Chain-up Delay Tracking with Bluetooth

Prospective Deployment Recommendations and Sources for Bluetooth Readers

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TABLE OF CONTENTS

INTRODUCTION

The work presented in this report is part of a two-phase project entitled, Prospective Deployment Recommendations and Sources for Bluetooth Readers. Phase One's primary objective is to develop a preliminary algorithm for estimating chain-up delay, determine locations for Bluetooth loggers to facilitate the algorithm, and deploy Bluetooth loggers relative to the Fawndale, CA chain up area and verify their operation.

In Phase Two of this project, data will be collected and the preliminary algorithm will be evaluated and refined to determine delay over the affected segment.

This report provides a summary of the outcomes of Task 2 and Task 5 from Phase 1. The purpose of Task 2 was to identify sources for Bluetooth readers. The purpose of Task 5 was to identify the number of locations of Bluetooth readers for prospective deployment.

BACKGROUND

On northbound I-5 north of Redding, CA, when chain controls are in place, trucks are required to chain up near Fawndale. Figure 1 shows a map of the area and includes CCTV and CMS locations.

Figure 1: Map of I-5 near Fawndale – Google Maps

When these chain restrictions are in place, there can be a backup of trucks for 5 miles or more, all the way to Pine Grove, CA and beyond. See Figure 2 and Figure 3. In the four lane section near Fawndale the backup is one lane of trucks. Closer to Redding, there is a six lane section that develops a truck queue in the number two and three lanes. Determining accurate delay times that could be displayed on changeable message signs (CMS) before the backup starts may reduce the wait times and backup length, which could improve safety within this corridor.

Figure 2: Back-up at Fawndale – Caltrans Image

Figure 3: Back-up at Pine Grove – Caltrans Image

The intent of this project is to deploy Bluetooth loggers that will log time and MAC address, and to use the readings from these loggers in conjunction with chain control status to develop and algorithm to estimate travel time/delay through the affected area. At least one logger will be positioned upstream from the chain up area to associate a timestamp with vehicles prior to entering the affected area. Since backed-up traffic can reach Redding, it may be necessary to position another logger south of Redding. A logger may also be positioned at the point where vehicles initiate free-flow following chain up. Another logger will be positioned subsequent to the chain up area, where vehicles resume full speed travel, relative to conditions. The location for this logger will most likely be the Pit River Bridge CCTV site. The Bluetooth loggers will log as many events and as much normal traffic as possible. Camera images and chain control indications will also be logged.

Caltrans District 2 chain control requirement types are listed below:

- W: **No Restrictions** - Watch for snow on pavement.
- R-1M: Chains are required on single-axle drive vehicles with trailers (commonly referred to as R1 Modified).
- R-1: Chains are required on all commercial vehicles (trucks or buses). All other vehicles (cars, pick-ups, vans, etc.) must have either snow tread tires or chains on the drive axle.
- R-2: Chains are required on all vehicles except four-wheel drives with snow tread tires on all four wheels and provided that tire traction devices for at least one set of drive wheels are carried in or upon the vehicle.
- R-3: Chains required - ALL VEHICLES- no exceptions.
- **Vehicles Towing Trailers**: For chain control levels R-1M, R-1, R-2, and R-3, the following applies: All vehicles, including four wheel drive vehicles, that are towing trailers must have chains on one drive axle. Trailers equipped with brakes must have chains on one axle.
- C: **Road Closed**
- T: **Truck Hold** - During major storms when traffic flow is heavy, Caltrans may hold tractor-trailer combinations at specific points below the snow line.
- TS: **Truck Screening** - All semi-trucks will be checked to make sure they have a full set of tire chains before being allowed to travel into areas where chains will be required.
- VS: **Vehicle Screening** - All vehicles will be checked to make sure they have a full set of tire chains before being allowed to travel into areas where chains will be required.
- MT: **Metering Traffic** - Implemented when necessary to control the number of vehicles that feed into the snow area. This congestion control procedure gives Caltrans a better chance of keeping the freeway open.

R-1 and R-2 are the most common chain controls. The highway will often be closed before an R-3 control is imposed.

(Source: http://www.dot.ca.gov/dist2/chainup/requirements.htm)

Chain Requirement Types One and Two would result in a mixed flow, with some vehicles required to stop and chain up while others may proceed. Assessment of speeds for these multiple classes of vehicles is desirable.

The project team will use an iterative approach to develop a delay estimation algorithm. Prior to deployment, conditions will be observed for an entire bad-weather season, using CCTV images and chain requirements. A preliminary algorithm will be developed in conjunction with determining the prospective locations and number of the Bluetooth loggers. Loggers will then be deployed and data from the deployment will be used to evaluate and refine the algorithm.

One simple deployment and model to estimate delay associated with chain requirements near the Fawndale site would use a detection point prior to chain up and another subsequent to chain up, and determine travel time via measured travel times between the two points. There are multiple problems with this approach. First, when a chain requirement is implemented, there will be a gap between the time in which the first vehicles chain up and subsequently pass the second detection point. A delay might not be recognized during this gap. Second, chain requirements may be implemented requiring chains for one class of vehicles (trucks) and not for others. These separate vehicle types will experience different travel/delay times, and should be handled separately. Bluetooth detection does not distinguish vehicle types. Third, the length of queue will vary depending on the duration of the chain requirement and the volume of traffic. Bluetooth detection does not detect every vehicle and the proportion of vehicles detected may vary over time, by vehicle class, and by the type or demographic of the drivers. As such, it would be challenging to accurately estimate volume, and then use estimated volume to further estimate queue length. It is also possible that the queue would grow sufficiently large to exceed beyond the first collection point. In this case, delay prior to the collection point would not be taken into account.

Given these challenges, we hypothesize that at least three collection points will be necessary for accurate and timely estimation of delay time. Further collection points may be necessary. And, additional information such as time and status of chain requirements will be needed to obtain accurate estimates.

It is desirable that estimates be accurate to within 10 minutes. It is understood that USDOT uses a 20 minute maximum error.

Note further that this project does not include implementation of display of real-time delay estimates to the traveling public via CMS, the World Wide Web, or otherwise. Doing so would require subsequent implementation of the algorithm developed within this scope, and interfaces to external systems for message display.

DEPLOYMENT LOCATION RECOMMENDATIONS

The project team investigated a number of potential sites for prospective deployment of Bluetooth readers relative to the Fawndale chain-up area. Only sites with existing infrastructure (power and structure) were considered. While data communication capability at a site is necessary, some sites were considered that currently do not have communication equipment. It was assumed that communication could be established at these sites. Existing CCTV and CMS sites were considered, as well as locations having luminaires and road signs. A total of 21 prospective sites were identified.

The prospective sites were then prioritized based on the assumption that between three and eight Bluetooth readers would be deployed. Two readers could possibly be used to estimate delay, with one reader prior to the queue and a second reader subsequent to the queue. Additional readers could detect presence in the in the queue, given sufficient range. However, with queues potentially reaching Redding, multiple readers would be necessary to accurately determine the length of the queue. Therefore, we assume that at least three readers would be necessary.

Table 1 and Table 2 show the prospective sites with prioritization and alternatives identified, along with specific location information. For several of the prioritized sites, alternatives are designed with an apostrophe.

The highest priority (1) is given to the Fawndale Rd, corresponding to the overpass immediately north of the chain-up area. It is assumed that this site could be used to detect vehicles immediately exiting the queue as well as vehicles at the head of the queue. The second highest priority (3) is given to the CCTV site on the Pit River Bridge, which would correspond to free flow subsequent to chain up. Two alternatives are presented for a third site, with priority given to the Anderson CCTV site (3) over the SR44 CCTV site (3') in Redding. It is understood that queues could potentially reach beyond the SR44 site (3'), so it may be necessary to go as far as the Anderson CCTV site (3) for free flow prior to the queue. A potential drawback of using a site that far away is that there will be more detections corresponding to traffic that is not intent on following I-5 north or Redding.

Additional sites (4 or 4', 5 or 5', 6 or 6', 7 or 7', 8 or 8') would provide a balance in distinguishing between free flow and the queue prior to chain up, helping to better determine the queue length. If feasible, it is assumed that more readers will provide more accurate estimates of queue length and delay.

See Figure 1 for a map of the prospective sites.

Table 1: Prospective Sites for Bluetooth Readers with Priorities and Alternatives

No.	Priority	Name	Area	Type	Distance from Fawndale	Traffic Lane
1	2	Pit River Brdg	Shasta Lake	CCTV	2.6	NB
2		Pit River Luminaire	Shasta Lake	Luminaire	1.8	NB
3	1	Fawndale Rd	Fawndale	CCTV	0.0	SB
4	5'	Fawndale Rd	Fawndale	Luminaire	0.5	NB
5	5	Fawndale Rd	Fawndale	Luminaire	0.9	NB
6	6'	Old Oregon Trail	Mountain Gate	Luminaire	1.6	NB
7	6	Old Oregon Trail	Mountain Gate	Luminaire	2.2	NB
8		Cascade Blvd	Shasta Lake City	Overhead Sign	3.6	SB
9	7	Shasta Dam Blvd	Shasta Lake City	Luminaire	3.9	NB
10		Shasta Dam Blvd	Shasta Lake City	Overhead Sign	3.9	
11	7'	Shasta Dam Blvd	Shasta Lake City	Luminaire	4.2	NB
12		Shasta Dam Blvd	Shasta Lake City	Road Sign	4.3	NB
13	4	Pine Grove Ave	Pine Grove	CCTV	5.0	SB
14	4'	Pine Grove Ave	Pine Grove	CMS	5.0	Overpass
15	8'	Oasis Rd	Redding	CMS	6.6	Overpass
16	8	SR273	Redding	CCTV	7.4	SB
17	3'	SR44	Redding	CCTV	10.6	Between lanes
18		Hartnell Ave	Redding	CCTV	12.1	SB
19		South Bonnyview	Redding	CCTV	13.9	SB
20		Smith Road	Redding	CMS	15.2	Overpass
21	3	Riverside Ave	Anderson	CCTV	19.3	SB

Table 2: Prospective Sites for Bluetooth Readers with Specific Lat/Lon Locations

No.	Priority	Name	Area	Type	Traffic Lane	lat	lon
1	2	Pit River Brdg	Shasta Lake	CCTV	NB	40.757574	-122.319179
2		Pit River Luminaire	Shasta Lake	Luminaire	NB	40.753145	-122.321419
3	1	Fawndale Rd	Fawndale	CCTV	SB	40.730836	-122.320437
4	5'	Fawndale Rd	Fawndale	Luminaire	NB	40.724468	-122.323994
5	5	Fawndale Rd	Fawndale	Luminaire	NB	40.719512	-122.328300
6	6'	Old Oregon Trail	Mountain Gate	Luminaire	NB	40.709976	-122.334307
7	6	Old Oregon Trail	Mountain Gate	Luminaire	NB	40.702829	-122.338737
8		Cascade Blvd	Shasta Lake City	Overhead Sign	SB	40.683147	-122.347547
9	7	Shasta Dam Blvd	Shasta Lake City	Luminaire	NB	40.679579	-122.348119
10		Shasta Dam Blvd	Shasta Lake City	Overhead Sign		40.679457	-122.348588
11	7'	Shasta Dam Blvd	Shasta Lake City	Luminaire	NB	40.674442	-122.350208
12		Shasta Dam Blvd	Shasta Lake City	Road Sign	NB	40.673489	-122.350711
13	4	Pine Grove Ave	Pine Grove	CCTV	SB	40.663542	-122.355925
14	4'	Pine Grove Ave	Pine Grove	CMS	Overpass	40.663417	-122.355437
15	8'	Oasis Rd	Redding	CMS	Overpass	40.641515	-122.364831
16	8	SR273	Redding	CCTV	SB	40.630400	-122.369041
17	3'	SR44	Redding	CCTV	Between lanes	40.585071	-122.360535
18		Hartnell Ave	Redding	CCTV	SB	40.563934	-122.359417
19		South Bonnyview	Redding	CCTV	SB	40.538300	-122.351334
20		Smith Road	Redding	CMS	Overpass	40.520044	-122.345063
21	3	Riverside Ave	Anderson	CCTV	SB	40.468052	-122.307651

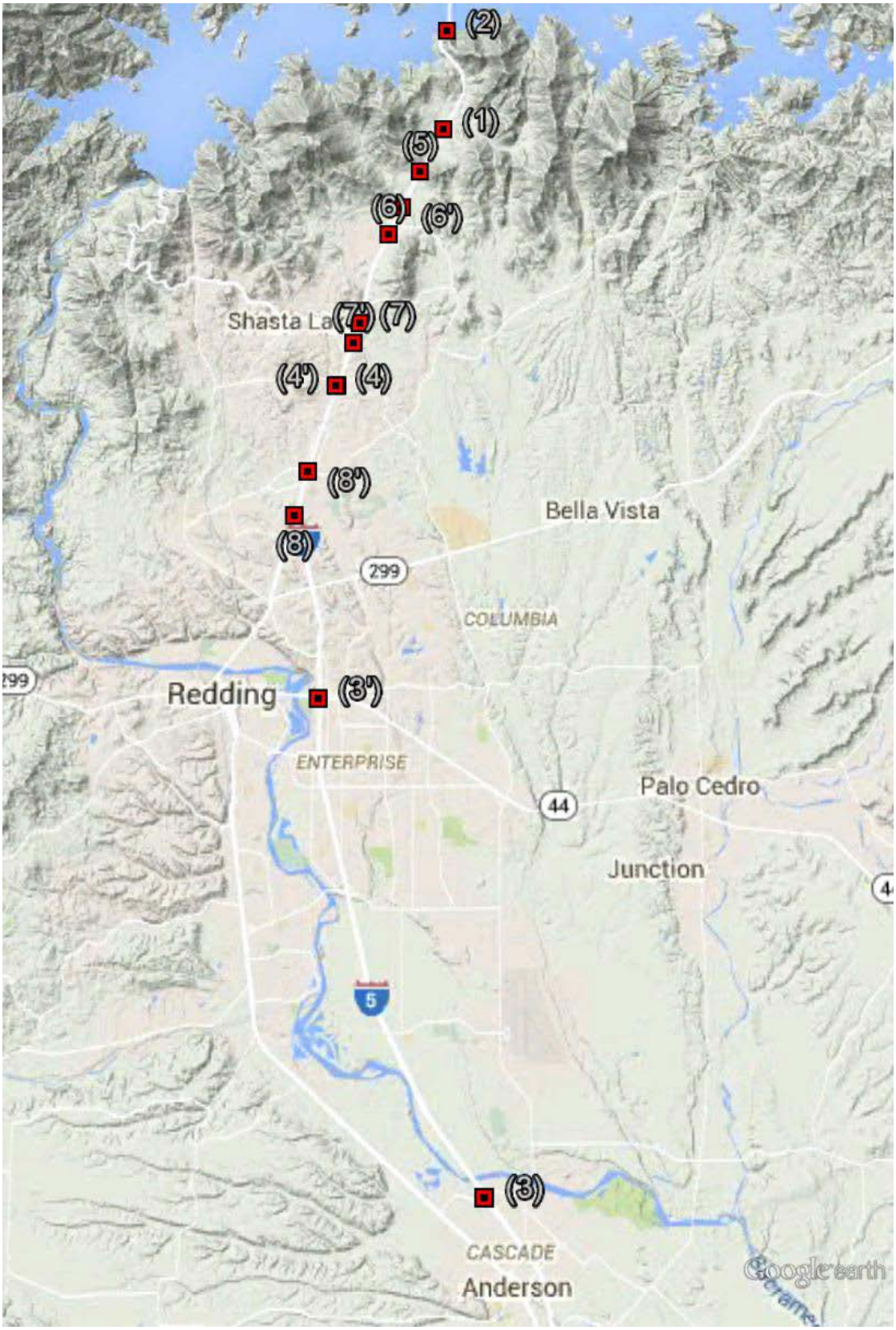

Figure 4: Prospective Sites for Bluetooth Readers

BLUETOOTH READER SOURCES AND RECOMMENDATIONS

Sources of applicable Bluetooth readers were identified. Initially Bluetooth readers developed by Caltrans were to be used but those readers are no longer available. The project team determined that the most important criteria for Bluetooth readers for this application are:

- Availability of raw data (MAC addresses and timestamps), which is needed for algorithm development and evaluation.
- Long detection range – the greater the range the better the detection percentage. A 100 meter minimum is realistic, and a longer range would be better.
- No (cellular) data service required – this would be an extra/unnecessary expense and the service may not be available at all deployment locations. At a minimum, for the purposes of algorithm development, logging capability with significant local storage would be necessary. For implementation, an Ethernet interface and capability to operate on a through a private network are necessary.

Useful options include:

- WiFi reader capability – several research reports indicate an increase in detection percentage.
- GPS receiver – for consistent time stamps across readers without network connectivity.

One very important aspect that is not addressed in this summary is the dependence on a central server and aggregation point for real-time aggregation and analysis of the data collected by the readers. Certainly every commercial product requires this. However, the intent of this project is not to analyze the algorithms used by commercial vendors or other sources, but instead to develop an algorithm that is customized for the chain-up situation at Fawndale. As such, it is most important that the systems collect and store the raw data so that it can be subsequently retrieved and analyzed. This could be done in the context of a client-server based source offering or by way of local storage and retrieval from the individual readers. Further investigation will be necessary to determine which of these alternatives is most feasible for deployment on this project.

Table 3 and Table 4 below show a list of available Bluetooth readers with the most important features. The readers recommended for further investigation are highlighted.

Table 3: Bluetooth Reader Provider List (Part 1)

Company	Model	Raw Data Available	Range	WiFi	Comm.	Reader Cost/ea.	Product Link
Traffic Cast	Blue TOAD	no	30m	no	GSM cellular	$4000	http://trafficcast.com/docs/TrafficCast-BlueTOAD-Cutsheet-Cellular-Ethernet-Final021412.pdf
"	POE-Blue TOAD	no	30m	no	Ethernet		http://trafficcast.com/docs/TrafficCast-BlueTOAD-Cutsheet-Cellular-Ethernet-Final021412.pdf
"	Mini-Blue TOAD	no	none given	no	none	-	none
Blip Systems	Blip Track	no	150m	no	3G, Ethernet	-	http://www.blipsystems.com/wp-content/uploads/2014/08/BlipTrack-Bluetooth-Traffic-Sensor_ENG.pdf
"	Blip Track WiFi	no	none given	yes	none	-	http://www.blipsystems.com/wp-content/uploads/2014/08/BlipTrack-Wi-Fi-Traffic-Sensor_ENG.pdf
Traffax Inc.	BluFAX	Yes	100m	no	GSM cellular	-	http://www.traffaxinc.com/content/blufax-sensors
"	BluFAX Solar	Yes	100m	no	GSM cellular	-	http://www.traffaxinc.com/content/blufax-sensors
"	BluFAX Chandler	Yes	100m	no	GSM cellular, Ethernet	$3412	http://www.traffaxinc.com/content/blufax-sensors
"	BluFAX Card Unit	Yes	100m	no	GSM cellular, Ethernet	-	http://www.traffaxinc.com/content/blufax-sensors
Clearview Traffic Group Ltd	Golden River M830	Device Id	500m	no	GPRS/3G, Ethernet	-	http://www.clearviewtraffic.com/images/products/51-m830-bluetooth-traffic-monitoring-system_specsheet.pdf
TDC Traffic Systems	HI-TRAC BLUE	Not in specification	none given	yes	cellular, Ethernet	-	http://www.tdcsystems.co.uk/uploads/pdfs/products/HI-TRAC-BLUE-Datasheet-WebV5.pdf

Table 4: Bluetooth Reader Provider List (Part 2)

Company	Model	Raw Data Available	Range	WiFi	Comm.	Reader Cost/ea.	Product Link
Post Oak Traffic Systems	AWAM	Yes	100m	no	Ethernet	-	http://www.postoaktraffic.com/docs/potsi_awam_spec.pdf
Libelium	Vehicle Traffic Monitoring Platform	Not in specification	100m	yes	ZigBee, Bluetooth, GPRS	-	http://www.libelium.com/downloads/documentation/waspmote_datasheet.pdf
"	Meshlium Xtreme	Yes	20-30m	yes	WiFi, ZigBee, 3G/GPRS, Ethernet	-	http://www.libelium.com/downloads/documentation/meshlium_datasheet.pdf
Savari Networks	Street WAVE	Yes	none given	option	Ethernet, WiFi, 3G	$3250	http://www.savarinetworks.com/test/files/BT-RSU-Datasheet_web.pdf
DigiWest LLC	Blue MAC	yes	300m	no	Ethernet, GSM	$1590	http://www.mybluemac.com/?page_id=1255
Trafficnow	Deep Blue Cab	Not in specificaion	none given	no	Ethernet, GSM	-	http://www.deepbluesensor.com/images/pdf/CAB-I_en.pdf
"	Deep Blue SC	Not in specificaion	none given	no	Ethernet, GSM	-	http://www.deepbluesensor.com/images/pdf/SC_en.pdf
Iteris	Vantage Velocity	Yes	100m	option	Ethernet,	$3000	http://www.iteris.com/support/documents/906/VelocityDataSheet.pdf
ODOT	custom	-	-	-	-	-	None
WSDOT	MACAD	-	-	-	-	-	None

Earlier, we asserted that at least three collection points will be necessary for accurate and timely estimation of delay time. Adding one unit for WTI to work with brings the total necessary reader count to at least four.

The four readers recommended for further investigation are the Traffax Inc. BluFAX Chandler, the Savari Networks StreetWave, the DigiWest Blue MAC, and the Iteris Vantage Velocity. The StreetWave and Vantage Velocity are the only US Bluetooth readers identified with a WiFi option. Readers without a WiFi option include BluFAX Chandler and BlueMAC. Since BlueMAC and BluFAX did not have available data sheets it is difficult to tell exactly what the components and full specifications are.

Most readers have software available to purchase although some just give access to the data through a web link. With the web link all processing is done in the background and little data is available to the user just graphs and maps. The four sources recommended for further investigation reference a data collection server but give little detail.

The following sources are not recommended. Blip Systems only sells systems, no raw data and does not have a distributor in the USA, as of this writing. The Golden River M830 has no onboard data storage, only web based software and no USA distributor. TrafficCast does not provide raw data. Clearview Traffic, TDC Traffic Systems, Libelium and Trafficnow do not appear to have distributors or a presence in the USA. ODOT identified parts for their custom unit but did not have a unit to sell. Research on a University of Washington Bluetooth unit MACAD turned up Bluetooth research results but little information on the reader. Post Oak Traffic Systems AWAM has been licensed by Iteris so the reader's not available from Post Oak. Note Western Systems Networks is the distributor for Iteris and they say Iteris Vantage Velocity Bluetooth and WiFi will not work together; the technologies must be used separately. BluMAC and BluFAX do not have data sheets for their product.

CONCLUSION

In this document we presented prioritized locations and alternatives for prospective deployment of Bluetooth readers to assist in data collection for a system to estimate delay due to chain-up near Fawndale. It is estimated that at least three reader locations will be necessary, with as many as eight being desirable for greater estimation accuracy. The actual number will be determined by Caltrans relative to budgetary constraints and potential system complexity.

We recommended four sources for Bluetooth readers that are worth further consideration for the prospective deployment to test the algorithm. We noted that the intent is to test an algorithm developed within this project rather than test existing vendor-supplied algorithms. Depending on the timing of procurement relative to the publication of this document, we recommend that the list of potential providers be revisited and revised, since new offerings will likely become available and current offerings may undergo changes in functionality and pricing. For instance, at the time in which this report is being submitted, yet another vendor and product suite has come to our attention. A company named Acyclica (http://www.acyclica.com/) offers Bluetooth readers in their "Compass Product Line". There are surely other companies and products that we were not able to identify within the scope of this portion of the project.