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**Research Connection:**

# **PATH Research on Integrated Multimodal Mobility**

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California PATH  
University of California**

**May 27, 2010**



# Outline

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- The role of transit
- Opportunities for making transit as an integrated transportation solution
- PATH research – addressing the needs
- Future research areas

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# The Role of Transit

# Highway vs. Rapid Transit in the Bay Area

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	24ERock	24WRock	80EUniv	80WUni	880NFru	880SFru	101NSFO	101SSFO
Vehicle volume per direction	78,531	72,633	38,541	36,277	101,738	104,582	125,304	105,291
Total vehicle volume	151,164		74,818		206,320		230,595	
BART Riders	76,797		52,103		110,298		113,895	
Caltrain Riders							36,778	
Total travelers	227,961		126,921		316,618		381,268	
Transit riders/total travelers	34%		41%		35%		40%	

- Riders on rapid transit accounts for 20%\*\* to 40% travelers along corridors where BART and Caltrain operate
- \*\* Taking into consideration of some cars are shared by more than one traveler

# The Role of Transit \*

	Los Angeles	SF Bay Area	San Diego	San Jose	Riverside
Delays due to traffic congestion (hr)	485,000,000	129,000,000	85,000,000	55,000,000	48,000,000
Fuel waste (gallon)	367,000,000	94,000,000	65,000,000	35,000,000	38,000,000
Costing the region for lost time and productivity (\$)	10,000,000,000	2,600,000,000	1,700,000,000	1,000,000,000	1,000,000,000
Transit preventing additional delays (hr)	30,000,000	26,000,000	8,900,000	2,600,000	21,000,000
Savings by transit service (\$)	578,000,000	487,000,000	164,000,000	46,000,000	40,000,000

\*A study conducted by TTI

# Transit...

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...has become increasingly viable for travelers as a result of last year's gas price hike

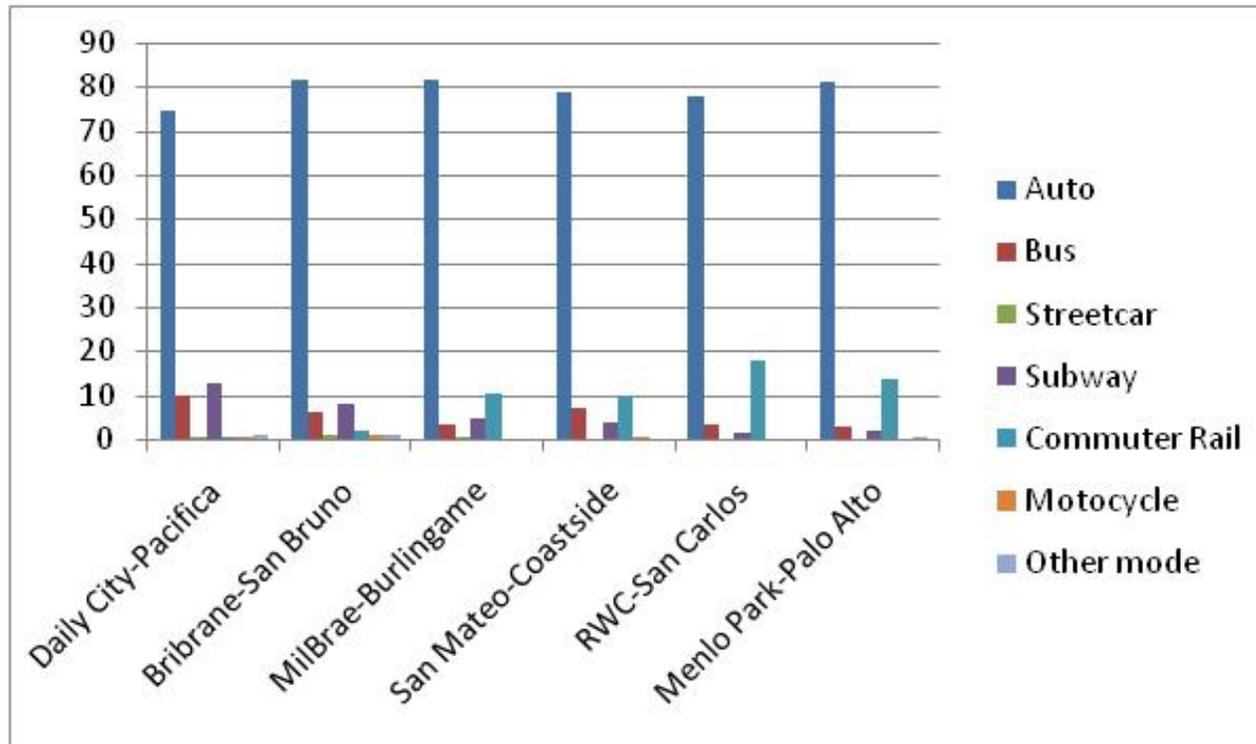
- ❑ APTA reported a 4.36 percent ridership increase in 2008 compared with 2007
  - ❑ The ridership increase for light rail transit is about 12%
  - ❑ Although transit users only account for 1% of total travelers nationwide, travelers using **Rapid Transit** accounts for much higher % of total trips in metropolitan regions

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# Opportunities for Making Transit As an Integrated Transportation Solution

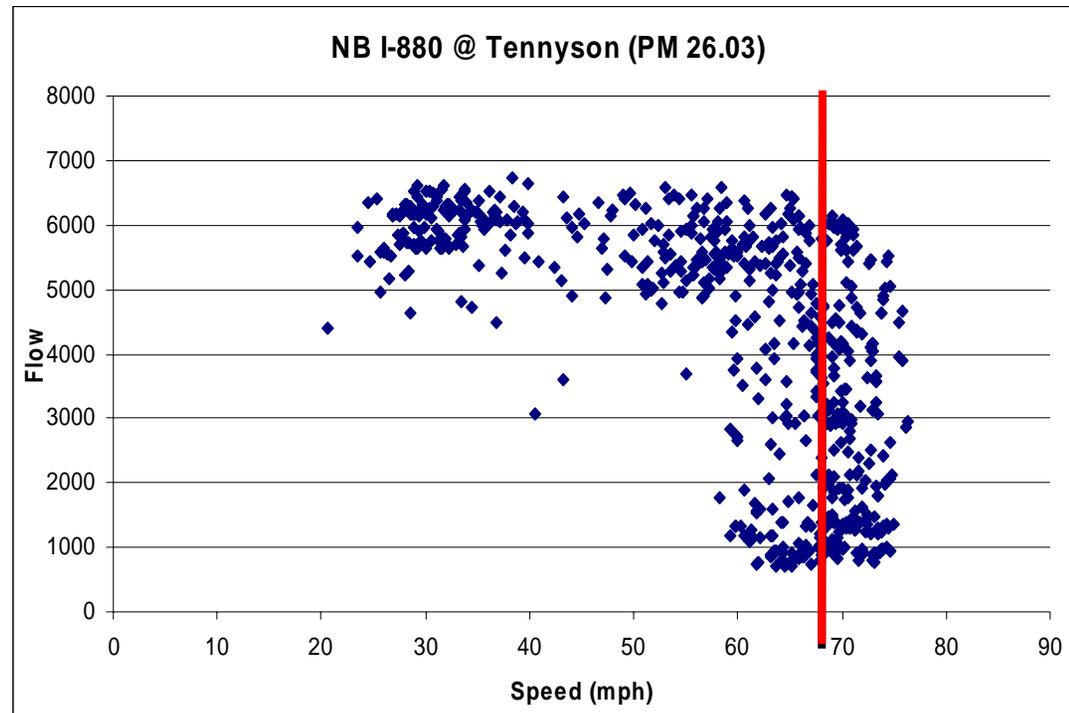
# Potential for Mode Shift

- Census data shows 80% of travelers use cars...

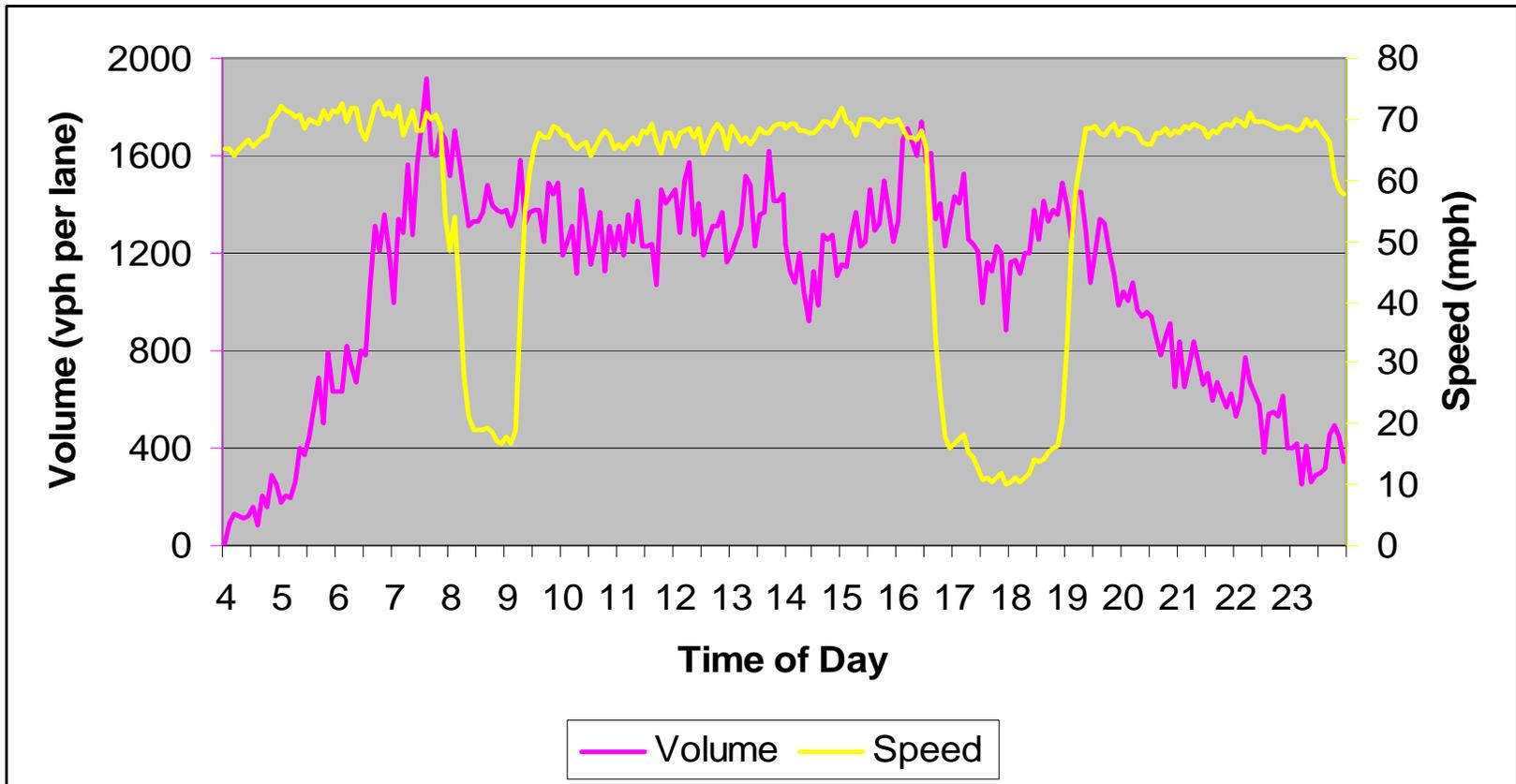


# Issues: Larger Picture

- ❑ Recurring congestions occurs when demand exceeds capacity
- ❑ Reducing demand will reduce congestions
  - ❑ More than 70 percent of VMT is from single occupant vehicles
  - ❑ Encouraging travelers to use transit or to travel off- peak can reduce demand

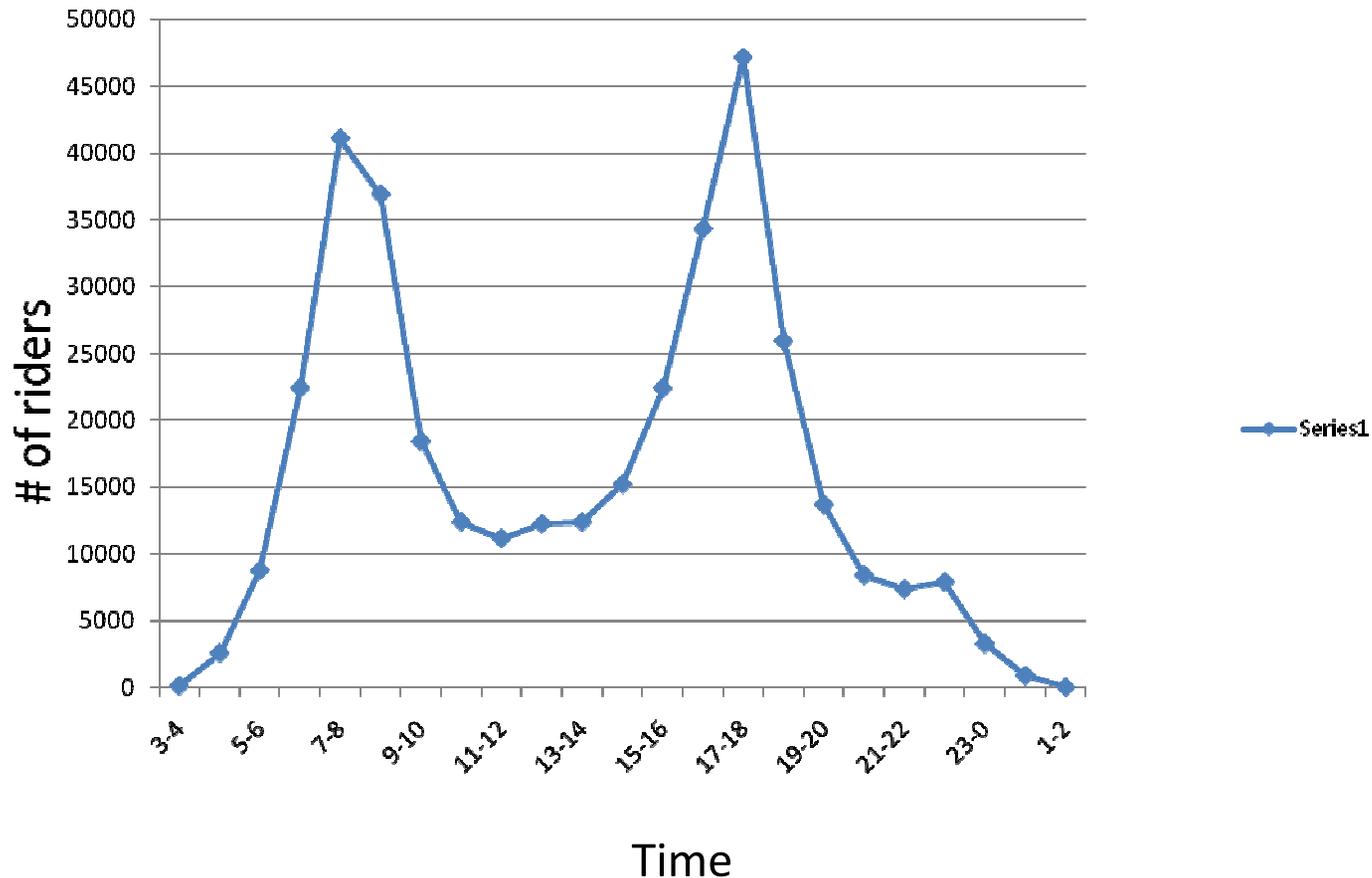


# Highway Capacity and Performance



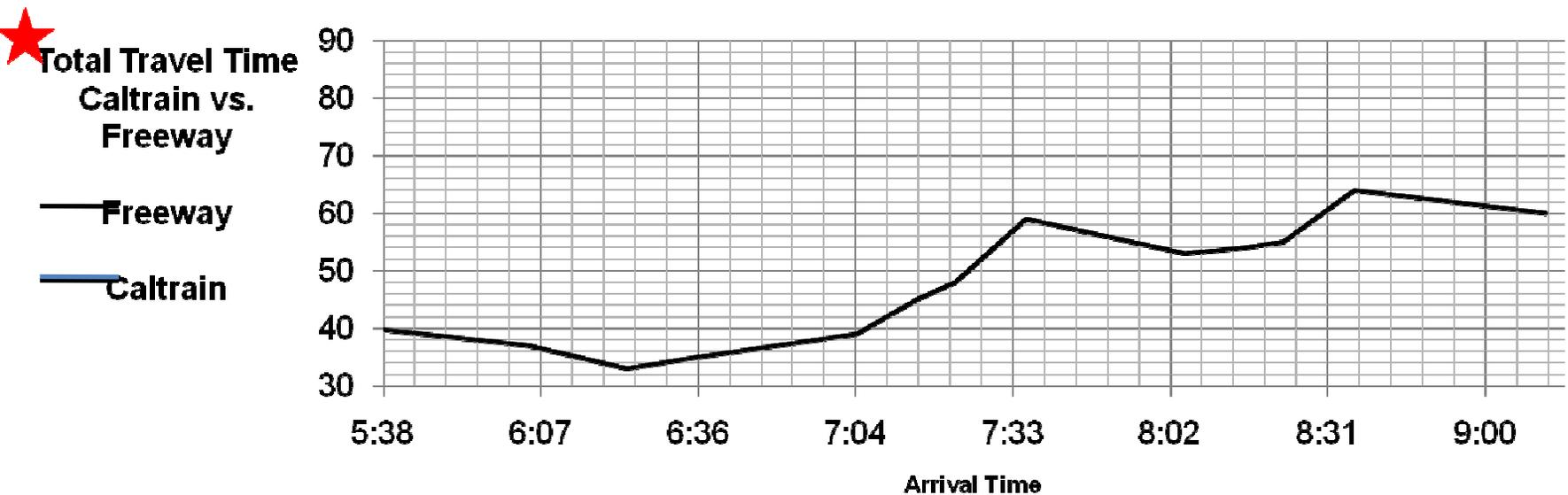
# BART Ridership Distribution

- Transit still has excessive capacity during peak hours



# Travel Times via Freeway vs. Caltrain: Palo Alto Station

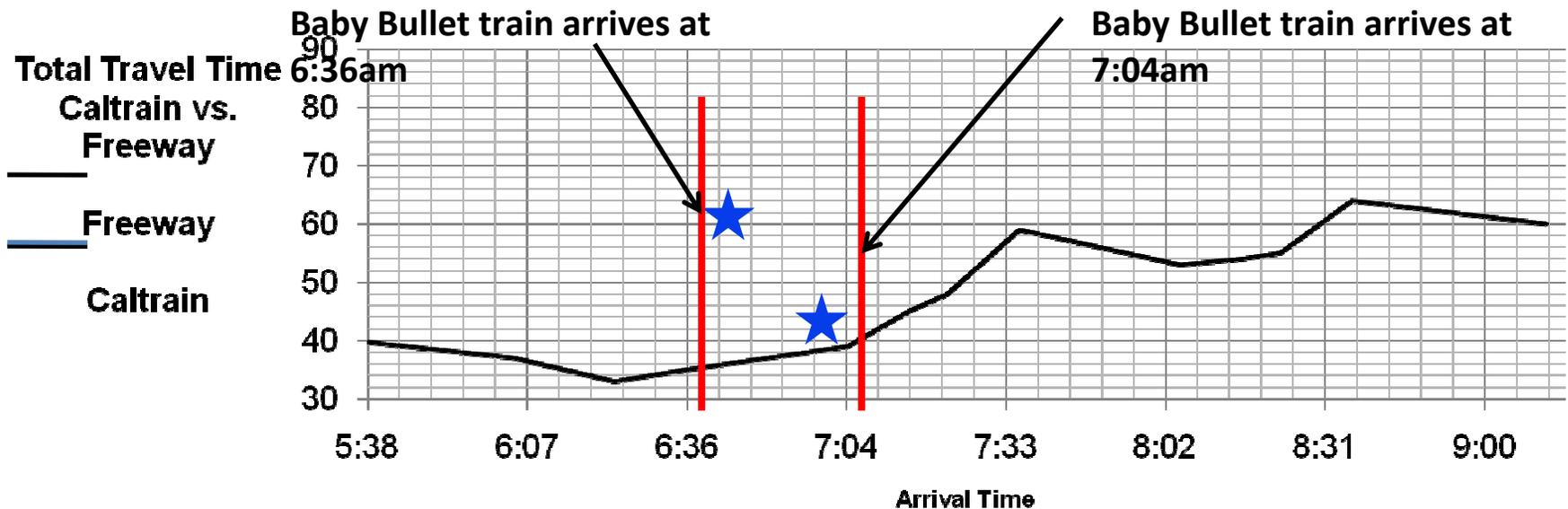
- Comparison of total transit travel time to freeway driving
  - Total Transit Travel Time: Time of **driving to train station, waiting for the train** and the **train travel time**



**Scenario 1:** Assume Parking Spaces Available at Palo Alto

# Travel Times via Freeway vs. Caltrain: Palo Alto Station

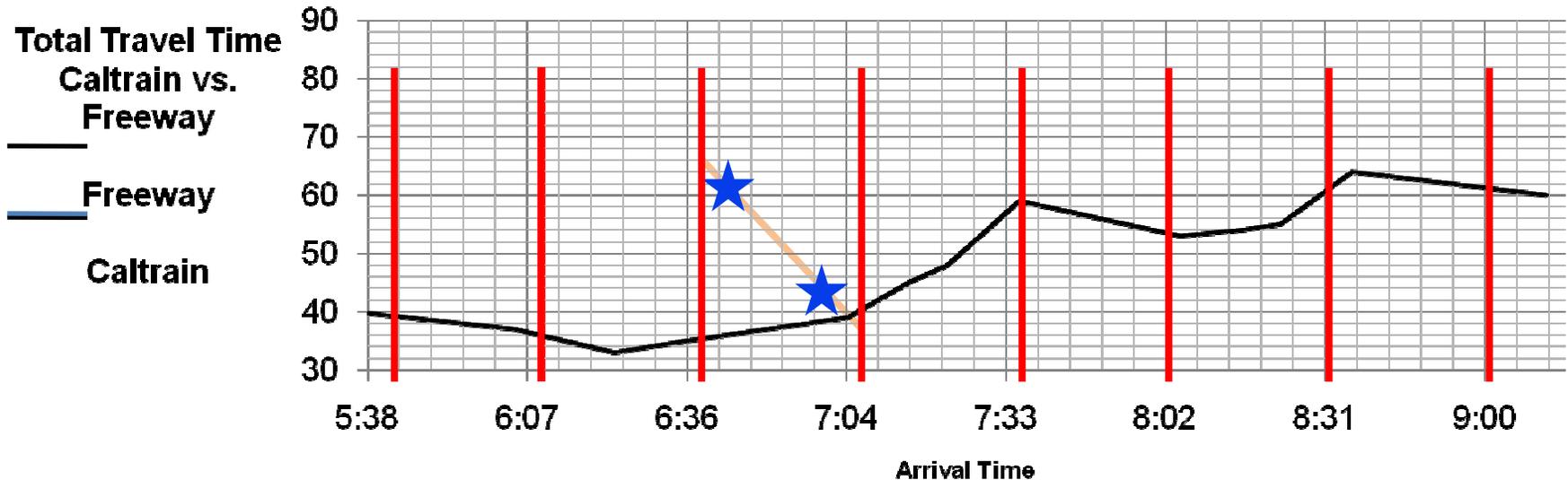
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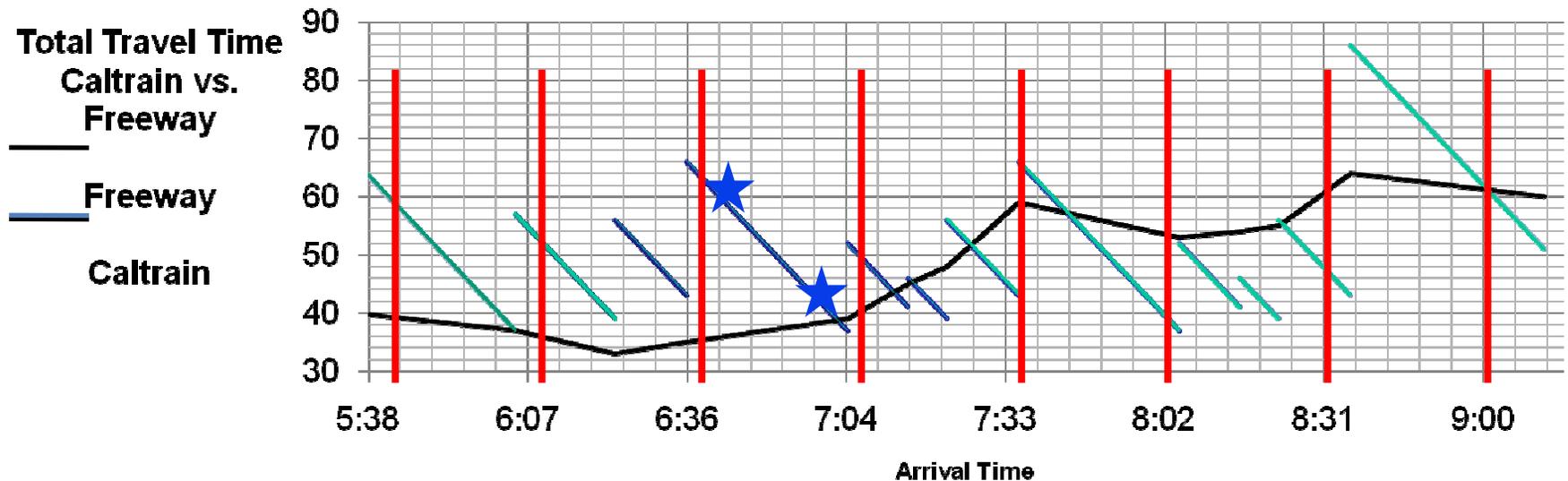
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**Scenario 1:** Assume Parking Spaces Available at Palo Alto

# The Viability Argument

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- ❑ Trips along corridors where rapid transit is available, travel time using transit can be competitive
- ❑ Observation: Travelers who have changed to transit stay with transit
- ❑ Why transit not attractive to larger percentage of travelers?
  - Travel time: Travel from/to O &Ds far from rapid transit stations takes too long
  - Perceived transit disadvantage: Travelers tend to think transit is slow and parking lots are full
  - Travelers generally do not know their travel alternatives

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# PATH Research

## – Addressing the Needs

# Needs for Improvements

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- Longer travel time with transit
  - Slow travel speed
  - Longer and viable dwelling time
  - Intersection delays
- Connectivity difficulties for many
  - Lack of effective means for first/last mile
  - Lack of connection info
- Usability
  - Lack of real-time information
- Cost effectiveness
  - Independently procurement
  - lack of integration
- Transit has not been considered as an integrated portion of the congestion relief tool

# PATH Related Research

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- PATH research to address the issues
  - Faster transit services
    - BRT planning and decision support tools
    - VAA for improve BRT performance and cost effectiveness
    - Grade crossing for rail improvements
    - Transit signal priority for reducing bus travel time
  - Better connectivity
    - Dynamic transit service
  - Making transit easy to use
    - Real-time information Safetrip/DPI
    - EDAPTS – for rural transit information and management
  - Integrated multimodal transportation system
    - Integrated Corridor Management
    - Transit real-time information as as demand management tool
  - Cost effectiveness
    - To be addressed through integrated deployment of transit systems
  - Incentivized travelers' behavior change
    - Area yet to be explored

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# Electronic Guidance for High Quality BRT

UC Berkeley and UC Riverside Team

AC Transit

Lane Transit

Caltrans

FTA

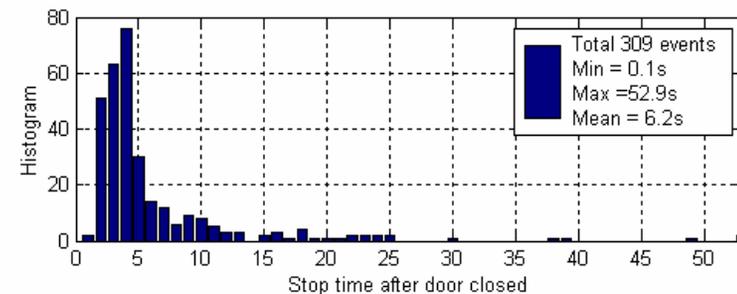
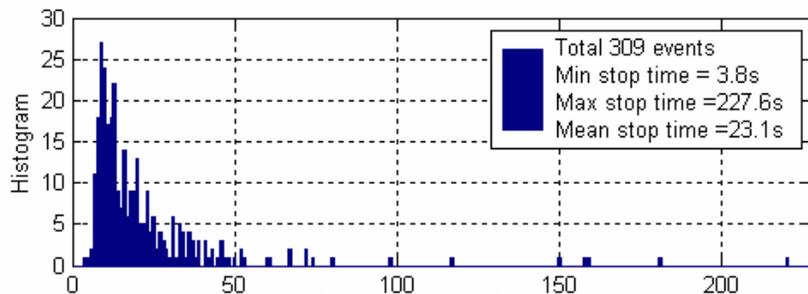
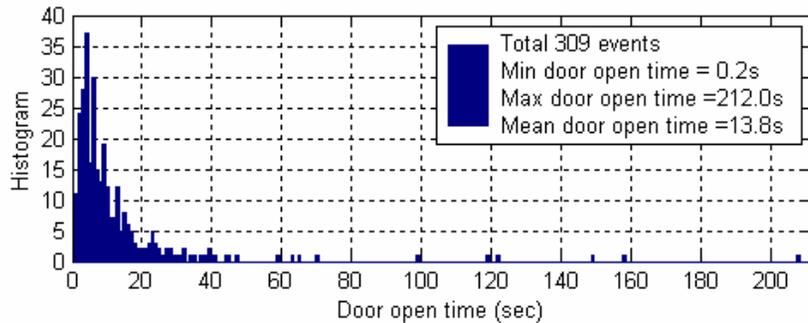
Private Partners

# Why VAA?

- Problems and Challenges
  - Right-of-way purchase costs are high and increasing
  - Transit agencies seek safe and cost-effective transit systems
  - Transit customers demand high-quality transit service
- Potential Benefits
  - Reduced right-of-way requirements and infrastructure costs (potential go-no-go decision)
  - Reduced accidents
  - Reduced operating and maintenance costs
  - Smoother ride and level boarding for faster travel and reduced dwell time
  - “Rail-like” status
    - More attractive to choice riders
    - Encourage transit oriented development



# Benefit of Precision Docking



## Observation

- Per bus stop operation between 3.8 s to 3m47s, with large variance
- Wheelchair deployment significantly increasing total station operation time (up to 4 minutes)

# VAA Program Scope

- LTD, Eugene Oregon
  - Lane guidance for on dedicated BRT lane
  - Precision docking
- AC Transit
  - Lane guidance on HOV lane
  - Guidance through toll bridge
- Full range of VAA applications for BRT
  - Highway and urban BRT application
  - Precision docking and guidance
  - Very low to highway speed (65 mph)
  - Degrees of driver assist



# VAA Demonstration

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- Project Team
  - Federal Transit Administration
  - Caltrans
  - AC Transit
  - Lane Transit District
  - Partners for Advanced Transit and Highways (PATH)
  - Other partners
- Goals
  - Demonstrate the technical merits and feasibility of VAA technology applications
  - Assess benefits and costs
- \$1.9 million in federal funds + \$500k California cost share
- FY09 – FY11

# E-14 Magnetic Marker Installation

- Installation of 1 mile test track
- Completed installation in two weekend days, with a total cost of \$26k (=\$17k if weekdays)
  - Magnets - \$3,478
  - Weekend installation -- \$19,150
  - Traffic control - \$3,600

Note: \$10+k per mile for previous installation on freeways



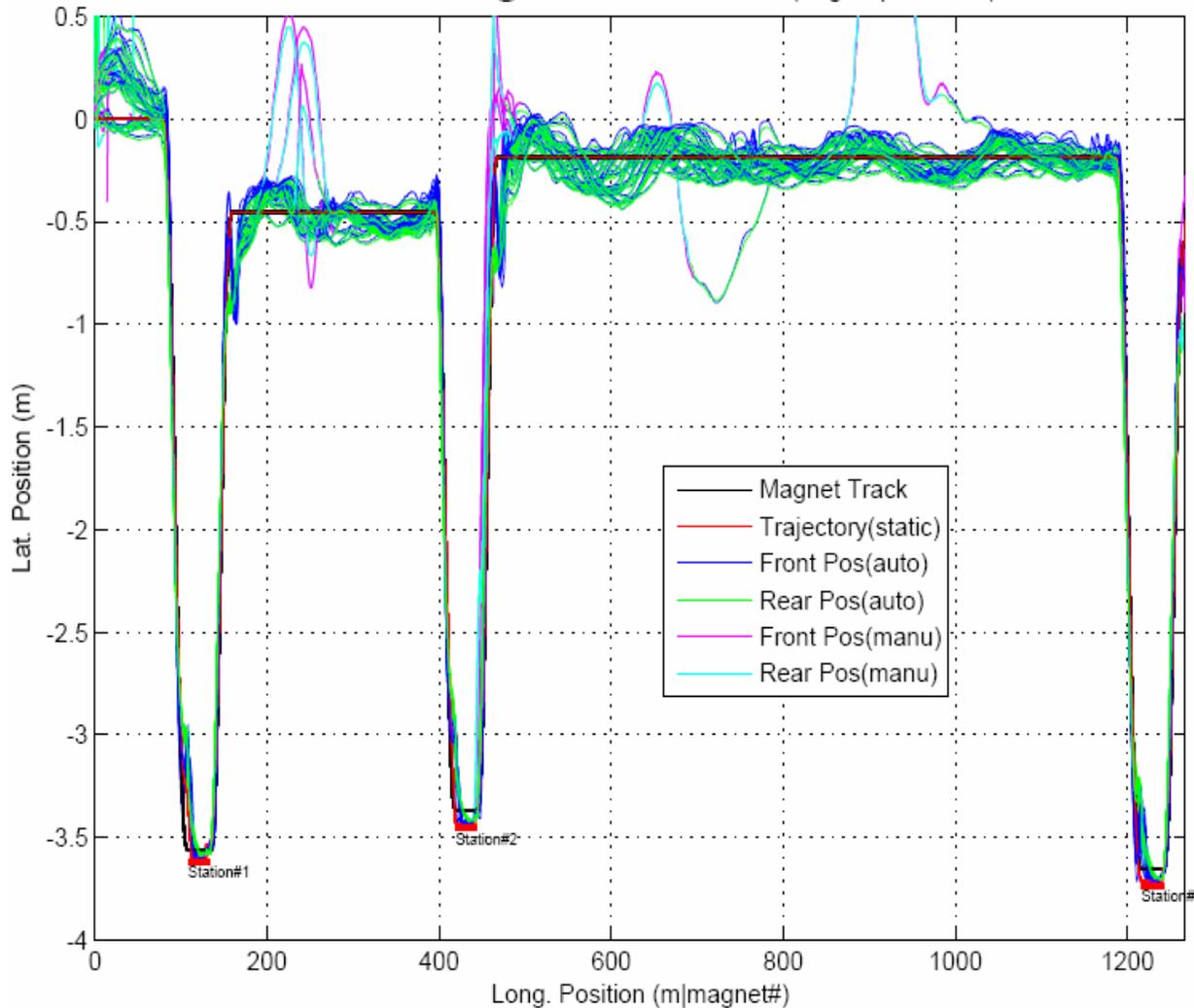
# E14 Lane-Assist System Field Test

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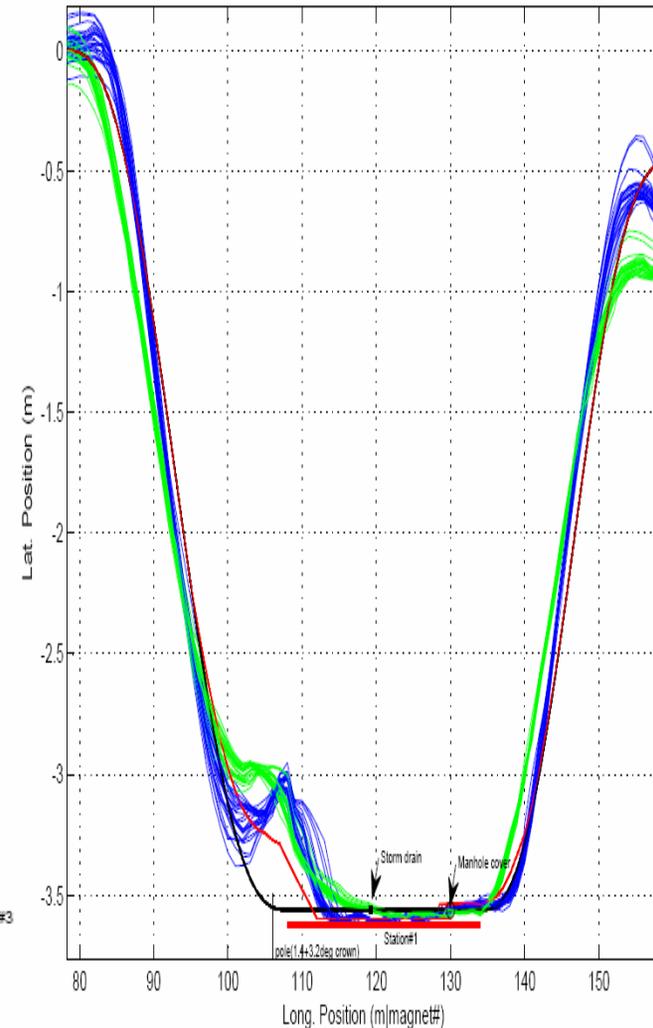


# E14 Lane-Assist System Field Test

60' Articulated Bus @E14 St San Leandro 2008 (Aug-Sept:35 runs)



60' Articulated Bus @E14 St San Leandro 2008 (Aug-Sept:35 runs)



# E14 Lane-Assist System Field Test

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- Over 120 trips in 13 test days
- Successful demonstrations and multiple transit agency participation
- Accuracy (based on last 35 recorded runs, 0-40mph)
  - Under automated steering control: 10.52 cm (STD)
  - Under automated steering control (excluding S-curves): 7.20cm (STD)
  - Final docking approach (along stations): 1.10cm (STD)
  - Docking accuracy: 0.67cm (STD)

# Why VAA Enabled BRT

Case Example: Santa Clara/Alum Rock Transit corridor  
(Data from VTA MIA)

Captical Costs Description	Light Rail		BRT	
	Option A	Option B	Dedicated	Dedicated with VAA
Construction	158.5	179.1	47.5	39.6
Mobilization/Maintainance of Traffic	22.2	25.1	6.6	6.6
<b>Subtotal</b>	<b>180.7</b>	<b>204.2</b>	<b>54.1</b>	<b>46.2</b>
Contingency (25%)	45.2	51.1	13.5	11.5
<b>Construction Total</b>	<b>225.9</b>	<b>255.3</b>	<b>67.6</b>	<b>57.7</b>
Add-on allowances (52%)	117.4	132.7	35.2	35.2
<b>Total Construction Estimate</b>	<b>343.3</b>	<b>388.0</b>	<b>102.8</b>	<b>92.9</b>
Right of Way	21.4	21.2	8.3	6.9
Vehicle (including contingency)	28.2	28.2	16.5	21.5
<b>TOTAL COST</b>	<b>392.9</b>	<b>437.4</b>	<b>127.6</b>	<b>121.3</b>
<b>Operating and Maintenance Costs</b>				
Single Car Light Rail	11.7	11.7		
Route 522 upgrade & new route 523			5.6	5.6

# VAA Project Findings

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- VAA supports:
  - Cost savings
  - Travel time reductions
  - Smoother ride and level boarding
- California/Oregon team selected magnetic guidance as the primary guidance technology based on thorough evaluation and technical merits
- Extensive development and testing have been conducted during the past twenty years
- Technologies are ready for deployment
- FTA's / ITS JPO's VAA Demonstration will address VAA deployment issues and assess benefits and costs in revenue-service operations

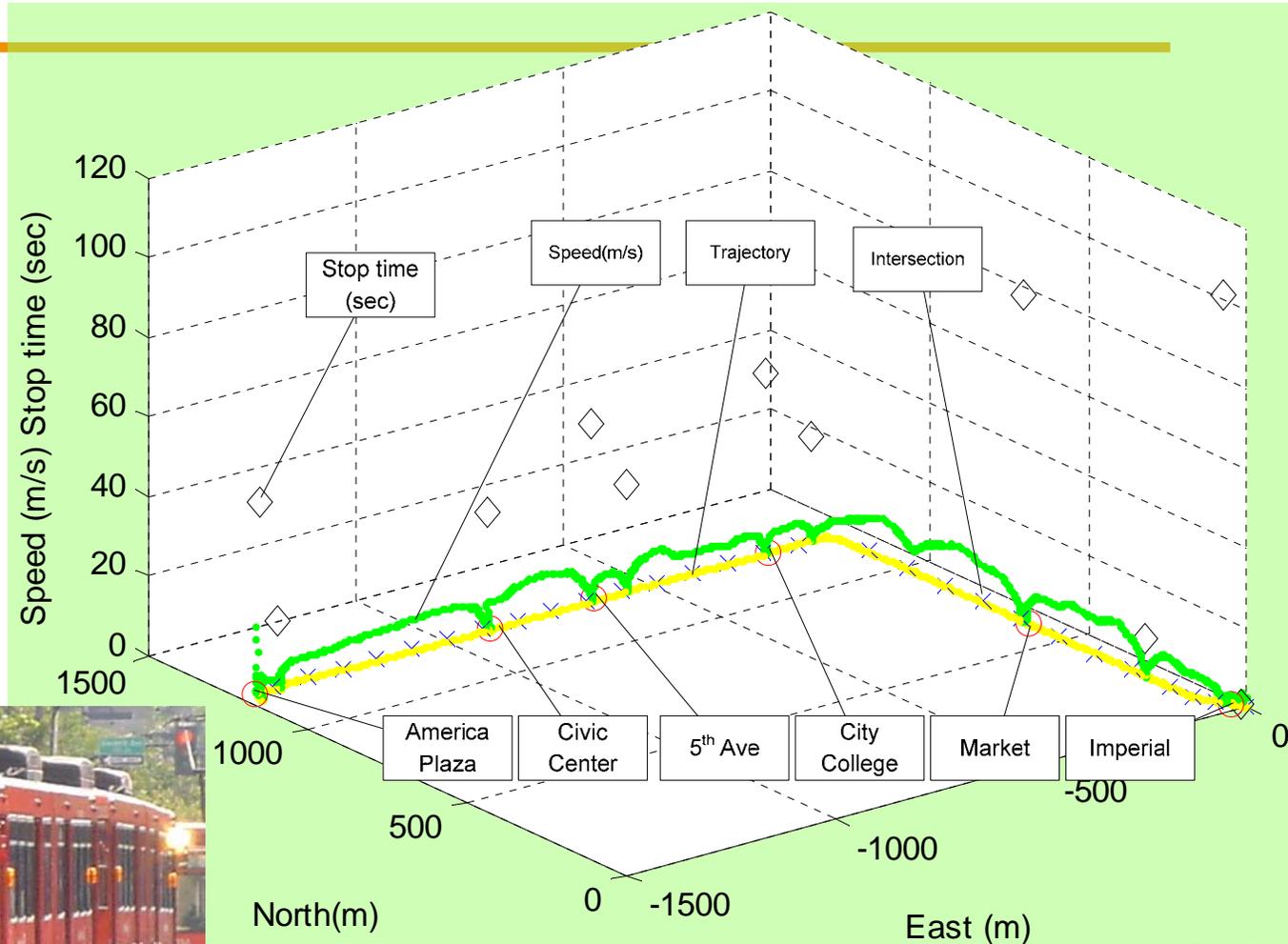
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# Grade Crossing Signal Optimization

UC Berkeley Team  
Sandag  
City of San Diego  
San Diego Trolley  
North County Cities  
Sprinter  
Caltrans

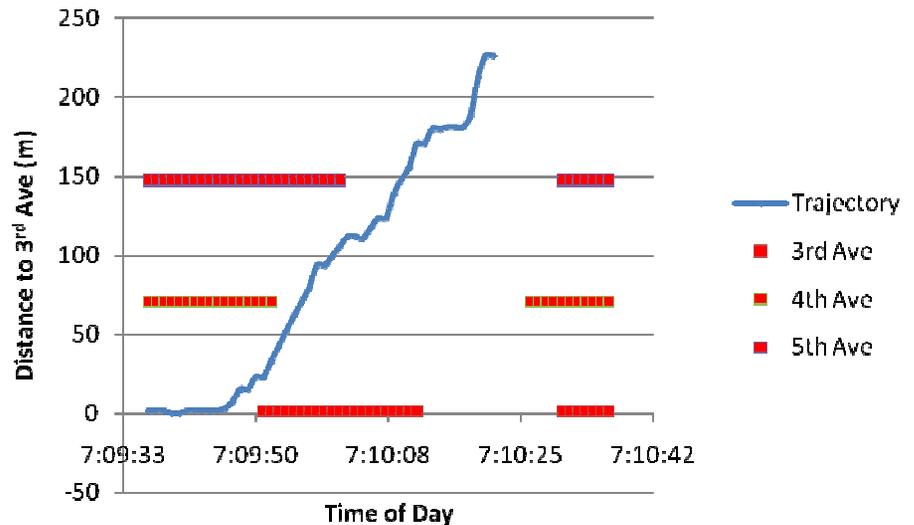
# San Diego Trolley Priority System

- Non-station stops
  - 5 stops at signals
  - Total stop time is 78 seconds
- Actual travel time
  - 854 seconds
  - 134 seconds behind schedule



# An Example of Successful 'Green Band'

- An outbound trip of Trolley #8 starts at 06:58:54 on Oct. 16<sup>th</sup>, 2009
- Traveled along C Street between Civic Center and 5<sup>th</sup> Ave without stops



Characteristics of Exemplar Trip from Civic Center to 5<sup>th</sup> Ave

	3 <sup>rd</sup> Ave	4 <sup>th</sup> Ave	5 <sup>th</sup> Ave
Pred. Leave Time	07:09:43	07:09:59	07:10:08
Act. Leave Time	07:09:46	07:09:57	07:10:09
Pred. Error (sec)	-3	2	-1
Block Travel Time (sec)	11	12	

# An Example of Successful ‘Green Band’ (Cont’d)

Signal Timings of “Before” and “After” for This Trip

	3 <sup>rd</sup> Ave		4 <sup>th</sup> Ave		5 <sup>th</sup> Ave	
	FO 2	FO 4	FO 2	FO 4	FO 2	FO 4
Before Timings	0	34	0	34	0	34
After Timings	23	52	0	32	0	37
Expected Delay (sec)	>=16		0		0	

## What has been achieved with priority ‘green band’:

- Without priority, the trolley would face the second half of red at 3rd Ave; with priority, the trolley passed 3 signals without stop
- A small green band on trolley direction guaranteed this trolley’s non-stop movement
- A wide green band on the opposite trolley direction makes sure the priority execution not affecting opposite trolley movement

**Test results show the prediction still needs improvements. PATH is working with Sandag, city of San Diego to make improvements for FOT**

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# Adaptive Transit Signal Priority

UC Berkeley and UC Riverside Team

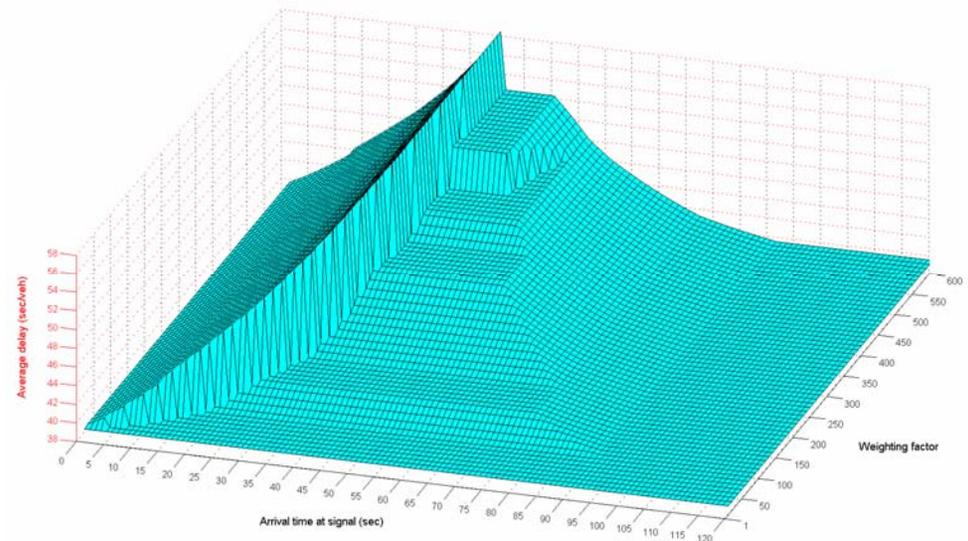
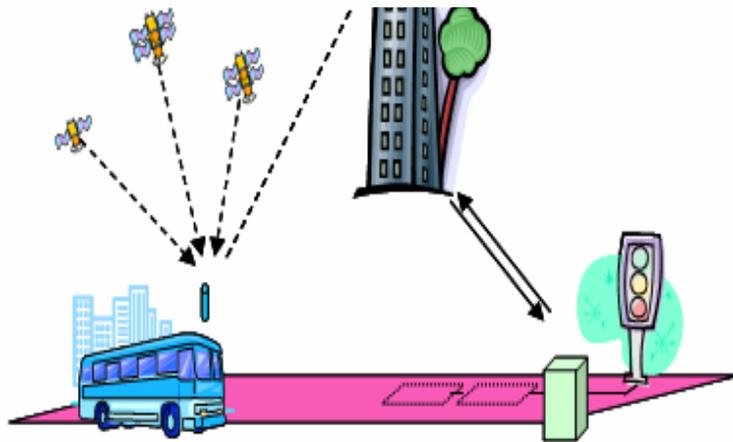
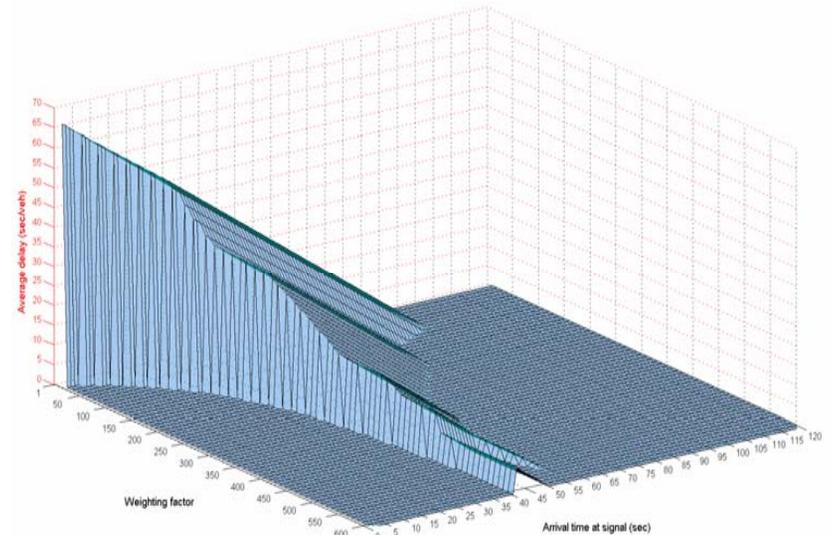
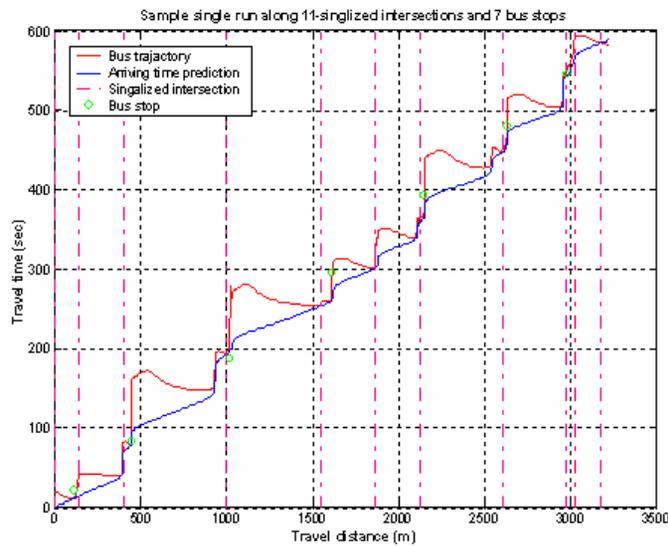
Samtrans

Caltrans

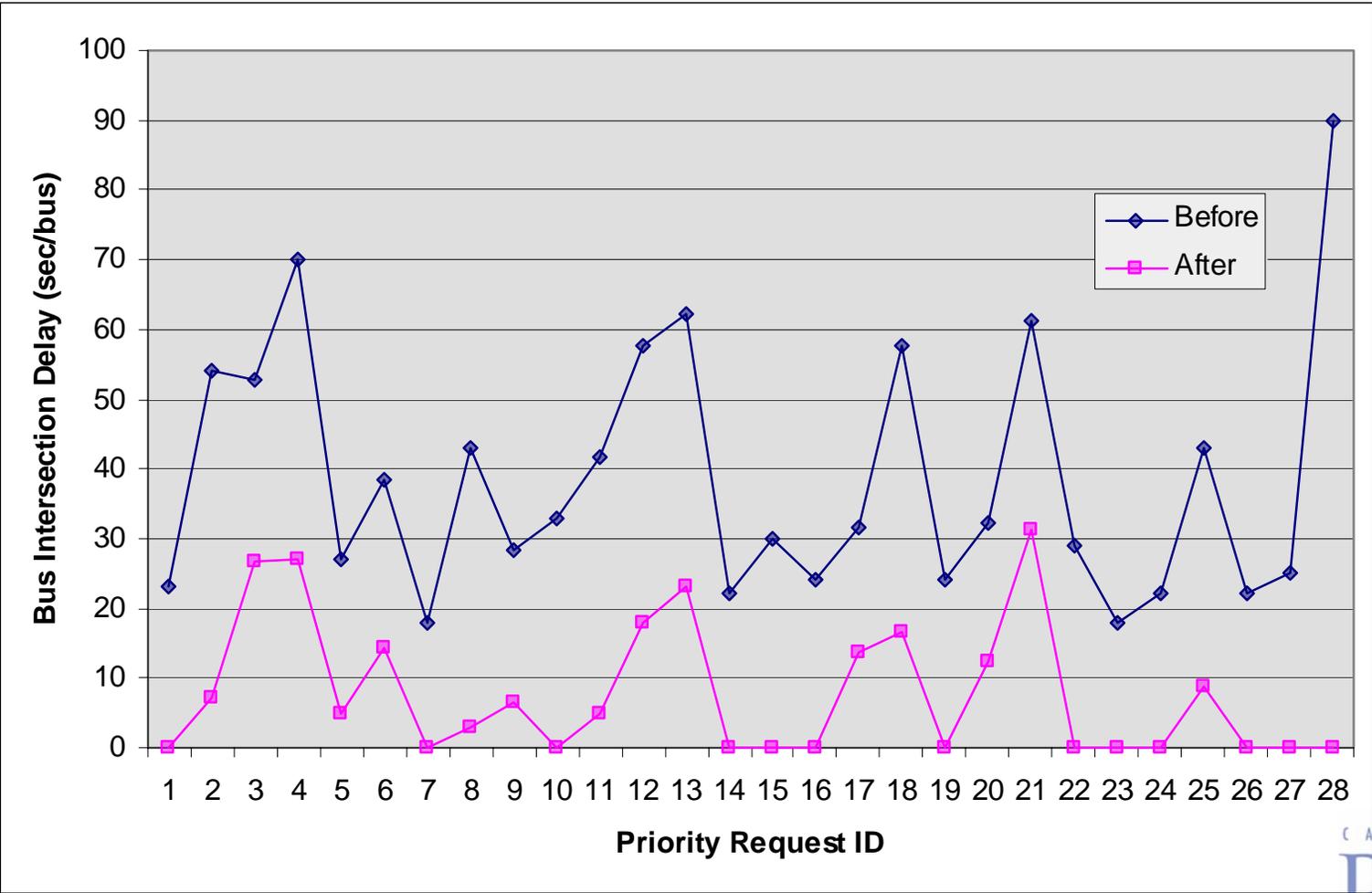
Caltrans

Bay Area Air Quality District

# Cooperative Intersection Control and Fleet Management - Adaptive TSP



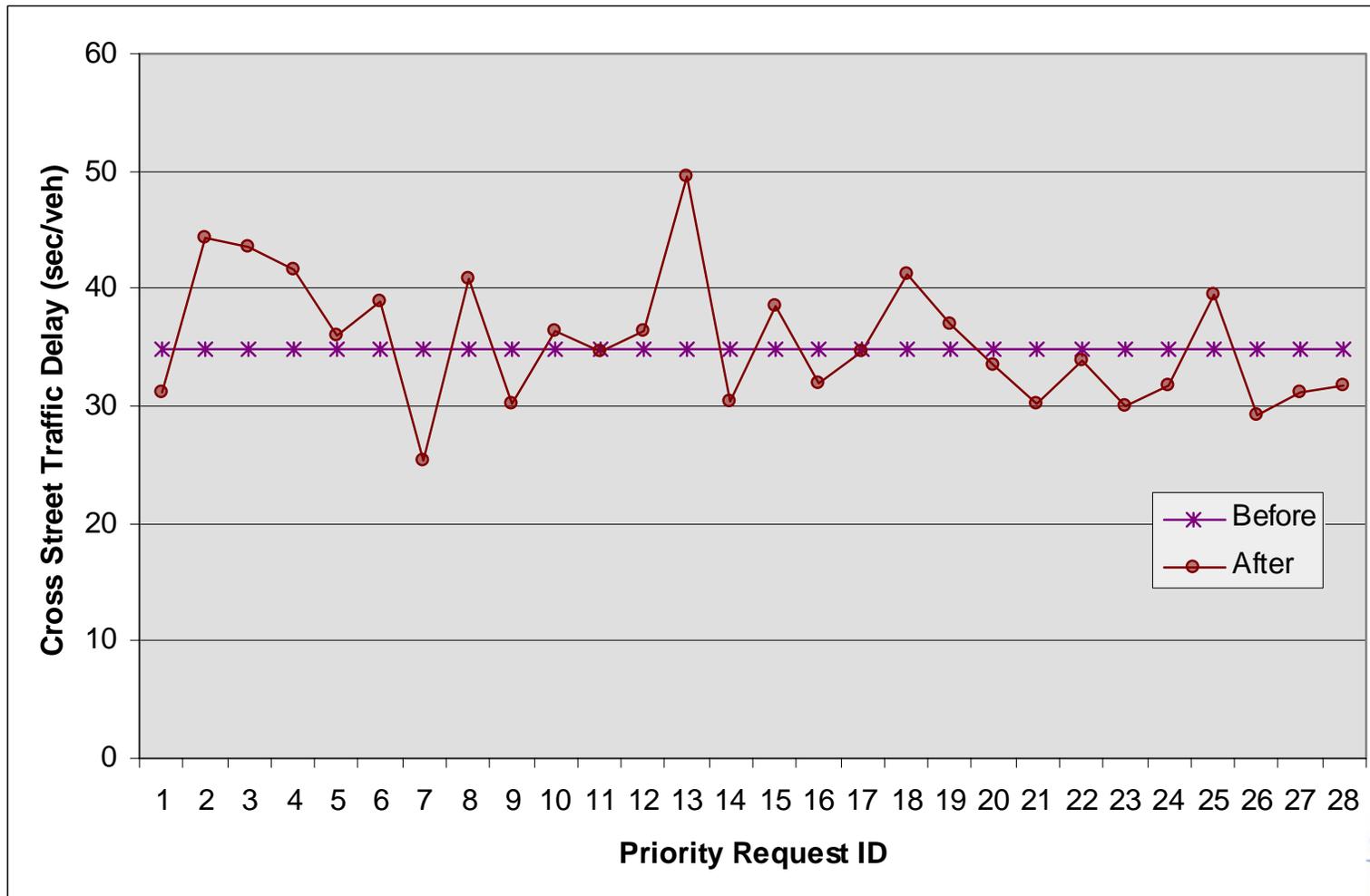
# Impacts on Bus Intersection Delays



# Impacts on Bus Intersection Delays (cont.)

		Number of cases	Bus intersection delay (seconds/bus)			
			Before	After	Change	
					(sec)	%
Early Green	NB (Ø6)	15	33.58	7.05	-26.53	-79.01%
	SB (Ø2)	12	40.61	9.36	-31.25	-76.96%
Green Extension	NB (Ø6)	1	90.00	0.00	-90.00	-100.00%

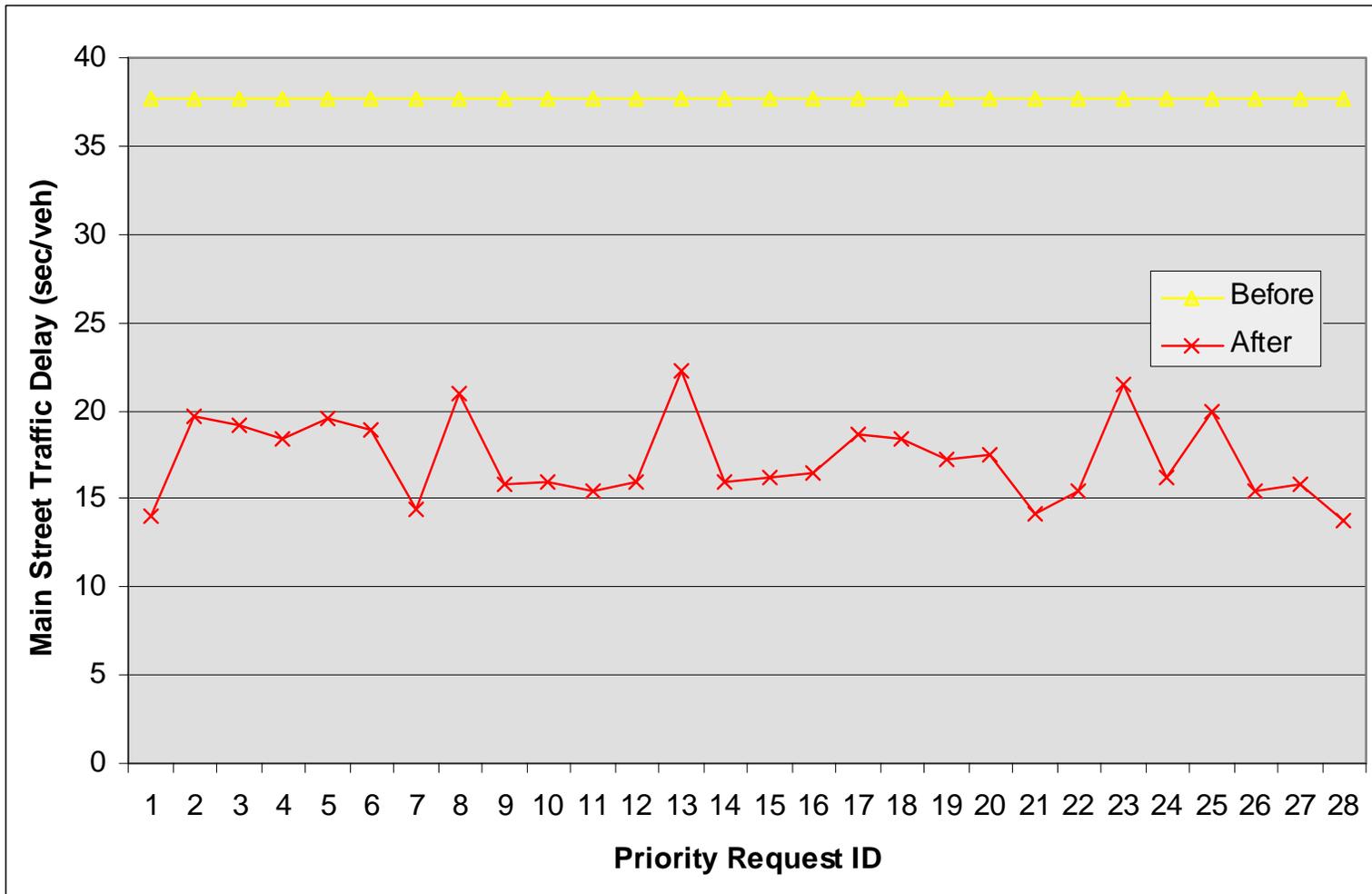
# Impacts on Cross Street Traffic



# Impacts on Cross Street Traffic (cont.)

		Total cross street traffic delay (seconds*vehicle)			Average cross street traffic delay (seconds/vehicle)			
		Before	After	Change (sec)	Before	After	Change	
							(sec)	%
Early Green	NB (Ø6)	967.52	964.30	-3.22	34.85	34.82	-0.03	-0.09%
	SB (Ø2)	978.34	1023.93	45.60	34.85	36.59	1.75	5.01%
Green Extension	NB (Ø6)	924.26	839.28	-84.99	34.85	31.65	-3.20	-9.19%

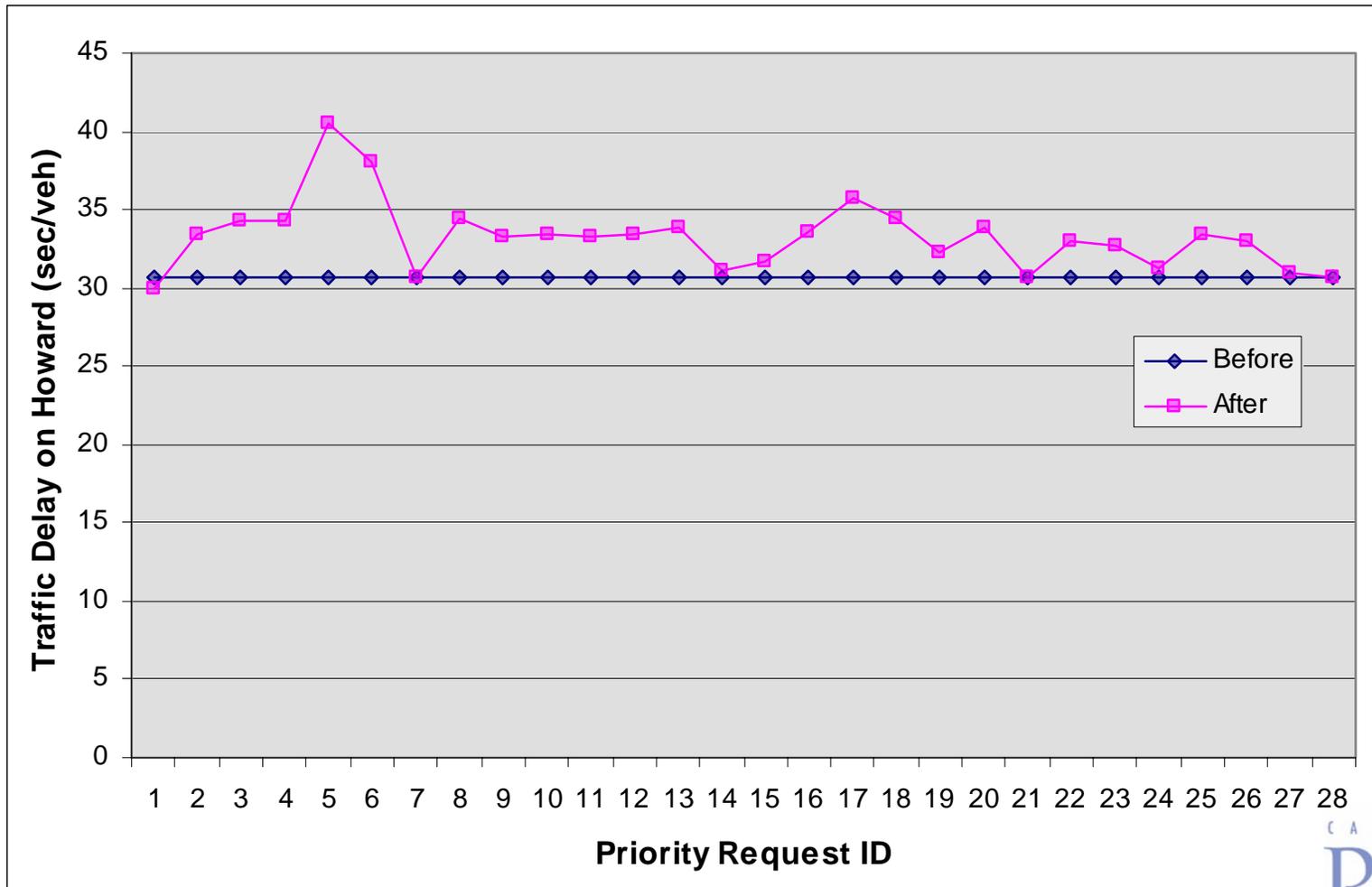
# Impacts on Main Street Traffic



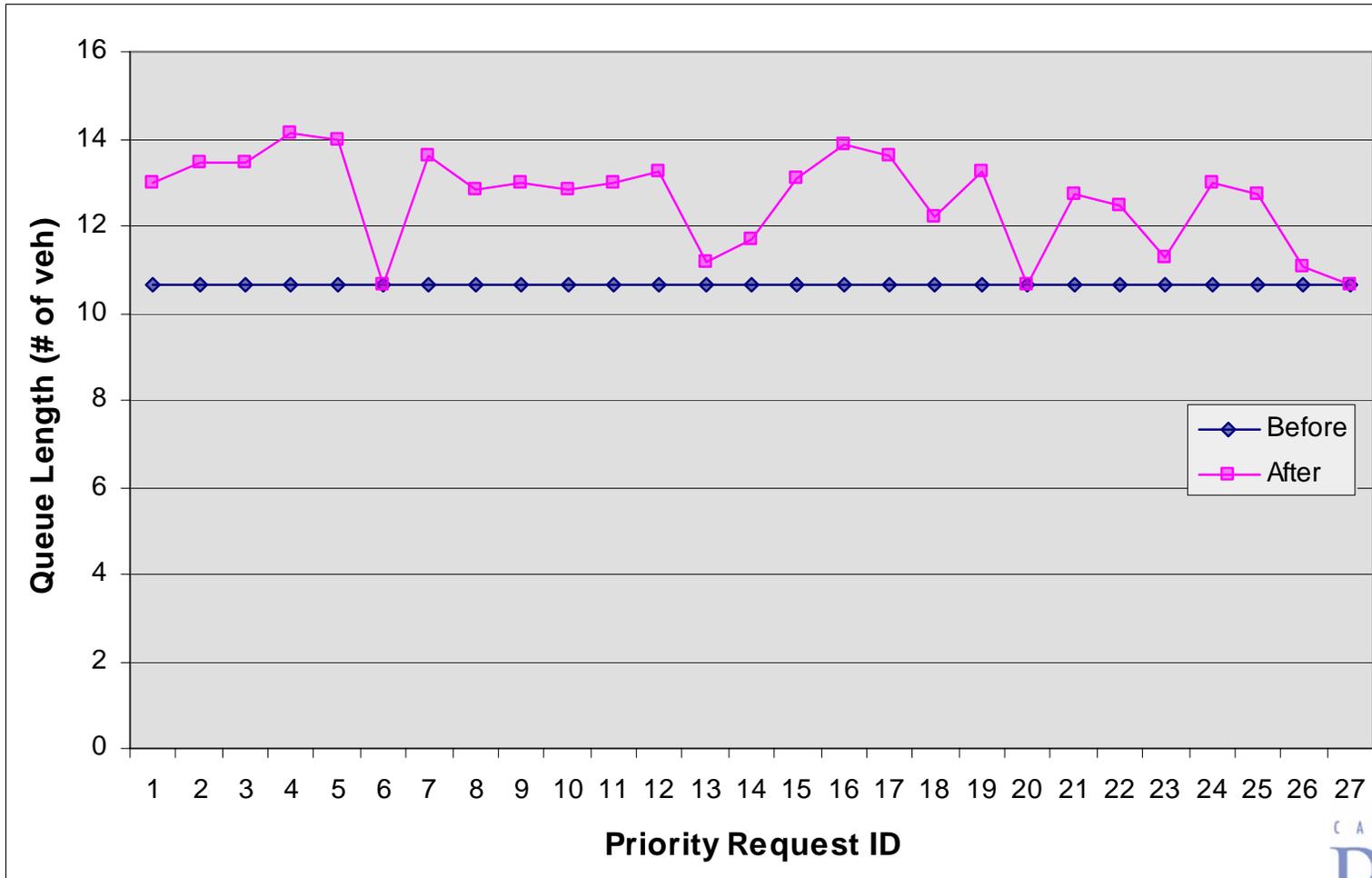
# Impacts on Main Street Traffic (cont.)

		Total main street traffic delay (seconds*vehicle)			Average main street traffic delay (seconds/vehicle)			
		Before	After	Change (sec)	Before	After	Change	
							(sec)	%
Early Green	NB (Ø6)	4732.13	2189.81	-2542.32	37.63	17.41	-20.22	-58.01%
	SB (Ø2)	4732.13	2181.68	-2550.45	34.85	17.35	-17.50	-50.22%
Green Extension	NB (Ø6)	4732.13	1737.56	-2994.57	37.63	13.82	-23.81	-63.28%

# Impacts on Old County Road



# Impacts on Old County Road (cont.)



# Impacts on Old County Road (cont.)

		Average traffic delay (seconds/vehicle)				Average back of queue on Ø5 (number of vehicles per cycle)		
		Before	After	Change		Before	After	Change
				(sec/veh)	%			
Early Green	NB (Ø6)	30.61	32.77	2.16	7.04%	11	12	1
	SB (Ø2)	30.61	34.07	3.46	11.31%	11	13	2
Green Extension	NB (Ø6)	30.61	30.61	0.00	0.00%	11	11	0

# ATSP Field Testing Findings

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- Successful verification of the ATSP approach at all intersections
- Significant saving for bus intersection delays
- Benefits on traffic along ECR
- Minimum impacts on cross streets
- Implementation of ATSP using existing transit AVL/Advanced Communication system – substantial savings for TSP deployment

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# BRT Planning Tools

UC Berkeley

San Jose State University

Caltrans

# BRT Planning

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- Design of a single lane BRT system
  - Results demonstrated a promising potential of the concept of a one-dedicated-lane BRT or light-rail system for efficient operation
- Bus Rapid Transit systems performance assessment guidebook
- Assess the Trade-Offs between people throughput and LOS degradation in the conversion of a mixed flow lane to a bus only lane

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# Multimodal Real-time Traveler Information

UC Berkeley Team  
Caltrain  
Samtrans  
VTA  
MTC  
USDOT  
Private partners

# FOT Site

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- US 101 is an ideal corridor for a Networked Traveler FOT
  - Congested
  - Multi-modal
  - Excess Caltrain carrying and parking capacity
    - 60% full (over all trains)
    - Total travel time for a direct or even a connected trip is competitive
    - Over 1000 available parking spaces
- Field testing of a CMS-based system shows parking information encourages transit use along US 101
- Data shows that travelers continue to use transit mode once shift occurs
- Stakeholders are interested in Caltrain and parking information
  - Caltrans, MTC, VTA, SamTrans/Caltrain, CCAG

# Test Site



# Real-Time Multi-Modal Information to Encourage Mode Shift

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- To facilitate mode choice through pre-trip planning
  - Multimodal trip planning tool using real-time traffic and transit data ([planner](#))
    - Comparative highway, parking and ride, transit options: travel time, costs, emission, etc.
    - Real-time 'congestion' alert and transit trip alternative advice
  - Real-time travel information
    - Transit arrival time, total trip time, etc.
    - Parking availability information

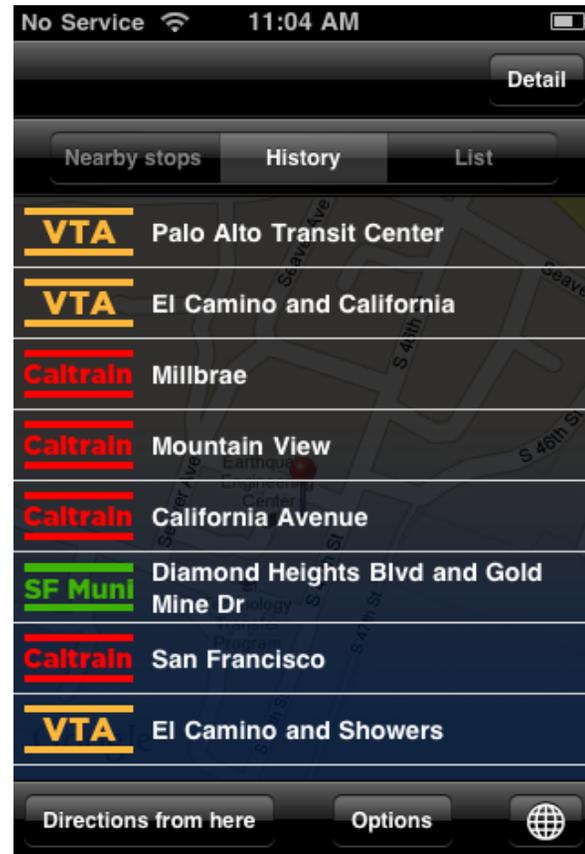
# Real-Time Multi-Modal Information to Encourage Mode Shift

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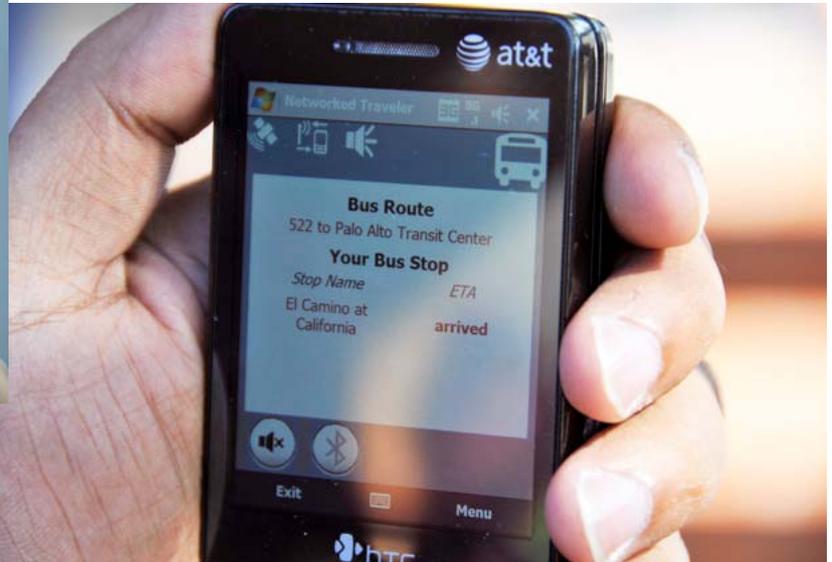
- To help in travel through handheld 'mobile navigator'
  - Park and ride and transit trip planning
    - Transit options
    - Total trip time
  - Real-time transit information
    - Next bus arrival time alert
    - Connection alert
    - Destination notification
  - Geo-fencing (to preclude use while driving)

# Mobile Platforms

- Window  
Mobile/iPhone/  
Gphone  
applications



# Real-Time Notification and Alert



# Transit Information on CMS

- Station-to-station trip time
- Using real-time info for both highway and Caltrain travel time
- Parking availability on exit ramps



# Expected Results

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- Working with a USDOT designated independent evaluator to evaluate
  - How integrated real-time multimodal information is used?
  - Whether such information can lead to mode shift? and
  - What element of such information will help the most?
  - Whether the mode shift induced by real-time information will cause congestion relief (analysis)?
- Recommendations
  - Ways of using real-time information and other means as traffic demand management tools
  - Follow-on larger scale FOT
  - How trip tracking data (AVL) can be used for transportation planning

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# EDAPTS

Cal Poly San Luis Obispo and Pomona team  
Bronco Express Bus

# EDAPTS

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- EDAPTS stands for Efficient Deployment of Advanced Public Transportation Systems (APTS)
- EDAPTS is a cost effective method and a framework for deploying APTS solutions to small and medium size transit properties
- EDAPTS involves technical and institutional aspects:
  - Technical: Focuses on low-cost, off-the-shelf, open source, easy-to-be-deployed APTS (or EDAPTS systems)
  - Institutional: Focuses on how to efficiently deploy EDAPTS systems

# EDAPTS

- Tested and validated EDAPTS concepts for procuring and deploying an APTS solution on Cal Poly Pomona's Bronco Express Bus system
- Evaluated how well an APTS solution could be put out to bid, procured, integrated, and installed in the commercial environment
- Analyzed and documented the effectiveness of the deployment process and assess the functional operation and capabilities of the deployed APTS solution (or the Bronco Express EDAPTS system)
- Improved the operation and increased Bronco Express service level through the use of the EDAPTS system



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# Tool Development to Evaluate the Performance of Intermodal Connectivity (EPIC) to Improve Public Transportation

UCLA and UC Berkeley

# Principal Findings

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- From passengers/users perspective, one principal findings stands out:
  - The most important determinant of user satisfaction with a transit stop or station is frequent, reliable service in an environment of personal safety, and only indirectly the physical characteristics of that stop or station
- From transit managers perspective
  - For operators, safety- and security-related factors far outweighed other attribute factors at transit stops, stations, and transfer facilities

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# Improving Mobility Through Enhanced Transit Services

UC Berkeley and UCLA

AC Transit

Caltrans

# Transit Taxi Concept

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Service that

- Is publicly available
- Uses existing transit stop/station infrastructure as “origins” and/or “destinations
- Is offered when regular buses tend not to be operational
- Allows for a shared-ride experience

# Major Findings/Preliminary Conclusions

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- Factors contributing to creation and continuation of programs for targeted operators include
  - Demographics: high densities, lower-income levels, universities and hospitals
  - High community demand (LAMTA, AATA, AC Transit)
  - University support (Rimouski, AATA, Boston, Vancouver)
  - Strong agency support (OCTA, King County)
  - Regulatory and political environment
  - Relative cost savings over traditional fixed route service option
- Community pressure has contributed to transit agencies focusing beyond day-to-day O&M of existing system
  - MADD in Boston
  - Bus Riders Union in Los Angeles
  - Transportation & Land Use Coalition in San Francisco Bay Area

# Major Findings/Preliminary Conclusions

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- Innovative financing mechanisms, e.g., AC Transit in SF Bay Area, should be considered to help deal with agency-wide financial constraints
- Most common form of transit taxi is *fixed-route skeletal*
- In-house operation is predominant operational strategy
- Cities with smaller populations with universities (Ann Arbor, 114,000 and Rimouski, 40,000) tend to have feeder/hybrid transit taxi services, utilizing taxi cabs
- Little, if any, service assessment performed

# Major Findings/Preliminary Conclusions

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- Examined alternative methods for providing transit services for low demand density, and
- Modeled providing regional transit access to a rapid transit line, with both fixed-route operations and flexible-route shared-ride taxi operations.
- Found that utilizing flex-route demand-responsive transit taxi can dramatically reduce overall cost per trip under certain circumstances
- Insight: To efficiently serve areas with low passenger demand density, we should
  - Target focused demand patterns
  - Design flexible route transit-taxi operations
  - Explore innovative institutional arrangements

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# Integrated Corridor Management

UC Berkeley as a Member of the Consulting Team

Sandag

Cities in the region

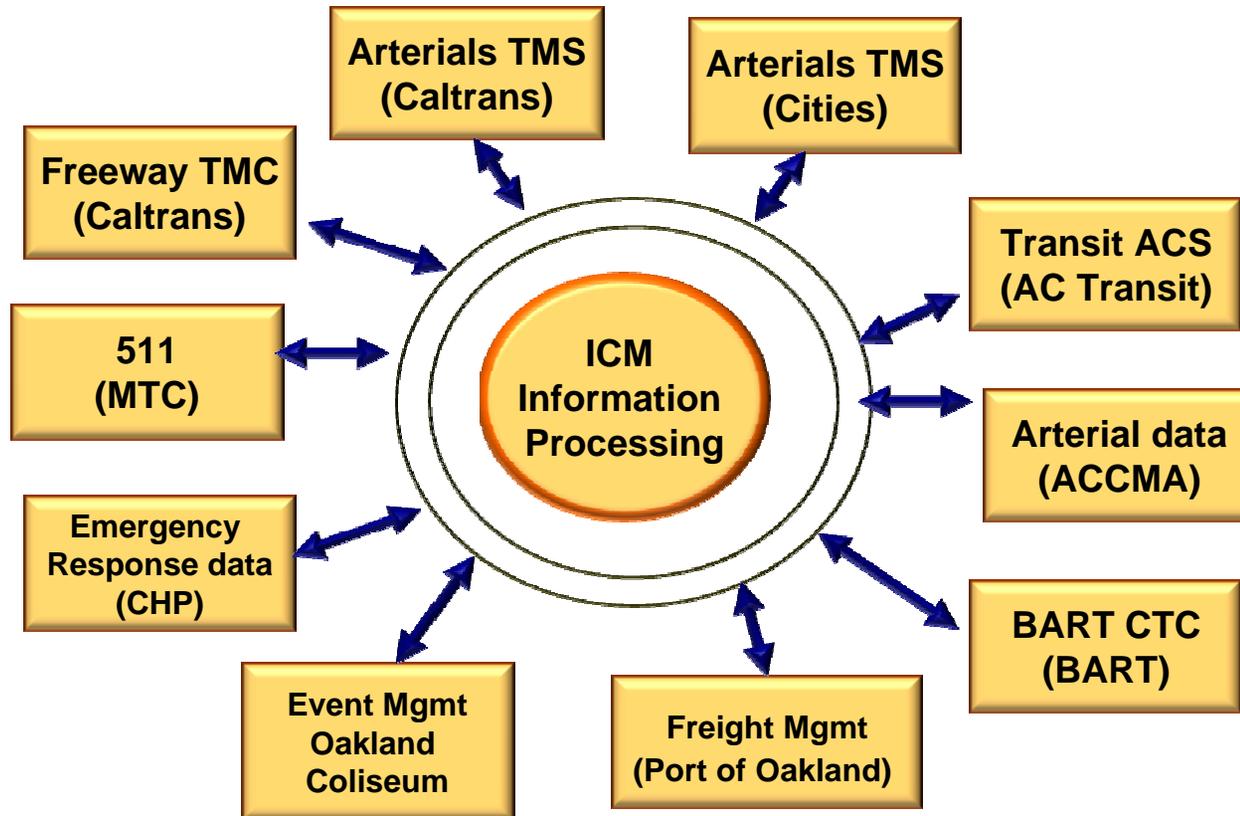
Caltrans

USDOT

Private partners

# Integrated Corridor Management

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# I-15 ICM Multi-Modal Corridor



Main Lanes

Ramp Metering

Express Lanes

Parking

Local Arterial Traffic Signals

CMS

Transit BRT Station

# I-15 ICM Strategies

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- Sharing and dissemination of information among corridor's agencies
- Improving network junctions especially at freeway on-ramps and off-ramps where freeway and arterial networks converge
- Promoting shifts between networks such as arterials accommodating traffic diverted from I-15 or travelers using transit instead of their cars based on 511 information
- Managing needs of people who want to travel given capacity limits of available roadway facilities

# I-15 ICM Operational Scenarios

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- I-15 ICMS needs to operate in different environments and respond to variety of situations along the corridor
- Scenarios representative of travel conditions along the I-15 corridor
  - Daily operations (recurring congestion)
  - Freeway incident (major, minor)
  - Arterial incident (major, minor)
  - Transit incident
  - Special Planned event
  - Disaster response

# I-15 ICMS User Needs to Achieve ICM Goals

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User needs assessment was performed based on input from stakeholder team

1. Access/Store ICMS configuration data
2. Collect and Process Data
3. Access/Store ICMS historical data
4. Publish information to system managers
5. Interactively conference with multiple agencies
6. Display information
7. Coordinate transportation & public safety operations
8. Share control of devices
9. Manage video imagery
10. Respond to corridor planned & unplanned events
11. Assess impact of corridor management strategies
12. Publish information to system users
13. Measure corridor performance
14. Manage corridor demand & capacity to optimize long-term performance
15. Measure system performance
16. Manage ICMS System
17. Document system & train system users and maintainers

# Stage 2 AMS ICM Strategies/Scenarios

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- Daily Operations:
  - Pre-Trip and En-Route Traveler Information;
  - Transit Signal Priority;
  - Ramp-Metering and Arterial Signal Coordination;
  - BRT; and
  - Congestion Pricing for Express Lanes
- Freeway Incident:
  - Pre-Trip and En-Route Traveler Information;
  - Transit Signal Priority;
  - Ramp-Metering and Arterial Signal Coordination;
  - BRT; and
  - Congestion Pricing for Express Lanes

# I-15 ICM System/Subsystems

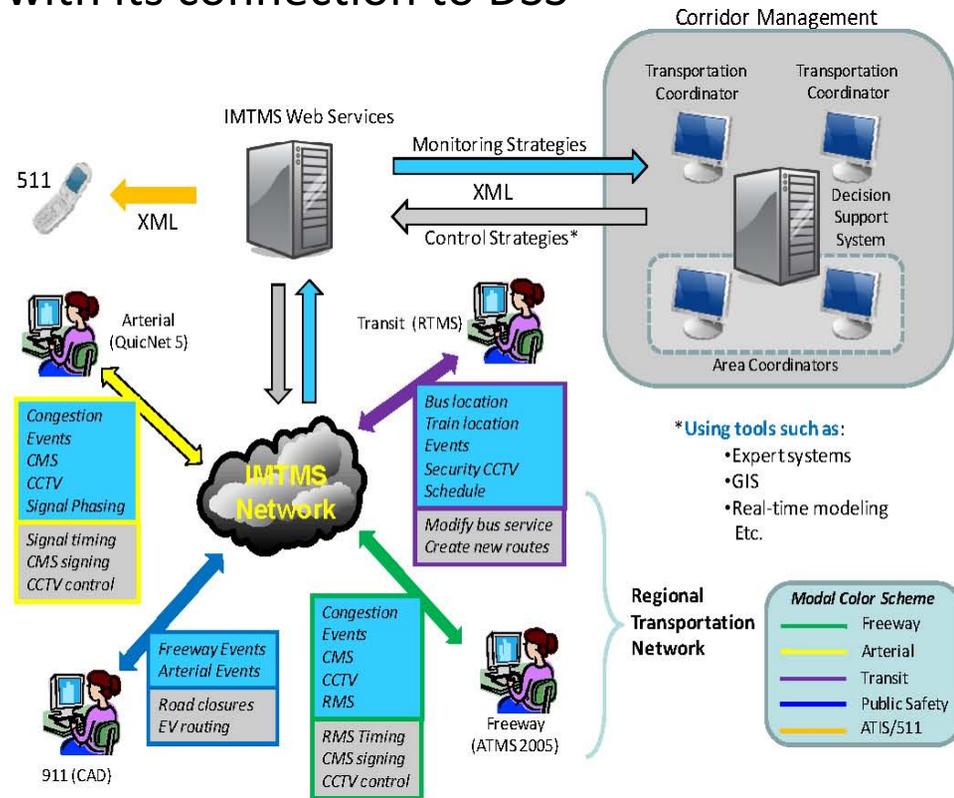
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- Lot of what SD envisions for I-15 ICMS already exists as systems that manage the networks for individual modes
  - Modal management systems (ATMS, RTMS, RAMS)
  - Intermodal Transportation Management System (IMTMS)
    - Connecting modal management systems; facilitates communication
    - Allows for sharing of data across modes, e.g., allows a transit agency to receive information on traffic conditions; allows cities to share event management information
- Major component to be developed: Decision Support System
  - Support ability to generate action plans in response to regional events
    - Recurring
    - Planned
    - Unexpected

# I-15 ICMS System Concept

Schematic representation of IMTMS and connections to various modal management systems together with its connection to DSS

IMTMS collects/routes data;  
DSS has tools to develop,  
recommend, transmit  
actions to specific traffic  
control devices and public  
transportation systems



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# Integrated Transit ITS System

UC Berkeley Team

VTA

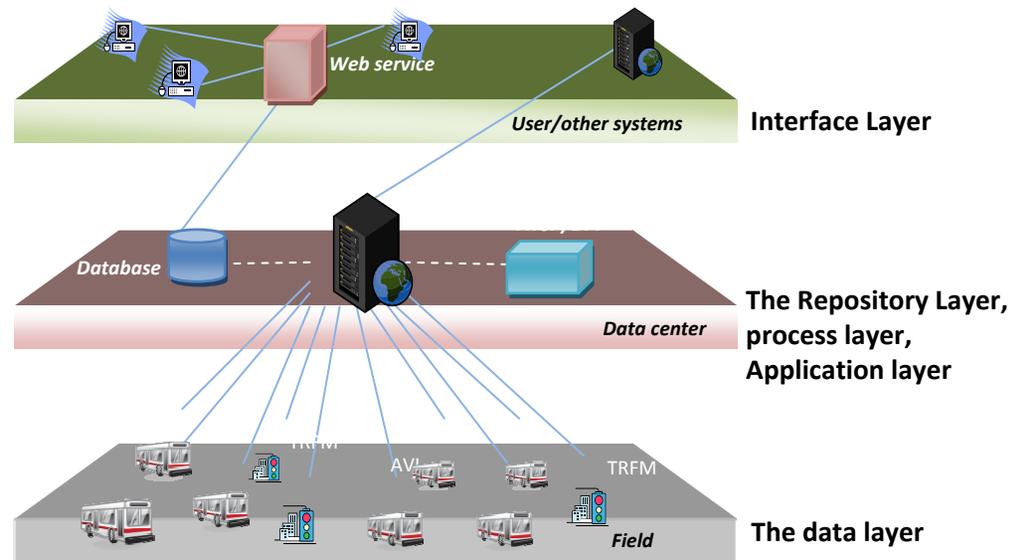
# Integrated Deployment of Transit ITS

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- Current practice: made significant headway on ITS deployment, but
  - Deployment of transit ITS is mostly capital grant driven
  - Proprietary Technologies
  - Difficult and costly for system upgrade
  - Systems not integratable with each other
- Moving toward an integrated system
  - Integrated and open architecture
  - Sound system requirements/specifications
  - Procurement process

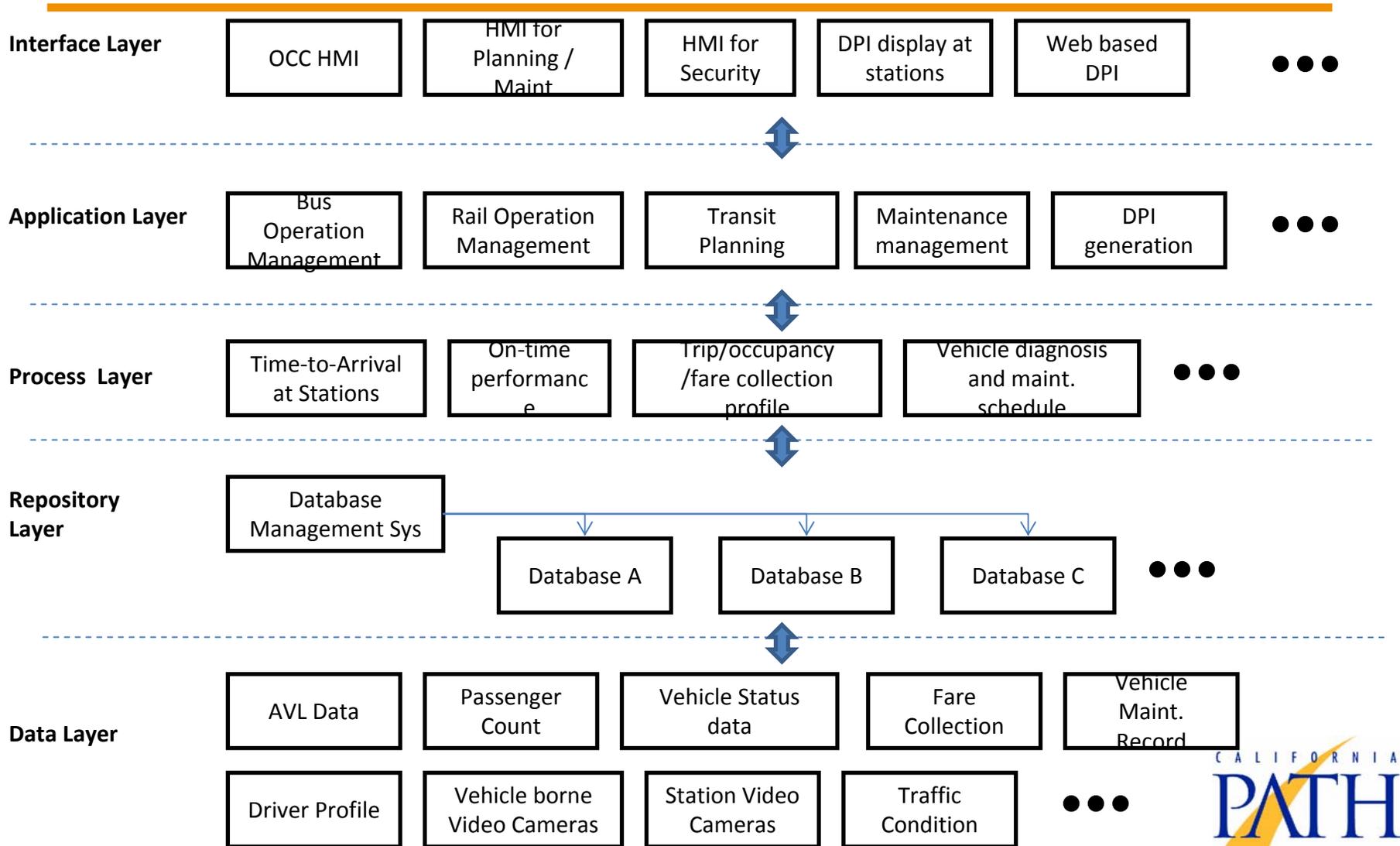
# A Platform for an Integrated Transit Information and Management System

- **Integrated real-time traveler information -- through web, handheld, bus station displays (now)**
  - Traffic information
  - Parking availability at transit stations
  - Arrival and connection info
  - On-board alerts
- **Dynamic transit operation based (future)**
  - Detailed O-D data
  - Traditional transit management functions
  - Dynamically manage bus transit schedule for more efficient operation
  - Adaptive transit Signal Priority



Layered architecture to allow scalability and integrated implementation

# An Integratable and Open Architecture



# Summary

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- Transit systems have been operated and managed as independent elements
- Research is needed to close the gaps to
  - Enable the transit systems to become fast, reliable, more efficient, and accessible
  - Make transit an integral portion of the overall transportation solution

# Current PATH Research

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- Addressing the gaps by
  - Understand the needs through thorough analysis of field data
  - Develop innovative technologies and methodologies that will cause mode shift thereby help to reduce congestions
  - Moving toward deployment of research products to demonstrate technical feasibility and the benefits
    - VAA
    - ATSP
    - ICM
    - EDAPTS
    - Grade crossing signal optimization

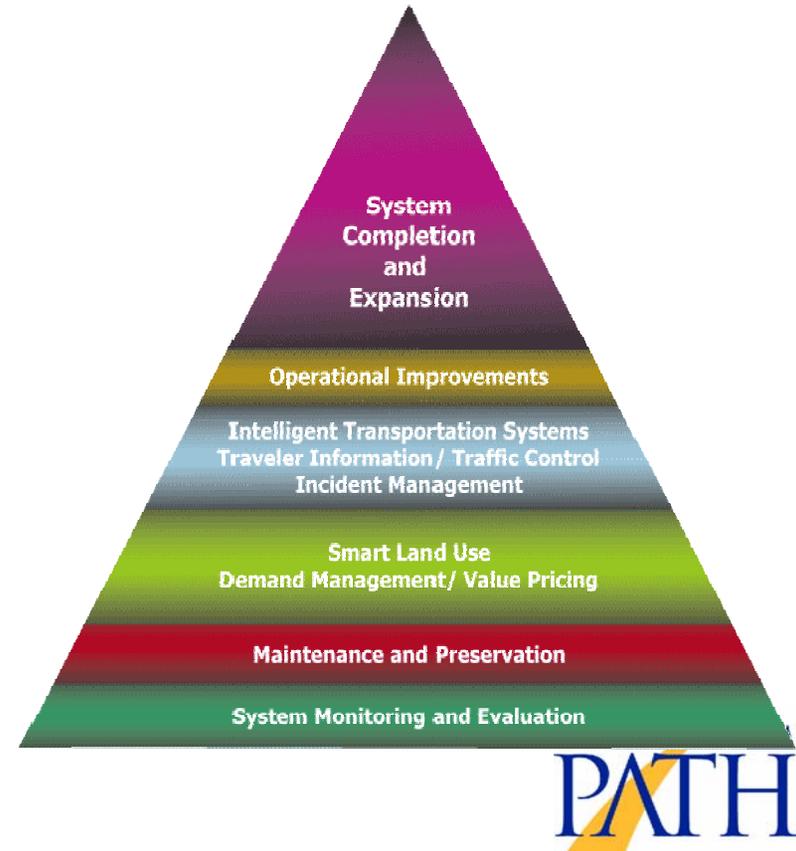
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# Future Research Direction

# Transit as Congestion Relief Strategies

- Capacity and Traffic Management
  - Improve transit service to make it a true viable solution
  - Integrate transit into the transportation system
- Demand Management
  - Congestion pricing together with effective incentive program

**Mobility Pyramid**



# Future Research: Recommendations

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- Demand management
  - Real-time multimodal information and incentives as demand management tools
- Transit operation improvements
  - Dynamic/flexible transit operations
  - VAA speed control and coordination with signals
- Improvement of connectivity
  - Effective means for first mile and last miles
- Cost effective deployment of transit ITS
  - Integrated transit ITS: architecture, requirements and deployment case study

# Transit Research that Matters...

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- Build a vision that incorporates transit as a tool as a part of an integrated multimodal transportation system
- Address both short term improvements as well as long term solutions (for achieving larger benefits)
- Build a robust research program
  - Roadmaps: application oriented research → FOT → deployments
  - Solicitation (RFP) of strongest research teams
  - Involving transit stakeholders for guidance and support

# Questions

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