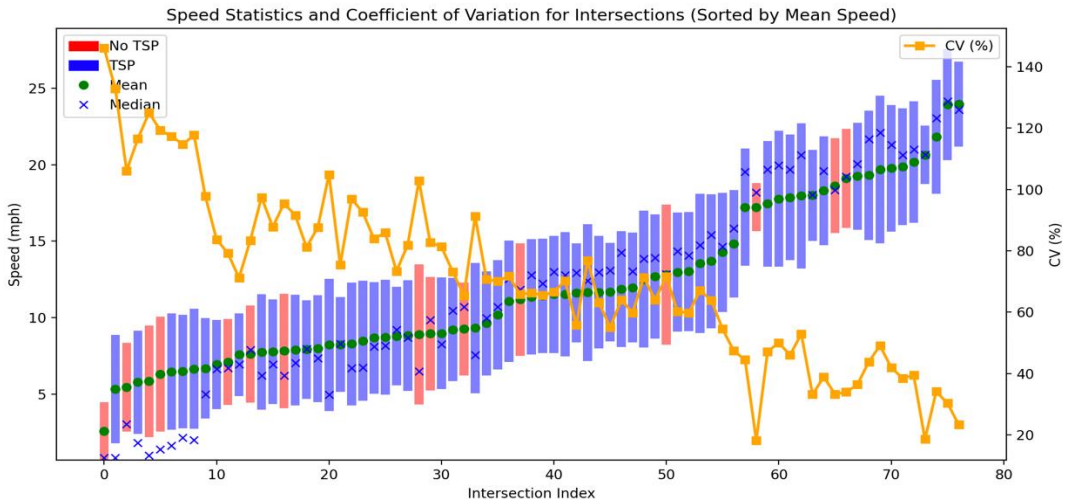
Top 10

Bottom 10

Unpredictable

The Coefficient of Variation (CV) is a statistical measure of the relative variability in a dataset. The lower the CV, the more predictable the system is, in our case the intersection. A CV > 30% is considered unpredictable.

- The intersections Route 49 traverse through are ***all unpredictable*** except for 3 (Hayes, Grove, Greenwich)
- No clear distinction between intersections with or without TSP
- Transit Planners respond to unpredictable intersection behavior by adding vehicles to the system



1. Executive Summary

Public transportation is a vital public service that many Californians depend on to get around their communities. Increasingly, technology and innovation are changing the way transit is managed, improving the delivery of services from operations to rider experience. Transit providers are interested in taking advantage of new technologies but, despite many technology companies offering services in California, face barriers to accessing and leveraging transit technologies in a modular, scalable, and competitive way. Previous work by Caltrans found that transit providers would welcome support in addressing barriers and leveraging technology to improve their service delivery.

The full report identifies five transit technologies which have the potential to improve transit services but face critical market frictions limiting their use – Automatic Passenger Counters (APCs), Charge Management Software (CMS), Computer Aided Dispatch / Automatic Vehicle Location (CAD/AVL), Non-cellular Connectivity, and Transit Signal Prioritization (TSP). While the market for each transit technology is unique, the barriers facing transit providers from using them fall into five dimensions: market existence, market competition, product interactions, access to market, and market knowledge.

This document summarizes TSP technology and the relevant recommendations to cultivate a modular, scalable, and competitive transit technology market in California. While the recommendations are interrelated and build upon each other, the priority actions are to:

- **Overall** | Define standard performance metrics and incorporate these into state-level reporting requirements and grant applications to streamline efforts.
- **TSP** | Adopt NTCIP protocol for all signals statewide, sunset proprietary data format, and investigate the need for a data standard.

This report serves as a roadmap for where and how California state agencies can direct support to help small and rural transit providers better access and implement priority transit technologies to serve riders.

"Vital public service" is to resonate through everything we do and encourages us to seek excellence

Why are the markets considered unique? We service the riders and taxpayers with mobility services of which transit is a component. The technologies are enabling. With that perspective, the boundaries fall away to allow determining investment in the components based on contribution to the total service delivery

Yes, but without full-service perspective, part of the transformation we're seeking (service contains process, roles&responsibilities (people), technologies, managerial aspects

Technical detail. Communication protocol is low-level and should be developed once, deployed everywhere.
Multi-mode, dynamic algorithms should become the competitive differentiators for vendors

SMART CITY MOBILITY COUNCIL

What is TSP?

Transit Signal Prioritization (TSP) allows transit vehicles to be given priority or preemption over regular traffic by changing the signals to facilitate the transit vehicle's journey. A priority request is where the signal phase is extended or shortened to speed up the vehicle journey time. Priority requests can be granted or denied; it is not always a "given" response. Priority is the most common TSP request by transit vehicles. A preemption request is a more forceful override that is immediately granted and is mostly used for emergency vehicles, such as ambulances. The focus of this section is on priority-based TSP software.

Fundamentally, TSP attempts to influence the duration of the green time – control remains at the intersection.
Taking control, with the data available, the green time can be allocated to move other vehicles, hold pedestrians, and provide green to transit. Not as a request, but as an order. When volume exceeds capacity, the system is to limit inflow and increase outflow dynamically for the transit vehicle to traverse through the network

TSP system architecture includes a detector, priority request server (PRS), and a signal controller. The detector identifies when a vehicle wants priority and estimates the arrival time. The PRS coordinates these priority requests, checks them against the business rules, and determines any signal phase changes to be implemented. The signal controller physically changes the lights based on the updated timing plan provided by the PRS.

Single mode optimization with partial data. No/limited awareness of other objects or dwell time. It remains a request to the controller.

Broadly speaking, these components can be used to deploy the two main types of TSP priority systems, which differ in how requests are processed: distributed or centralized. In a distributed system, the communication is vehicle to infrastructure (V2I). Decisions are made at the intersection level and TSP requests are made by the vehicle as it approaches the intersection. This tends to be a "simpler" TSP deployment as it is not managing other data inputs. In a centralized system, the communication is center to center (C2C). Decisions are managed in a centralized system with multiple intersection visibility and, as such, can consider bigger picture implications of the request (i.e., impact on other intersections, overall system schedule adherence).

I consider Center to Center where the object is handed over between e.g., cities when the transit vehicle crosses jurisdictional boundaries

Why settle for multiple intersections, given it is software-based, it should be all, including control over inflow from side streets

rule parameters. Passive priority may be a better option for areas with a high frequency of transit vehicles as the volume of requests could potentially be disruptive. Active priority systems may be better suited to more complex environments that require additional control and situation-based decision making or more rural routes with limited traffic flow.

"disruptive" is spoken from a car-centric perspective

MOBILITY

A third option is to use infrastructure-based multi-mode sensors and floating car data

The business rules also must define how to handle conflicting requests. The majority of existing deployments use a "first come first serve" approach, but there are other ways to prioritize. Examples include basing prioritization of conflicting requests on magnitude of schedule deviation (greatest deviation gets priority), corridor type (major road vs. side road, local vs. express), level of crowdedness (more passengers get higher priority).

Business rules are to incorporate multi-modal prioritization, events, construction, policies

Market Competition | There are several active and quality vendors in the market, but there is limited pricing transparency.

Contracts are in the public domain. Solutions can be scored against a standardized set of needs agencies seek to meet. Pricing information should reflect the level and completeness of meeting the agency's needs. The market is to be transparent, and vendors are to compete on the ability to improve service, ease of deployment and operation, and cost

TSP vendors appear to price per intersection, as opposed to per vehicle. This means that the price is agnostic to the number of requests made or the number of vehicles involved in the deployment. Cloud-based technology vendors are opting for a paid-up-front subscription based on a "as a service" (SaaS) model, with flexible payment terms (i.e., buy one year up front, five years up front, etc.). Vendors interviewed as a part of this research recognized that transit providers are often dependent on grants to implement TSP and that those grants vary in how they can be used (ex., operating expenditure vs. capital expenditure); vendors indicated a general willingness to work to create a payment schedule that is mutually beneficial.

Dutch vendors price on instance for licensing/maintenance/support, regardless of number of intersections and vehicles. Professional Services for implementation is proportional to intersections. "Mutually beneficial" suggests finding ways to make it work… This needs further structural work to align funding towards maximizing benefit realization and establishing self-sustaining programs

Hardware-based deployments require some amount of upfront investment to purchase the hardware itself. This hardware often must exist on each vehicle, making this the main exception to the intersection driven cost model, but then also allows the project to be deemed a capital expenditure. There may be intersection hardware costs regardless of deployment type if the signals are not yet "smart."

Leveraging a mobile app eliminates the need for hardware in vehicles.
With signal controllers connected to an IT network, there is no need for additional HW in cabinet. **ASSUMPTION: ability to send calls/omits/force-offs to signal controller – RISK: only communication with AB3418**

Important to note is that one element of the cost uncertainty is the integration costs from adjacent vendors. These costs are not charged by the TSP vendor themselves. Rather, it is a required integration with a third-party vendor to receive the data required for TSP to operate (ex., a five second or less polling rate of location data). Some of these costs can be mitigated by implementing an open data and standardized transit technology stack; however, any integration work from a third-party vendor will likely come with a time and materials cost.

California has the influence to set standards and governance to adopt open standards. The limited number of integrations (as mentioned CAD/AVL, data feeds, etc.) and existing standards are to remove this large cost vendors are allowed to charge.

Moreover, Caltrans uses its own state specific format that de facto functions as a proprietary system; this format is not compatible with NTCIP without additional integration work. This creates significant hurdles for vendors looking to deploy TSP across multiple jurisdictions; if any Caltrans signals are involved, there is immediately additional work needed for the TSP product to work. The cost for this work is often passed off to transit providers, who must pay for the custom integration.Recommendations / Interventions

Same remark: develop once, deploy often

3. Recommendations / Interventions

The following section presents recommendations for potential interventions which Caltrans, alongside other California state agencies, could implement to mitigate or minimize the market failures identified. Some of the recommendations are technology agnostic (Section 3.1) and others are specifically targeted to an individual technology. These recommendations are often interrelated, and these solutions should be implemented holistically. Without them, the transit providers will continue to face critical challenges related to vendor lock-in, reduced interoperability, and limited access to certain transit technologies which will hinder California's ability to deliver efficient and effective transit service statewide.

Spot on.

Holistic should include more than outlined

3.1 Overall / Technology Agnostic

Define standard performance metrics and incorporate these into state-level reporting requirements and grant applications to streamline efforts.

Performance metrics are a key tool for transit providers to use in evaluating the benefit generated by transit technology. However, some technologies do not have standard way to measure success, leaving transit providers to either come up with a methodology on their own or to not measure benefits at all. Other times, different vendors will use different formulas to achieve the same metric. This lack of standardization means that transit providers are left comparing apples to oranges that can make benchmarking difficult.

I rest my case – the Transit Opportunity Index is designed and proven to identify where transportation agencies don't provide transit agencies with sufficient flow services. The Index makes the apples comparable with apples

Finally, Caltrans would benefit by standardizing performance metrics, because it would streamline reporting requirements. Requirements – for annual reports and for grant applications – can be directly pulled from the published standard performance metrics. For transit providers using the standardized performance metrics, their data outputs would be ready to use for these submissions without any additional manipulation.

After one-time model configuration, the TOI can be updated as often as desired as the dynamic data is AVL and APC.
Publishing can be done through websites, reports, or any other form

3.2 Transit Signal Prioritization

Adopt NTCIP protocol for all signals statewide, sunset proprietary data format, and investigate the need for a data standard.

Note our opportunity here: Europe has built infrastructure to deliver high transit levels. This is cost-prohibited to do in California. However, the dynamic multi-mode traffic flow optimization solution can NOT work in Europe due to closed signal controllers. NTCIP gives us the opportunity to surpass Europe – near effortless changing relative priority by mode by approach, complete route pre-emption for emergency vehicles, HW-less delivery robot throughout city, mobile app to extend crossing time for people in wheelchairs, truck routes, etc. etc.

Provide guidance on when to use TSP.

Transit providers need guidance on when to consider TSP. Not all providers will benefit from TSP, and for the ones that do, not all of the intersections their vehicles pass through need to be equipped with TSP to derive benefits. For example, TSP typically provides greater benefits to intersections with far side stops, as opposed to those with near side stops, as it allows the vehicle to clear the intersection prior to passengers boarding or alighting. Near side stops do not receive the same benefit from TSP as delays in passenger boarding and alighting could cause the vehicle to miss the requested TSP phase. Transit providers with near side stops looking to improve headways may see greater benefits from all door boarding, for example, as opposed to TSP.

A comprehensive end-to-end life cycle is to include this and the following sections in the remainder of the document

Transit providers need a neutral third party – Caltrans – to help issue guidance on when TSP should be considered and how to work with local communities to streamline planning and implementation. This guidance should go beyond TSP to provide potential alternative solutions (such as all door boarding) that may be a better fit if the intersection / route / corridor is not a prime TSP candidate. Caltrans is in an excellent position to provide this type of technical advice and help transit providers focus their resources on choosing solutions which will have meaningful impact on congestion and operational reliability.

Caltrans has the opportunity to lead.

A Center of Excellence would be appropriate given the large portion of the >$7B spent annually on Transit OpEx with over 30% waste.


SMART CITY
MOBILITY
COUNCIL