Using Bluetooth Detection to Estimate the Traffic Impacts of Bridge Construction Alternatives for a Construction Manager/General Contractor Project in Fairbanks, Alaska

by Aiza Miguel, Randy Kinney, Jeanne Bowie

Abstract
The Alaska Department of Transportation and Public Facilities (DOT&PF) is developing the University Avenue Rehabilitation and Widening Project in Fairbanks, Alaska using the Construction Manager/General Contractor (CM/GC) Project delivery method. The project will widen and reconstruct University Avenue, an urban arterial with a design year AADT of 22,000 vehicles, to include access control improvements, improved pedestrian and bicycle facilities, and capacity and safety improvements for major intersections. University Avenue crosses the Chena River, and the existing 4-lane bridge will be replaced with a new structure that matches the widened University Avenue.

The CM/GC delivery process selects the Construction Contractor during the design phase to provide key input on design issues. The University Avenue Contractor proposed that a complete closure of University Avenue in the vicinity of the Chena River Bridge would enable accelerated new bridge construction at a greatly reduced cost. In addition to complete closure, a second bridge construction alternative that would maintain one lane of traffic for each direction of travel was considered. Bridge closure or constriction would alter travel patterns for a substantial portion of the University Avenue traffic, and DOT&PF was concerned about impacts on other parts of the street system. DOT&PF retained Kinney Engineering, LLC (KE) to determine impacts of the bridge construction options and necessary mitigation measures at other portions of the system that would have to be implemented as a part of the project.

To estimate the diverted traffic and the consequent impacts on the system, KE deployed 3 Bluetooth detectors in various configurations along the University Avenue corridor during December 2015. Fairbanks’ sub-zero temperatures and very limited daylight (3 hours and 40 minutes) presented considerable challenges in the data collection effort. However, it was completed with only a few complications.

KE synthesized the Bluetooth data with turning movement counts to develop a model travel patterns which would be disrupted by bridge construction. According to the model, constricting the bridge to one lane of travel in each direction would not alter travel patterns and no system improvements would be necessary. For the complete closure alternative, KE redistributed affected traffic to other system streets and intersections by assigning traffic to minimize out of direction travel. As expected, the greatest impacts occur at the immediately adjacent facilities, in particular at the nearest intersections to the University Avenue corridor. As traffic moves radially away from the project, it disperses over more links and intersections, with less impact. KE then prepared mitigation options for the impacted intersections, including modified geometrics and signal phasing.

Introduction
University Avenue is a principal urban arterial roadway in Fairbanks, Alaska, owned and maintained by the Alaska Department of Transportation and Public Facilities (DOT&PF). University Avenue is a north/south, 4-lane undivided corridor from the Mitchell Expressway to College Road/Alumni Drive with a bridge over the Chena River. The roadway, which connects to major east/west arterial roads, carries approximately 17,750 vehicles a day and is expected to serve 22,000 vehicles a day by the 2035 design year. The University Avenue Rehabilitation and Widening Project will widen the roadway to include a
raised center median with median openings and left turn lanes at regular intervals and will limit left-turn access from minor roads. The project will also include bicycle lanes and positive left-turn offset lanes at key intersections, and reconstruct the bridge over the Chena River to match the widened roadway.

The University Avenue Rehabilitation and Widening Project is using the Construction Manager/General Contractor (CM/GC) project delivery method where the Construction Contractor is part of the design phase to provide key inputs about the constructability of the project. For the reconstruction of the Chena River Bridge, the University Avenue Contractor proposed that a complete bridge closure would speed construction and reduce construction costs, as compared to the other alternative which would maintain two lanes, one in each direction during construction. Completely closing the bridge structure would divert all traffic to the Parks Highway and Peger Road, the adjacent arterial roads parallel to University Avenue. DOT&PF retained Kinney Engineering, LLC (KE) to determine the traffic impacts both bridge construction alternatives have on the surrounding intersections and mitigations that could help relieve heavily congested intersections during construction. The study area is presented in Figure 1.

![Figure 1 – Study Area](image)

This paper estimates the additional delay that would be experienced by vehicles utilizing the nearby intersections under each construction alternative and proposes mitigations that could reduce the delay at individual intersections. This paper does not quantify the costs of the proposed mitigations, the construction time reduction expected under the full closure alternative, nor the expected reduction in construction costs.

**Bluetooth Methodology**

Bluetooth detectors were used to gather origin-destination information for vehicles passing over the Chena River Bridge. Many devices such as digital cameras, cell phones, and laptop computers communicate with each other using the point-to-point networking protocol known as Bluetooth. Devices identify each other using MAC addresses. The Bluetooth detector records the MAC address and time of detection for each device it detects. This information can be compared to data collected by other Bluetooth detectors located elsewhere to determine travel time and origin-destination trends.
Three Bluetooth detectors were used for this analysis and were deployed during December of 2015. Two of the detectors were set up on Airport Way on both sides of University Avenue and were fixed there for the duration of the data collection. The third detector was set up at three different locations near the Geist Road/Johansen Expressway intersection with University Avenue. The length of deployment for each configuration of the Bluetooth detectors was determined based on traffic volumes, the assumed detection percentage of 2.5%, a 95% confidence level, and 10% allowable error. Figure 2 below presents the location and time period the detectors were operational at each location.

![Bluetooth Detector Locations](image)

At the time of deployment, the outside temperature of Fairbanks reached a low of -30 degrees Fahrenheit. The cold temperatures quickly decrease the battery life of the detectors; therefore, spare batteries were kept charged and were routinely switched out of the detectors. The detectors were mounted on light poles and had to be placed at least 6 feet above the traveled way and facing traffic. With the daylight hours being limited in the winter, during the initial deployment, the first detector was set up prior to the sun rising and the last detector set up after the sun had set. In the subsequent weeks, the movable detector was set up in the morning during twilight.

Bluetooth detectors do not detect every vehicle that passes; therefore, the data was compared to the turning movement counts at the Airport Way intersection with University Avenue to develop a percentage factor to estimate the total volume for each origin-destination pair. Figure 3 presents the volume collected from the two Bluetooth detectors on Airport Way compared to the eastbound and westbound through movement counts at the Airport Way at University Avenue intersection.
The transformed data was used to determine the hourly traffic demand crossing the Chena River Bridge. Table 1 and Table 2 below present the inferred distribution of origin-destination volumes over the bridge during the PM Peak for northbound and southbound traffic. Figure 4 graphically depicts the volumes found in the tables, with different colors representing the origin of travel and line types representing the travel destination.

<table>
<thead>
<tr>
<th>from Airport Way (eastbound left)</th>
<th>to Geist Road (continue westbound)</th>
<th>to University Avenue (continue northbound)</th>
<th>to Johansen Expressway (continue eastbound)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>106</td>
<td>93</td>
<td>75</td>
</tr>
<tr>
<td>from University Avenue (northbound)</td>
<td>40</td>
<td>181</td>
<td>125</td>
</tr>
<tr>
<td>from Airport Way (westbound right)</td>
<td>80</td>
<td>140</td>
<td>47</td>
</tr>
</tbody>
</table>

Table 1 – Origin-Destination for Northbound Traffic over Chena River Bridge, PM Peak

<table>
<thead>
<tr>
<th>from Geist Road (eastbound right)</th>
<th>to Airport Way (continue westbound)</th>
<th>to University Avenue (continue southbound)</th>
<th>to Airport Way (continue eastbound)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>80</td>
<td>106</td>
</tr>
<tr>
<td>from University Avenue (southbound)</td>
<td>80</td>
<td>225</td>
<td>125</td>
</tr>
<tr>
<td>from Johansen Expressway (westbound left)</td>
<td>33</td>
<td>112</td>
<td>79</td>
</tr>
</tbody>
</table>

Table 2 – Origin-Destination for Southbound Traffic over the Chena River Bridge, PM Peak
Two-Lane Bridge Closure

Under the two-lane bridge alternative, the analysis worst-case condition considers traffic that will enter the reduced lane section in platoons that are released from the signals to the north and to the south (Geist Road/Johansen Expressway and Airport Way intersections with University Avenue). As the traffic is released from the signal, vehicles will merge into one lane to cross the bridge. Vehicles towards the end of a platoon who must wait for their turn to enter the reduced-lane section will experience the maximum delay. The entering flowrate into the reduced-lane section was calculated using turning movement counts, signal timing, and 95th percentile queues calculated in Synchro. The discharge flowrate through the reduced-lane section was estimated to be 1 vehicle every 2 seconds, or 1,800 vehicles per hour. An additional delay that was not quantified is decreased speeds due to the merge condition. Merging will increase lane density, and principals of traffic flow indicate that speed is inversely proportional to lane density. As such, we expect that vehicle speeds within the single platoon after the merge will initially decrease. Given sufficient length of roadway after a merge point, traffic speeds will likely increase as the density is reduced through headway adjustments and finally will fully recover with the transition from one lane back to two lanes.

Table 3 presents expected conditions for vehicles that travel along University Avenue during the PM Peak hour with only two lanes open on the bridge. For comparison, Table 4 presents the additional travel time to take the Parks Highway or Peger Road instead of taking University Avenue. As the additional travel time to take another route is significantly greater than the estimated delay due to the merge condition, it is concluded that very few drivers would choose to take another route to avoid the construction; so that no mitigation would be necessary at area signalized intersections under the two-lane bridge alternative.
<table>
<thead>
<tr>
<th></th>
<th>Northbound</th>
<th>Southbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Additional Delay (s)</td>
<td>29</td>
<td>7</td>
</tr>
<tr>
<td>Maximum Additional Delay (s)</td>
<td>46</td>
<td>19</td>
</tr>
<tr>
<td>Maximum Number of Queued Vehicles</td>
<td>25</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 3 – Expected Conditions due to Merge for Traffic Crossing Two-Lane Chena River Bridge in PM Peak

<table>
<thead>
<tr>
<th></th>
<th>Parks Highway</th>
<th>Peger Road</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Northbound</td>
<td>Southbound</td>
</tr>
<tr>
<td>Additional Travel Time (s)</td>
<td>260</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>Northbound</td>
<td>Southbound</td>
</tr>
<tr>
<td></td>
<td>230</td>
<td>225</td>
</tr>
</tbody>
</table>

Table 4 – Additional Travel Time to Redirect from University Avenue to Alternate Route

**Complete Bridge Closure Analysis**

Completely closing the Chena River University Avenue Bridge would divert all traffic that currently crosses the bridge. This analysis conservatively assumes that all traffic would use either the Parks Highway or Peger Road to cross the Chena River, and the overall traffic volumes will not be reduced nor will drivers alter their schedule in response to the construction. In actuality, it is likely that some people will revise their travel patterns or will change the time of day for their travel during construction, which would result in less delay than what is shown in the analysis. There are 12 signalized intersections within the study area that would each carry portions of the diverted traffic.

Origin-destination data obtained using the Bluetooth detectors was used to redistribute the diverted traffic to either the Parks Highway or to Peger Road. Turning movement volumes for each intersection were determined by superimposing the redistributed traffic onto the existing turning movement volumes provided by DOT&PF. It was assumed that overall traffic volumes during construction will be the same as the existing traffic volumes.

Intersection operations for University Avenue and the surrounding road network were modeled in Synchro (Highway Capacity Manual methodologies). The diverted traffic is generally expected to increase delay at the study area intersections, especially for intersections where left-turn volumes are increased. Eight signalized intersections were not significantly impacted by the additional traffic and were disregarded from further discussion. Intersections and movements significantly impacted by the diverted traffic include:

- **Parks Highway Southbound at Geist Road (West Ramp)**
  - Westbound left turns – These currently operate with permissive-only phasing. The increase in delay would be mitigated by changing the phasing to protected-permissive. This involves changes to the signal infrastructure.
- **Parks Highway Northbound at Geist Road (East Ramp)**
  - Northbound left turns – Altering the signal timing by shortening the cycle length may be adequate improvements to this intersection.
- **Geist Road/Johansen Expressway at University Avenue**
  - Westbound right turns – As diverted traffic turns right onto University Avenue to resume their original route, the right-turn volume is expected to be great enough to spill out of the existing right-turn pocket, increasing delay for westbound through vehicles. This could be mitigated by lengthening the right-turn lane.
- **Peger Road at Airport Way**
  - Southbound left turns, eastbound left turns, and westbound through vehicles – This intersection operates very close to capacity in the existing condition and therefore experiences significant delay as diverted traffic is added to it. The most significant change is an increase in eastbound left-turn volumes. To accommodate the expected increase, the proposed mitigation would convert an eastbound through lane to a left-and-through lane,
thereby increasing the eastbound left turn capacity. To do this, it would be necessary to split-phase the eastbound and westbound traffic so that these movements could not enter the intersection at the same time. The impacted movements will still have a substantial delay even with the proposed mitigation, operating at LOS F.

Figure 5 presents the effects of the bridge closure on the impacted intersections and summarizes the proposed mitigation. The tables at the bottom of the figure show the increased delay and change in Level-of-Service (LOS) expected if the bridge is closed with no mitigation, as well as the increased delay and change in LOS expected if the bridge is closed and the suggested mitigation is applied. The suggested mitigations for the heavily affected movements are expected to reduce the impact of the additional traffic; however, there will still be an increase in delay for the affected movements. Note that the Peger Road intersection with Airport Way will still have significant delay even with the proposed mitigations.

It should be noted that the Airport Way intersection with University Avenue is not heavily impacted by the additional traffic and would not necessarily need to be mitigated. However, constructing the planned improvements for the intersection would allow the signal timing to accommodate the heavy movements during construction.

Conclusions
The existing Chena River Bridge is four lanes in width with sidewalks on both sides of the bridge. The four lanes on the bridge are consistent with the existing undivided four lanes on both approaches. Under the two-lane bridge alternative, two lanes of approach traffic would be merged into one lane in each direction on the bridge. The added delay due to the merge condition would be much less than the added delay for traffic diverted to Peger Road or the Parks Highway under the full bridge closure alternative. Under the two-lane alternative, we expect that very little traffic would be diverted and, therefore, no mitigations would be required at other intersections.

Under the full bridge closure alternative, all University Avenue traffic that currently crosses the bridge would be diverted to the Parks Highway or to Peger Road, significantly impacting four signalized intersections. Figure 5 identifies the intersections and movements significantly impacted by the additional traffic due to the bridge closure and the proposed mitigation.

Proposed mitigations include:

- Convert the permissive left-turn phase to protected-permissive at the west intersection of Parks Highway southbound with Geist Road (Intersection 1 in Figure 5)
- Extend the westbound right-turn lane to 425 feet at the Geist Road/Johansen Expressway intersection with University Avenue (Intersections 3 and 4 in Figure 5)
- Consider constructing the design improvements to the Airport Way and Geist Road/Johansen Expressway intersections with University Avenue prior to closing the bridge (Intersection 3 in Figure 5)
- Alter the eastbound lane assignments to include a left-through lane at the Airport Way/Peger Road intersection (Intersection 5 in Figure 5) and operate the signal with eastbound and westbound phases separated (split-phasing)
Figure 5 – Effects of Full Bridge Closure and Proposed Mitigation

1. Parks Hwy SB Ramps & Geist Rd (West)
   - Affected Movements
   - Change Due to Bridge Closure
   - Change with Mitigation
   - Description of Mitigation:
     Convert the Westbound left phasing from permissive only to permissive-protective and shorten the cycle length.

2. Parks Hwy NB Ramps & Geist Rd (East)
   - Affected Movements
   - Change Due to Bridge Closure
   - Change with Mitigation
   - Description of Mitigation:
     Shorten cycle length.

3. University Ave & Geist Rd/Johansen Expy
   - Affected Movements
   - Change Due to Bridge Closure
   - Change with Mitigation
   - Description of Mitigation:
     Extend the Westbound right-turn lane to 425 feet. Consider constructing design improvements at this intersection before closing the Chena River bridge.

4. University Ave & Airport Way
   - Affected Movements
   - Change Due to Bridge Closure
   - Change with Mitigation
   - Description of Mitigation:
     Consider constructing design improvements at this intersection before closing the Chena River bridge.

5. Peger Rd & Airport Way
   - Affected Movements
   - Change Due to Bridge Closure
   - Change with Mitigation
   - Description of Mitigation:
     Alter the Eastbound lane assignment and operate split-phased for Eastbound and Westbound movements. Remove from coordination and extend cycle length.