Analysis of Bluetooth and Wi-Fi Technology to Measure Wait Times of Personal Vehicles at Arizona-Mexico Ports of Entry

ITE 2016 Western District Annual Meeting
July 2016

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Background

Project: Analysis of Bluetooth and Wi-Fi Technology to Measure Wait Times of Personal Vehicles at Arizona-Mexico Ports of Entry

Project Owner: Arizona Department of Transportation, Office of P3 Initiatives and International Affairs
Ports of Entry:

A: San Luis
B: Lukeville
C: Mariposa
D: DeConcini
E: Naco
F: Raul Hector Castro (Douglas)

Total Volume of Personal Vehicles Entering the U.S. in 2014

- A: 3,028,042
- B: 316,429
- C: 3,286,532
- D: 298,368
- E: 1,571,929

Location
Purpose of Study

To determine whether ARID devices deployed at the six Ports of Entry could collect a sufficient sample size of passenger vehicle travel time matches in order to determine (with 95% confidence) the wait time and delay of U.S. and Mexico bound personal vehicles.

And also recommend the technology most suitable for permanent implementation, in priority order.
Anonymous Re-Identification Device (ARID)

Technology used to matches anonymous MAC addresses from discoverable electronic devices (e.g., smartphones) to determine travel time along a roadway segment

Inclusive of both Bluetooth™ and Wi-Fi technologies
Wi-Fi and Bluetooth Technology

Wi-Fi and Bluetooth technologies are capable of:
- Determining Travel Time
- Congestion Mapping
- Origin-Destination Reports

Primary devices detected:
- Wi-Fi: smartphones, personal laptops
- Bluetooth: smartphones, hands-free headsets, in-vehicle navigation systems
Wi-Fi and Bluetooth Technology

Bluetooth

Bluetooth Device is Continually Scanning for Mobile Devices

Match: 1 to 4

Wi-Fi

Wi-Fi Device is Continually Listening for Mobile Devices

Match: 1 to 2
Data Collection

Purpose

To identify the following measures:

- Average Penetration Rate
- Average Delay per Vehicle
- Average vehicle-hours of total delay

We needed to deploy:

- Miovision video for traffic counts
- ARID sensors
Before devices were temporarily installed at all 6 Ports of Entry, a pilot field deployment was conducted to test the data collection capabilities of Bluetooth and Wi-Fi technologies.
Data Collection

Wi-Fi was selected as the most suitable technology for deployment at the six Ports of Entry (POE)

- Pilot field deployment of Wi-Fi technology yielded 4 times greater unique matches than Bluetooth technology

Wi-Fi ARID sensors were temporarily installed at each Port of Entry for at least two days

Two to four devices were deployed at each location

- At least one device in Sonora, Mexico and one device in Arizona
- A third device was installed at the border crossing for several POEs
Penetration Rate:
The number of unique devices identified and matched using ARID technology divided by the traffic volume observed during the same time period.

Wait Time and Delay Calculations

<table>
<thead>
<tr>
<th>Measure</th>
<th>Units</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wait Time</td>
<td>seconds</td>
<td>Crossing Time (seconds) - time required at free flow condition from check point to downstream ARID device (seconds)</td>
</tr>
<tr>
<td>Delay</td>
<td>hours</td>
<td>Wait Time (hours) - time required at free flow condition (hours)</td>
</tr>
<tr>
<td>Vehicle Delay</td>
<td>vehicle-hours</td>
<td>Delay of each vehicle (hours) x Number of vehicles</td>
</tr>
</tbody>
</table>
Data Results

Ports of Entry:

- A: San Luis
- B: Lukeville
- C: Mariposa
- D: DeConcini
- E: Naco
- F: Raul Hector Castro (Douglas)
Location A: San Luis Port of Entry

Arizona, US

Sonora, MX
Location A: SB Penetration Rate

San Luis Port of Entry, Southbound

Average Wi-Fi Match Detection Rate: 21%
**Location A: SB Average Delay**

**Average Delay per Vehicle:** 0.013 hours (0.77 minutes)

**Average Daily Vehicle Delay:** 128.61 hours

**San Luis Port of Entry, Southbound**

**US ‡ MX**
Location D: DeConcini Port of Entry

Arizona, US

Sonora, MX
Location D: SB Penetration Rate

DeConcini Port of Entry, Southbound

Average Wi-Fi Match Detection Rate: 24.5%
Location D: SB Average Delay

DeConcini Port of Entry, Southbound

Average Delay per Vehicle: 0.013 hours (0.78 minutes)

US ✉ MX

Average Delay per Vehicle: 0.013 Hours (0.78 Minutes)
Average Daily Vehicle Delay: 70.42 Veh-Hours

Average Daily Vehicle Delay: 70.42 hours
Location D: SB Penetration Rate

DeConcini Port of Entry, Northbound

Average Wi-Fi Match Detection Rate: 30.6%

MX ‡ US
Location D: NB Average Delay

Average Delay per Vehicle: 0.048 hours (2.89 Minutes)

Average Daily Vehicle Delay: 302.96 hours
Location F: Raul Hector Castro (Douglas) POE
Location F: SB Penetration Rate

Average Wi-Fi Match Detection Rate: 32%

Raul Hector Castro (Douglas)
Port of Entry, Southbound

US ⇆ MX
Location F: SB Average Delay

Average Delay per Vehicle: 0.029 hours (1.75 minutes)

Average Daily Vehicle Delay: 197.7 hours
Location F: NB Penetration Rate

Average Wi-Fi Match Detection Rate: 25.8%

Raul Hector Castro (Douglas) Port of Entry, Northbound

MX † US

Graph showing the average number of vehicles, Wi-Fi matches, and penetration rate over time of day.
Location F: NB Average Delay

Average Delay per Vehicle: 0.040 hours (2.39 Minutes)

Average Daily Vehicle Delay: 210.45 Veh-Hours
## Study Results

<table>
<thead>
<tr>
<th>Port of Entry</th>
<th>Average Vehicle Waiting Time (seconds)</th>
<th>Segment Length (mi)</th>
<th>Average Speed (mph)</th>
<th>Average Delay Per Vehicle (Minutes)</th>
<th>Average Delay Per Vehicle (Hours)</th>
<th>Average Daily Vehicle Delay (Veh-Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>San Luis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exiting U.S.</td>
<td>174</td>
<td>0.25</td>
<td>5.0</td>
<td>0.77</td>
<td>0.013</td>
<td>128.6</td>
</tr>
<tr>
<td><strong>DeConcini</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entering U.S.</td>
<td>340</td>
<td>0.18</td>
<td>2.0</td>
<td>2.89</td>
<td>0.048</td>
<td>303.0</td>
</tr>
<tr>
<td>Exiting U.S.</td>
<td>168</td>
<td>0.18</td>
<td>4.0</td>
<td>0.78</td>
<td>0.013</td>
<td>70.4</td>
</tr>
<tr>
<td><strong>Mariposa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entering U.S.</td>
<td>610</td>
<td>0.33</td>
<td>2.0</td>
<td>5.46</td>
<td>0.091</td>
<td>238.2</td>
</tr>
<tr>
<td>Exiting U.S.</td>
<td>111</td>
<td>0.35</td>
<td>11.0</td>
<td>0.96</td>
<td>0.016</td>
<td>12.0</td>
</tr>
<tr>
<td><strong>Raul Hector Castro</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entering U.S.</td>
<td>229</td>
<td>0.20</td>
<td>3.0</td>
<td>2.39</td>
<td>0.040</td>
<td>209.1</td>
</tr>
<tr>
<td>Exiting U.S.</td>
<td>163</td>
<td>0.20</td>
<td>4.0</td>
<td>1.76</td>
<td>0.029</td>
<td>197.7</td>
</tr>
<tr>
<td><strong>Lukeville</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exiting U.S.</td>
<td>60</td>
<td>0.14</td>
<td>8.0</td>
<td>0.53</td>
<td>0.009</td>
<td>3.9</td>
</tr>
<tr>
<td><strong>Naco</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entering U.S.</td>
<td>82</td>
<td>0.17</td>
<td>7.0</td>
<td>0.72</td>
<td>0.012</td>
<td>4.9</td>
</tr>
<tr>
<td>Exiting U.S.</td>
<td>61</td>
<td>0.17</td>
<td>10.0</td>
<td>0.28</td>
<td>0.005</td>
<td>3.8</td>
</tr>
</tbody>
</table>

*Note: Data shown is representative of days sampled as part of this study only*
Statistical Validation

\[
\text{Sample Size} = \left( \frac{\text{Standard Deviation}}{\text{Standard Error}} \right)^2
\]

<table>
<thead>
<tr>
<th>Port-of-Entry</th>
<th>Travel Direction</th>
<th>Time of Day Data Used</th>
<th>Sample Size Required</th>
<th>Observed Vehicles (Wi-Fi)</th>
<th>Observation Vehicles Sufficient?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>3-Hr Period</td>
<td>1-Hr Period</td>
<td>3-Hr Period</td>
</tr>
<tr>
<td>Raul Hector Castro</td>
<td>NB</td>
<td>12 pm - 3 pm</td>
<td>127</td>
<td>43</td>
<td>325</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>12 pm - 3 pm</td>
<td>4</td>
<td>2</td>
<td>217</td>
</tr>
<tr>
<td>Mariposa</td>
<td>NB</td>
<td>12 pm - 3 pm</td>
<td>88</td>
<td>30</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>12 pm - 3 pm</td>
<td>1</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Naco</td>
<td>NB</td>
<td>12 pm - 3 pm</td>
<td>8</td>
<td>3</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>4 pm - 7 pm</td>
<td>1</td>
<td>1</td>
<td>71</td>
</tr>
<tr>
<td>DeConcini</td>
<td>NB</td>
<td>12 pm - 3 pm</td>
<td>140</td>
<td>47</td>
<td>333</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>12 pm - 3 pm</td>
<td>90</td>
<td>30</td>
<td>239</td>
</tr>
<tr>
<td>Lukeville</td>
<td>NB</td>
<td>12 pm - 3 pm</td>
<td>42</td>
<td>14</td>
<td>312</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>12 pm - 3 pm</td>
<td>9</td>
<td>3</td>
<td>75</td>
</tr>
<tr>
<td>San Luis</td>
<td>NB</td>
<td>6 am - 9 am</td>
<td>117</td>
<td>39</td>
<td>229</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>12 pm - 3 pm</td>
<td>6</td>
<td>2</td>
<td>448</td>
</tr>
</tbody>
</table>
Final Recommendations

Permanent installation recommendations based on:

- Penetration Rate (ARID sensor ability to detect and match vehicles)
- Volume of Personal Vehicles
- Average Delay
- Implementation Constraints

<table>
<thead>
<tr>
<th>Rank</th>
<th>Port of Entry</th>
<th>Disposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DeConcini / Mariposa</td>
<td>Recommended for simultaneous ARID implementation, with further evaluation of sensor location at the Mariposa POE due to low penetration rates observed for this study</td>
</tr>
<tr>
<td>2</td>
<td>Raul Hector Castro</td>
<td>Recommended for ARID implementation</td>
</tr>
<tr>
<td>3</td>
<td>San Luis</td>
<td>Recommended for ARID implementation</td>
</tr>
<tr>
<td>4</td>
<td>Lukeville</td>
<td>Not recommended due to low volumes, unless peak periods are a concern</td>
</tr>
<tr>
<td>5</td>
<td>Naco</td>
<td>Not recommended due to low volumes, unless peak periods are a concern</td>
</tr>
</tbody>
</table>
Principal Findings

- The ARID technology was successful in identifying unique matches between two locations across the border, which allowed for crossing time data collection and wait time, delay, and average speed analysis.

- The pilot study of ARID devices at POE determined that:
  - Wi-Fi matches > Bluetooth matches

- Greater penetration rates were observed in the Port of Entry study than in other deployments on AZ freeways and urban arterial roadways.

- Of the four POEs with data both entering and exiting the U.S., three had higher ARID penetration rates of passenger vehicles entering the U.S from Mexico.
Principal Findings

- The highest average individual vehicle delay entering the U.S. was observed at the Mariposa POE (5.46 minutes).

- The DeConcini POE has the greatest estimated average daily vehicle delay (303 vehicle-hours).

- The results of the study allowed for the prioritization of future permanent ARID installation at the six Ports of Entry based on:
  - ARID technology identification and matching rate
  - Average delay
  - Annual average vehicle volume
  - Constraints of device installation
  - Proximity to alternate routes
Thank You
Questions and Comments are Welcome

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