The unexpected closure of an interstate is a massive undertaking involving a variety of stakeholders. Such was the case in August 2015, when pier settlement of the Wildcat Creek Bridge on I-65 N in Indiana, USA required an unplanned closure of a 37-mile stretch of the interstate for approximately 31 days. The detour route had little existing intelligent transportation systems (ITS) infrastructure to assist engineers with managing operations. To fill this information need, real-time crowdsourced probe vehicle data were used to create real-time dashboards hosted on a website for use by Indiana Department of Transportation (INDOT) engineers and public safety officials to monitor mobility and queueing on the 62-mile detour route. This paper describes how the real-time dashboards were used to proactively identify congestion problems, as well as measure the impact of mitigation measures.

**Route Diversion**

The southbound bridge was too narrow to support bidirectional traffic, so the northbound traffic was diverted onto US-52 at mile marker 141 (Lebanon, IN) and returned to I-65 just north of Lafayette at Exit 193 (Figure 1a). This stretch of interstate usually carries an average annual daily traffic of 24,000 vehicles, including about 9,500 trucks, and it is an important connector between Indianapolis, IN and Chicago, IL, USA. Figure 1 shows the area of the closure and detour, with callout i of Figure 1b marking the location of the closed bridge. The detour consisted of US-52, SR-28, and US-231, shown in Figure 1a. INDOT deployed fifteen dynamic message signs (DMS) that were used to direct drivers, advising them of turns and potential queues. Additionally, there were 40 trailblazing signs marking the direction of the detour and 19 other signs, including warning signs for traffic lights and work zones. Figure 1b, callouts ii, iii, and iv, mark temporary signals that were installed, and callout v marks a four-way stop that was converted to a two-way stop, which are discussed later in the article.

Immediately after the closure, DMS near Indianapolis (and later in adjacent states) were used to advise drivers of the closure and encourage Chicago-bound traffic to take I-74 to I-57 in Illinois.
There was no traditional ITS infrastructure deployed along the rural detour route (Figure 1 and Figure 2), and only a limited number of the signals in West Lafayette had remote communication and monitoring capability. An INDOT road tube study on August 15 found that US-52 (Figure 1, Segment 1) was carrying a total of 11,000 vehicles, including 4,500 trucks, daily. The increase in US-52 volume from pre-detour traffic corresponds to just under 50 percent of the pre-closure volume on I-65.

**Probe Data Dashboard**

To support the development of a traffic management plan, the Purdue University–INDOT team adapted their freeway probe data monitoring tools to monitor speeds for the following six segments, numbered as follows in Figure 1a: 1, 2, 3

1. US-52 (I-65 Exit 141 to SR-28): 15.5 miles
2. SR-28 (US-52 to US-231): 10.7 miles
5. US-231 (US 52 to SR 18): 9.1 miles, photo shown in Figure 2

Probe data used to create the website for a real-time dashboard were obtained from a third party traffic data service that aggregates traffic speed data from a variety of sources, ranging from personal GPS units to fleet vehicle information, into one-minute representative speeds. These speeds are available on predefined segments of road that are approximately one mile in length. On busy roads, data are typically reported for every segment each minute. The dashboard data model uses the median speed from 15-minute data aggregation to represent each 15-minute period. Although quicker dashboard updates are technically possible, using the median over 15 minutes provides some basic filtering of transient anomalies and was sufficient for the dashboard described in the next section.

**Detour Route Traffic Ticker Concept**

A real-time dashboard was created to monitor the traffic along the detour route. This dashboard, named the Traffic Ticker, is shown in Figure 3. Figure 3a represents the miles of the detour route, color coded by segment, operating below 45 mph over a one-month period. This threshold has been used in previous research as a congestion threshold, but has been parameterized in the dashboard to allow users to choose different values. The colors used in Figure 3a are the same for the segments as shown in Figure 1a. 1, 2, 3

Figure 3b is a plot of the miles of detour by speed bin, with congested speeds in light orange (35–44 mph), dark orange (25–34 mph), red (15–24mph), and purple (0–14mph) over the same one-month period. In contrast to Figure 3a, Figure 3b provides an indication of severity of congestion on the detour route, but does not provide segment location information.

Figure 3a illustrates a configurable binary threshold, in this case 45 mph, and is useful for identifying gross trends at a glance. Figure 3b provides an indication of congestion intensity. Callout i shows August 7, the day that the bridge was closed. One can see that approximately 23 miles of the 60-mile detour route were operating below 45 mph (Figure 3a) and approximately 5 miles of the detour were operating in the 0–14 mph regime (Figure 3b). While this route operates at a lower speed than the Interstates, it is generally posted at 50 or 55 mph, and most of the route is not signalized. Most of the congestion during the first three days is on US-52 and SR-28 (Figure 1, Segments 1 and 2).

**Operational Changes**

To address capacity bottlenecks on segments 1 and 2, marked by callout ii in Figure 3, temporary signals were installed on US-52 at the intersection with SR-28 and SR-28 at US-231 over the first weekend of the detour. Callout iii points to the speed profile graph, where the 0–14 mph traffic (purple coloring) has largely disappeared after the installation.

With the initial capacity bottlenecks on the southern portion of the detour route addressed by two temporary signals, congestion shifted to US-231 in West Lafayette. This congestion was addressed by installing cellular modems and deploying new timing plans to synchronize the traffic signals in the West Lafayette area to prioritize northbound traffic. The positive impact of the signal synchronization on traffic congestion is shown in Figure 3 in the area of callout v.

On the northern end of the detour route (Figure 1, between segment 5 and 6), heavy queuing was observed northbound at the US-231 and SR-18 all red flasher (Figure 2). The flasher was changed from a four-way stop to two-way on August 11 (Figure 3a, callout iv). The implementation of the two way stop eliminated the queueing on that segment (Figure 4a).

![Image 2. Rural Section of US-231 and flasher at intersection with SR-18.](image)
On August 21, a third temporary signal was installed on US-52 at SR-47 (callout viii in Figure 3). This intersection is marked as callout iv on Figure 1b. The signal was installed to facilitate traffic on SR 47 entering and crossing US 52 (Figure 1a, Segment 1).

Impact of Operational Changes: Week 1
As indicated above, the temporary signals installed on US-52 at SR-28 and SR-28 at US-231 (Figure 1 callouts ii and iii) and the flasher change at SR 18 (Figure 1, callout v) were critical in resolving bottlenecks. Figure 4 provides a detailed look at the impact of those changes during the first four days of the detour. Callouts i, ii, and iii in Figure 4 correspond to new signal installations and major operational adjustments made on August 9. Callout i shows when the signal installed at US-52 and SR-28 was activated and callout ii shows the signal at SR-28 and US-231. Callout iii marks the time of the police dispatch to US-231 and SR-18 to clear the queue as a result of the 4-way stop. On Monday, August 10, the heavy queuing had all but disappeared. In the speed profile graph (Figure 4b) it can be seen that the worst queuing, shaded purple, had mostly been eliminated. Callout iv shows minor remaining congestion that was still in need of a response.

System Level Performance Summary
The previous sections described the callouts i, ii, iii, and iv in Figure 3 and the impact of temporary signal installation (see Figure 4). By the second week, the focus shifted toward operations optimization such as engaging public safety in incident response coordination (Figure 5) and signal optimization. Callout v in Figure 3 corresponds to the implementation of signal communication, cellular connection, and coordination of signal timing. As one can
see in Figure 3, immediately after the implementation of optimized timings on the corridor there were substantial improvements in corridor operations. Purdue University’s freshman student move-in on August 19 and 20 was a concern and was closely coordinated, but it did not add substantially to traffic delays.

One can also see how fragile the corridor was with regard to incidents and the importance of close coordination with public safety on incident response. Notable incidents along the corridor are shown in Figure 3 as callouts vi to xii:

- August 18 crash on Segment 1 on southern end of detour (callout vi)
- August 20 crash on Segment 1 on southern section of detour (callout vii)
- August 23 fuel truck tanker roll over on Segment 6 on northern end of detour on US 231 (callout ix)
- August 26 semi roll over and lane closure on Segment 1 on southern section of detour (callout x)
- September 4 crash on two-lane section of SR 28 on Segment 2 of detour (callout xi).

The I-65 bridge was reopened on September 6, ending the 31 day closure. Figure 6 shows an extended capture of the Traffic Ticker through September 19. Callout i corresponds to the time that the I-65 bridge was re-opened. Shortly after the re-opening, the signal timings on US-231 were returned to normal, but as can be seen by the uptick in congestion at callout ii, there were a substantial number of motorists who were still taking the detour route and it took several days for the corridor to return to pre-detour traffic conditions around September 13 (Figure 6, callout iii).

The server that the Traffic Ticker and other similar tools are hosted on experiences an average of 7,600 hits per day. During the course of the detour, that average rose to 54,417, which is a sevenfold increase. The busiest day was Aug. 18, when a crash occurred on US 52 (Figure 1a, Segment 1). On that day, there were 134,416 hits, seventeen times the usual daily average. This increase in website traffic shows how heavily this dashboard was used during the detour for monitoring conditions, particularly during incidents when there were lane closures.

![Figure 4. Detailed view of traffic ticker on first 5 days of detour operation](www.ite.org)

**Bridge Reopening and Impact on Detour Route**

The server that the Traffic Ticker and other similar tools are hosted on experiences an average of 7,600 hits per day. During the course of the detour, that average rose to 54,417, which is a sevenfold increase. The busiest day was Aug. 18, when a crash occurred on US 52 (Figure 1a, Segment 1). On that day, there were 134,416 hits, seventeen times the usual daily average. This increase in website traffic shows how heavily this dashboard was used during the detour for monitoring conditions, particularly during incidents when there were lane closures.
Conclusions

To facilitate the best possible traffic operation along the corridor, INDOT constructed three temporary signals, changed the operation of one flasher, installed 59 signs, deployed 15 message boards, and retimed the signals on US-231 to prioritize the detour traffic. Strong collaboration between INDOT, Purdue University researchers, and public safety officials allowed for anticipation of potential problems such as Purdue freshman move-in days.

This paper describes how the real-time dashboards were used to proactively identify congestion problems, as well as measure the impact of mitigation measures. After the interstate was reopened, the data show that it took about a week for the pre-detour traffic patterns to return to usual along the diversion corridor.

In addition to using the real-time data during the detour operation, the data archive has been extremely valuable for post-detour after-action reviews to help improve future response efforts.

Acknowledgments

The probe vehicle data used in this study was provided by INRIX. This work was supported by the Joint Transportation Research Program and the Indiana Department of Transportation (INDOT). The contents of this paper reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policies of the sponsoring organizations. These contents do not constitute a standard, specification, or regulation.

References

Margaret L. McNamara received bachelor and master of science degrees in civil engineering from the University of Virginia. She is currently pursuing a doctorate of philosophy in civil engineering from Purdue University, working with the Joint Transportation Research Program, conducting research in performance measures for interstate mobility, airport operations, and fleet management. She is an ITE student member.

Howell Li is a software engineer at Purdue University researching traffic signals and interstate operations. His published papers in the Transportation Research Record include signal performance measurement using big data and highway incident detection. He holds a bachelor of arts degree from New York University and a master of science degree from Purdue University.

Steve Remias, Ph.D. is an assistant professor at Wayne State University in Detroit, MI, USA. He received his bachelor of science in civil engineering from Michigan State and his master of science in civil engineering and doctorate of philosophy from Purdue University. His research interests include traffic operations, traffic signals, probe vehicle data, performance measurement, connected infrastructure, and using large data sets to solve transportation problems.

Lucy M. Richardson received a bachelor of science degree in civil engineering from Southern Methodist University in Dallas, TX, USA. She is currently pursuing a master of science in civil engineering from Purdue University and is conducting research with the Joint Transportation Research Program. She is an ITE student member.

Ed Cox, P.E. manages corridor operations for the Indiana Department of Transportation’s (INDOT) traffic management group. He has more than 23 years of experience in traffic operations for INDOT. Ed has a bachelor of science in civil engineering from Purdue University and is a registered professional engineer in Indiana. He is an ITE member.

Deborah Horton received a bachelor of science in mathematics and a master of science in education administration from Purdue University. She has 20 years of experience in grant and research administration and is currently the managing director of the Joint Transportation Research Program.

Darcy M. Bullock, P.E. is a professor of civil engineering at Purdue University and is the director of the Joint Transportation Research Program. His teaching and research interests are in the general area of traffic signal operations, probe data, and airport operations. Darcy is a registered professional engineer in Indiana. He is a member of ITE.