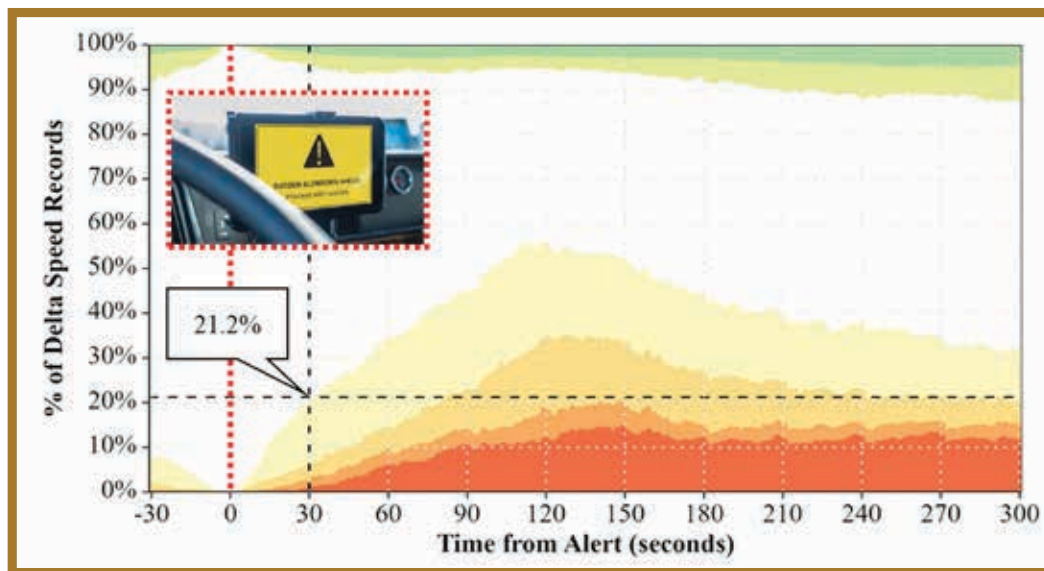


# JOINT TRANSPORTATION RESEARCH PROGRAM

INDIANA DEPARTMENT OF TRANSPORTATION  
AND PURDUE UNIVERSITY



## Communication of Fixed and Mobile Warnings to Commercial Trucks Using In-Cab Notification



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<b>16. Abstract</b> Improving commercial vehicle safety continues to be an important priority for all stakeholders. There has been considerable focus in Indiana on reducing work zone related crashes, particularly those involving commercial motor vehicles encountering unexpected slowdowns or stopped traffic on the interstate. Connected vehicle data have the potential to warn motorists of impending slowdowns and congestion in real-time. Multiple data providers have recently begun providing in-cab alerts to commercial vehicle drivers in areas of congestion, dangerous slowdowns, and work zone construction to increase driver awareness of potential hazards. This research utilized 1-second frequency data from trucks receiving in-cab alerts for Congestion or Dangerous Slowdown incidents on limited access roadways in Indiana to analyze the impact of these alerts on commercial vehicle driver behavior from about 30 seconds prior up to 5 minutes after an alert was received. Analysis of approximately 20,000 in-cab alerts sent to commercial vehicle drivers along 44 limited access corridors in Indiana for the months of April–June 2024 showed that 21.2% of drivers receiving a Dangerous Slowdown alert and 15% of drivers receiving a Congestion alert had reduced their speeds by at least 5 mph within 30 s of receiving an alert. As this area of in-cab alerts continues to evolve, it will be important to converge on a shared vision and common targets for these safety and mobility performance measures so that public agencies, in-cab alert providers, and trucking companies can work closely together to agilely improve these systems and increase driver confidence.			
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## EXECUTIVE SUMMARY

### Motivation

In 2021, there were approximately 494,000 crashes involving large trucks with about 1% of them being fatal crashes and 22% being injury crashes (Federal Motor Carrier Safety Administration [FMCSA], 2024b). Improving commercial vehicle safety continues to be an important priority for all stakeholders. There has been considerable focus in Indiana on reducing work zone related crashes, particularly those involving commercial motor vehicles encountering unexpected slowdowns or stopped traffic on the interstate. The objective of this study was to evaluate the impact of in-cab alerts received by drivers in advance of slow or stopped traffic on the interstate.

### Study

Connected vehicle data have the potential to warn motorists of impending slowdowns and congestion in real time. Multiple data providers have recently begun providing in-cab alerts to commercial vehicle drivers in areas of congestion, dangerous slowdowns, and work zone construction to increase driver awareness of potential hazards. This research utilized 1-s frequency data from trucks receiving in-cab alerts for Congestion or Dangerous Slowdown incidents on limited access roadways in Indiana to analyze the impact of these alerts on commercial vehicle driver behavior from about 30 s prior up to 5 min after an alert was received. The analysis provides stakeholders with quantifiable feedback on the impact of in-cab alerts and helps with data-driven informed decision making for future rollout of such deployments.

### Results

This study observed impacts of deployment of in-cab alerts to commercial vehicle drivers along 44 limited access corridors in Indiana for the months of April through June 2024. Approximately 20,000 alerts were generated with 92% of them being Congestion alerts and the rest being Dangerous Slowdown alerts. The evaluated vehicle speed after the alerts were used as a surrogate for determining if the driver responded to the alerts. The study found:

- 21.2% of drivers receiving a Dangerous Slowdown alert had reduced their speeds by at least 5 mph within 30 s of receiving an alert.
- 15% of drivers receiving a Congestion alert had reduced their speeds by at least 5 mph within 30 s of receiving an alert.

### Recommendations

Although these results are encouraging, the study also found that 8.1% of Congestion alerts and 8.3% of Dangerous Slowdown alerts were received by trucks when they were operating at speeds of less than or equal to 45 mph, indicating they were already in congested conditions. The study also found that 43% of trucks that received Dangerous slowdown alerts never reduced their speed below 45 mph, suggesting that drivers may lose confidence in the alerts if they do not encounter a significant slowdown in traffic after receiving the alerts. It will be important to improve these systems to further increase driver and fleet provider confidence in these systems and performance measures such as these that are essential to provide independent evaluations of in-cab alert deployments.

As this area of in-cab alerts continues to evolve, it will be important to converge on a shared vision and common targets for these safety and mobility performance measures—possibly including metrics on spatial and temporal latency of alerts as well as false positive alerting rates—so that public agencies, in-cab alert providers, and trucking companies can work closely together to agilely improve these systems and increase driver confidence.

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## 1. PROJECT OVERVIEW

### 1.1 Introduction

Recently, connected vehicle (CV) data companies have partnered with providers of in-cab devices to deliver in-cab alerts to commercial vehicle drivers in areas of congestion, dangerous slowdowns, and work zone construction to increase driver awareness of potential hazards. While past studies have utilized multiple methods to gauge driver reaction and feedback to in-cab alerts such as driver surveys, there has been a lack of visibility on actual speed data recorded from trucks receiving such alerts. Current deployments of in-cab alerts have the potential to obtain waypoint information from trucks receiving these alerts, thus enabling accurate analysis of driver response to receiving these alerts by observing changes in speeds recorded directly onboard.

Data from connected trucks receiving alerts are now available from 30 s before receipt and up to 5 min after the receipt of an alert. These before/after alert data provide an opportunity to assess driver response. An analysis of a pilot deployment in Ohio in fall 2023 observed that nearly 1 in 5 trucks receiving a Congestion or Dangerous Slowdown alert had reduced their speeds by at least 5 mph within 30 s of receiving such an alert (Desai, Mathew, & Bullock, 2024). The Federal Motor Carrier Safety Administration (FMCSA, 2024a) highlighted the valuable benefits of this technology at its April 2024 Safety Research Forum and reported that 70% of drivers receiving in-cab alerts slowed down by 8–11 mph.

It is important to ensure that commercial vehicle drivers are given sufficient advance warning but not so early that drivers lose confidence in the alert and not so late that drivers have already seen and reacted to slow or stopped traffic. In-cab alert technology can provide previously unavailable visibility into driver response using speeds recorded directly onboard the truck and, thus, has the potential to provide quantitative evidence on the effectiveness of these alerts at improving roadway safety, vital information for stakeholders at all levels looking to implement or accelerate the deployment of this technology on their roadways.

### 1.2 Scope and Objectives

The motivation behind this study was to utilize data from connected trucks that received in-cab alerts in the state of Indiana to evaluate the impact of these alerts on driver behavior as well as observe driver experience for up to 5 min after receiving such an alert. Truck speeds were used as a surrogate measure of roadway conditions experienced by the driver following an alert. The study also partitions the analysis to look at the impact of two types of alerts (Congestion and Dangerous Slowdown, as shown in Figure 1.1) on driver response. The objective of this analysis is to provide stakeholders with quantifiable data regarding the impact of in-cab alerts.

### 1.3 Dissemination of Research Results

The following research studies were prepared in part during this project to facilitate an agile dissemination of results for public and private sector stakeholders:

- Desai, J., Mathew, J., & Bullock, D. (2024) Quantifying the impact of in-cab alerts on truck speed reductions in Ohio. *Journal of Transportation Technologies*, 14(3), 273–288. <https://doi.org/10.4236/jtts.2024.143017>
- Desai, J., Saldivar-Carranza, E. D., Sakhare, R. S., Mathew, J. K., & Bullock, D. M. (2024). Impact of in-cab alerts on connected truck speed reductions in Indiana. *Vehicles*, 6(4), 1857–1871. <https://doi.org/10.3390/vehicles6040090>

A majority of the contents of this report are adapted from the research paper titled “Impact of In-Cab Alerts on Connected Truck Speed Reductions in Indiana” (Desai, Saldivar-Carranza, et al., 2024).

The research team also collaborated with *Roads & Bridges* magazine on an article highlighting the findings of this study titled “Do In-Vehicle Alerts Work?” (Bullock et al., 2024).

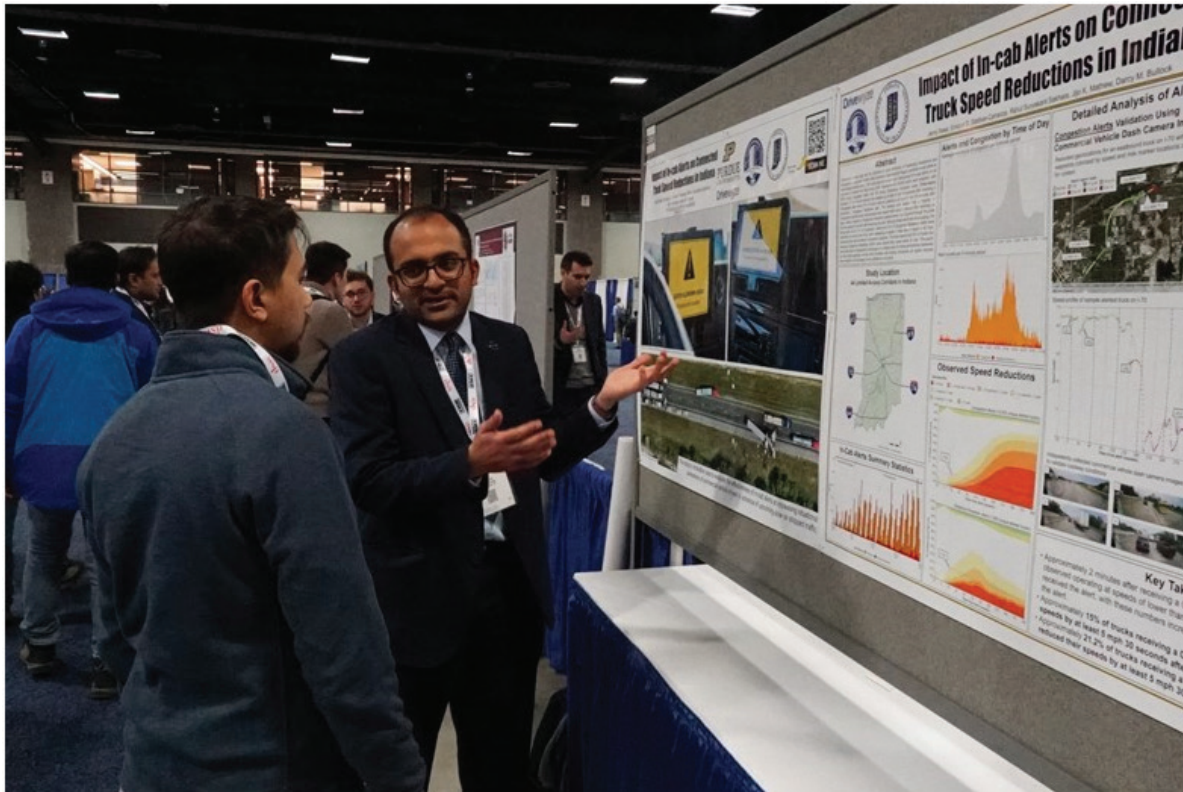
Furthermore, the findings from this study were presented to stakeholders over the course of this project at various conferences and workshops, as shown in Figure 1.2 and Figure 1.3.



**Figure 1.1** Dangerous Slowdown Alert (Used with permission: Drivewyze).



**Figure 1.2** Dissemination of Research Results: FHWA Advance Warning Workshop at Indianapolis Traffic Management Center October 2024.



**Figure 1.3** Dissemination of Research Results: Transportation Research Board Annual Meeting January 2025.

The following sections of this technical report summarize the key findings of this research.

## 2. LITERATURE REVIEW

### 2.1 In-Cab Alerts Background

Some large trucking companies have been utilizing in-cab alert technology for a number of years to advise truck drivers of upcoming delays at weigh stations through weigh station preclearance/bypass (Kwigizile et al., 2015; Lamb, 2017). This in-cab technology has additional potential in being able to warn truck drivers of upcoming traffic slowdowns, and high crash risk locations among others. The Georgia Department of Transportation (GDOT) conducted a pilot program with one such in-cab alerts provider in 2020 to issue rollover notifications to truck drivers entering predetermined zones in the Atlanta region and reported fewer incidents in some locations (Katsikides et al., 2022). More recently, a 2021 pilot study conducted by the Kentucky Transportation Cabinet (KYTC) in partnership with the Kentucky Transportation Center (KTC) and a private vendor showed the potential safety benefits of using in-cab alerts technology for warning commercial motor vehicles of upcoming roadway hazards (Howell et al., 2021). The

Virginia Department of Transportation (VDOT) has similarly partnered with an in-cab alerts provider to send out emergency weather and congestion-related alerts to commercial vehicle drivers in an ongoing study focusing on evaluating the penetration levels of this technology and driver reaction to alerts since December 2022 (Goodall & Lan, 2023). These alerts are either issued through the provider’s smartphone application or directly through the electronic logging device onboard a commercial vehicle, thus reducing the need for additional equipment retrofitting requirements in the cabin. These promising early results led to Indiana deploying this technology on its limited access corridors on 01 April 2024, and this study aims to evaluate the impact of this deployment using black box data collected from trucks receiving these alerts at a 1-s frequency.

## 3. INDIANA IN-CAB ALERTS DEPLOYMENT

### 3.1 Study Location

The study location covered 44 limited access corridors in the state of Indiana including interstate routes, US routes, and selected state and local routes, as shown in Figure 3.1. Five major primary interstates in Indiana—two running north-south (I-65, I-69) and three running east-west (I-64, I-70, I-74)—have been

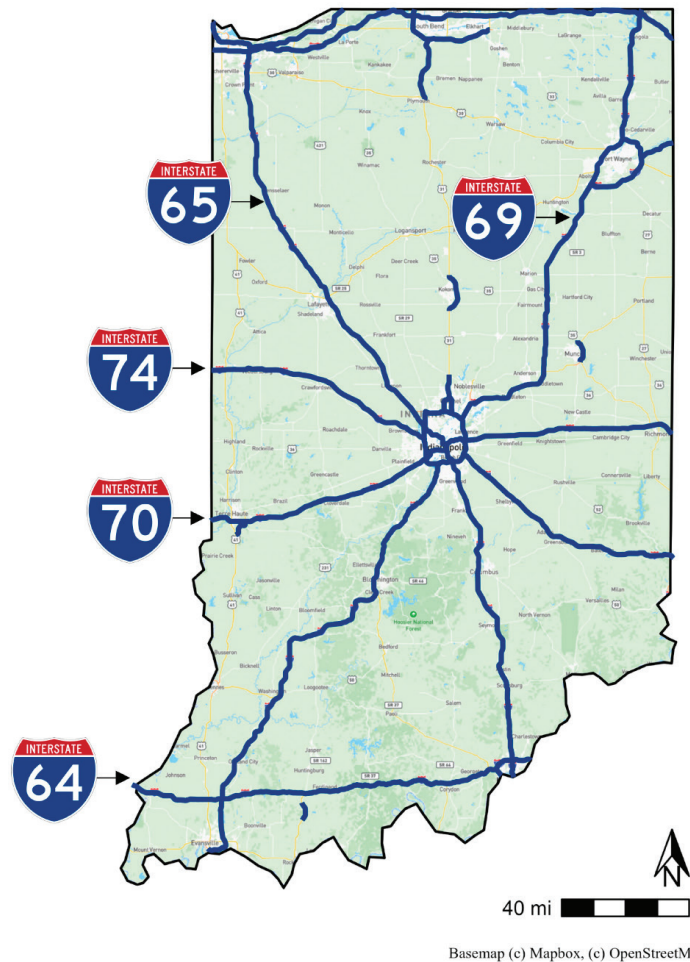


Figure 3.1 Study Location.

called out on the figure for an additional geographical context. In addition to all Indiana interstates (namely I-64, I-65, I-69, I-70, I-74, I-90, I-94, I-265, I-465, and I-469), sections of selected limited access corridors such as US-20, US-24, US-31, US-231, State Route 641, Muncie Bypass, and Keystone Parkway were also included in the Indiana deployment of in-cab alerts.

### 3.2 In-Cab Alerts Data Summary

For this study, data obtained from commercial vehicles receiving in-cab alerts through a third-party alerts provider were utilized. This data comprised waypoint information for commercial vehicles receiving an alert at nominally 1-s frequency and the corresponding speed, bearing, geolocation, and timestamp attributes for each waypoint. This data was provided to the research team through weekly transfers of files in JSON format. The overall dataset contained approximately 5.8 million waypoints representing approximately 20,000 instances of a truck receiving an alert for the period from 29 February to 30 June 2024.

- Approximately 91.8% of these alerts corresponded to Congestion alerts, which are often associated with recurring congestion.
- Approximately 8.2% of these alerts corresponded to Dangerous Slowdown alerts, which are generally associated with nonrecurring congestion.

The deployment of these in-cab alerts was conducted by a third-party alerts provider on a corridor-by-corridor incremental basis starting 29 February 2024 through the month of March. Full deployment across the study location was in place starting 01 April 2024. Daily counts of alerts sent out categorized by the type of alert are shown in Figure 3.2 with an overlay text indicating periods of incremental and full deployment. In the interest of consistency, all analysis following this section only uses data for the 3-month period of April through June 2024 when the full deployment of in-cab alerts in Indiana was in effect. This reduces the total number of alerts analyzed from 20,000 to about 18,000. Since the commencement of full deployment, on average, about 237 Congestion alerts and 20 Dangerous Slowdown alerts were observed on weekdays, while about 43 Congestion alerts and 8 Dangerous Slowdown alerts were observed on weekends.

It is informative to compare these alerts with overall interstate congestion, defined as mile-hours of interstate speeds below 45 mph. Indiana has been utilizing CV data in various forms (segment-based, trajectory-based, driver events) for the past decade (Day et al., 2016). Figure 3.2 demonstrates the weekly trends in alerts sent to commercial vehicles, with weekdays seeing the highest alert counts and significant drops on weekends in line with low truck traffic utilizing the roads on weekends. Figure 3.3 and Figure 3.4 shows a direct daily comparison between

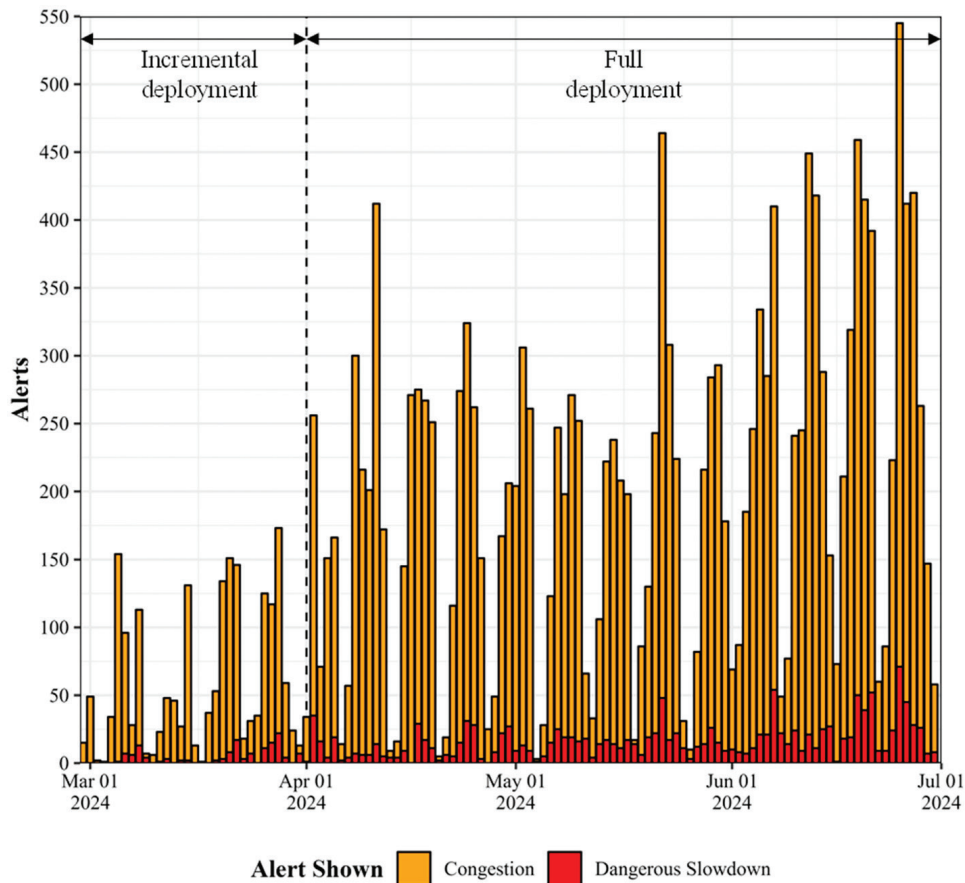


Figure 3.2 Daily Counts of Alerts Sent in Indiana.

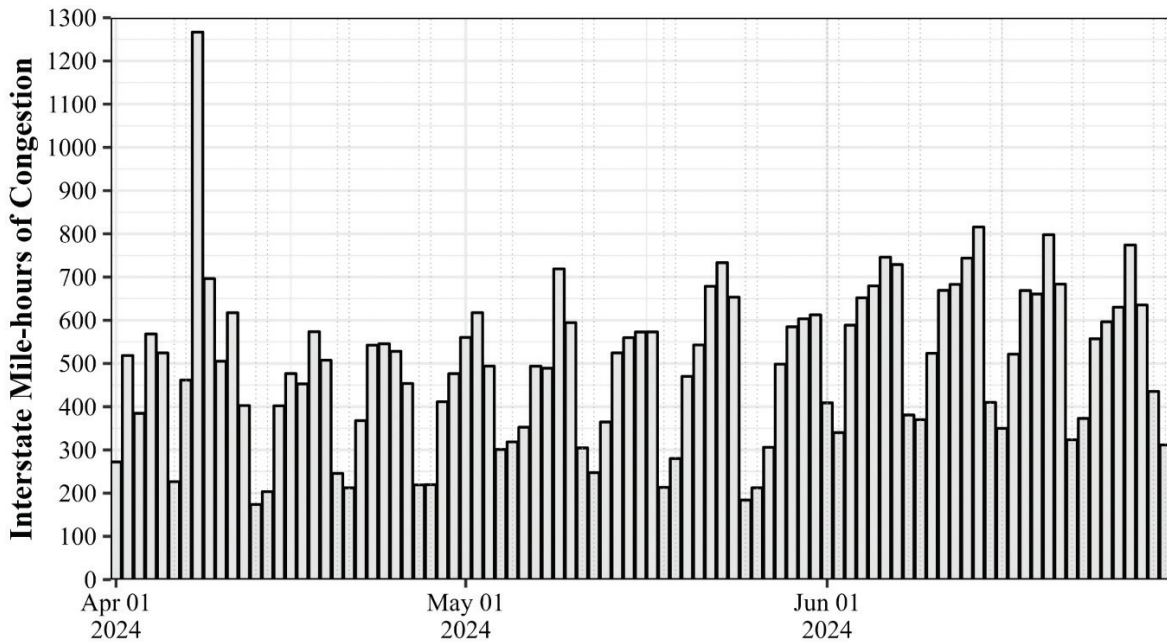


Figure 3.3 Indiana Interstate Daily Mile-Hours of Congestion By Date (April–June 2024).

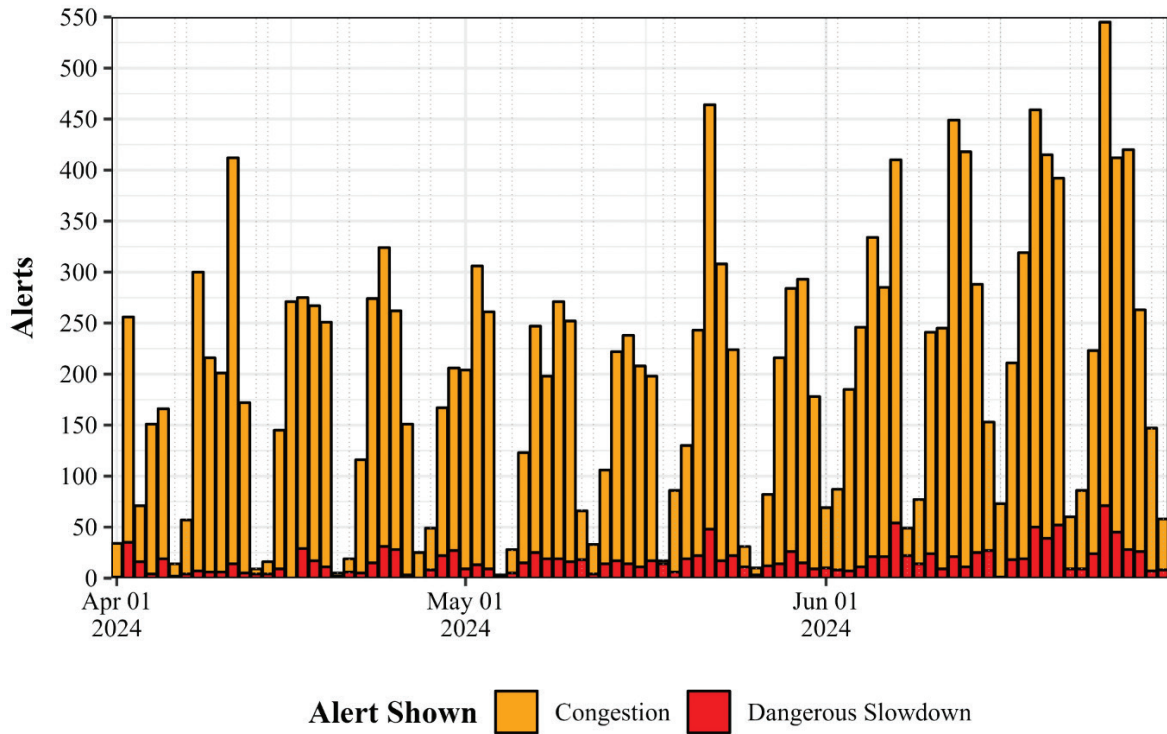


Figure 3.4 Daily In-Cab Alerts Summary Counts By Date (April–June 2024).

mile-hours of congestion on Indiana interstates and alert counts categorized by type from 1 April through 30 June 2024. Light grey vertical lines on each plot indicate Saturdays and Sundays over the analysis period. Corresponding lower numbers in alerts as well as mile-hours of congestion are evident on the weekends

on both plots. Wednesdays and Thursdays appear to show the highest congestion numbers on a weekly basis, a trend also observed in the number of alerts count in Figure 3.4.

Furthermore, a more granular comparison between alert counts and mile-hours of congestion is demonstrated in Figure 3.5 and

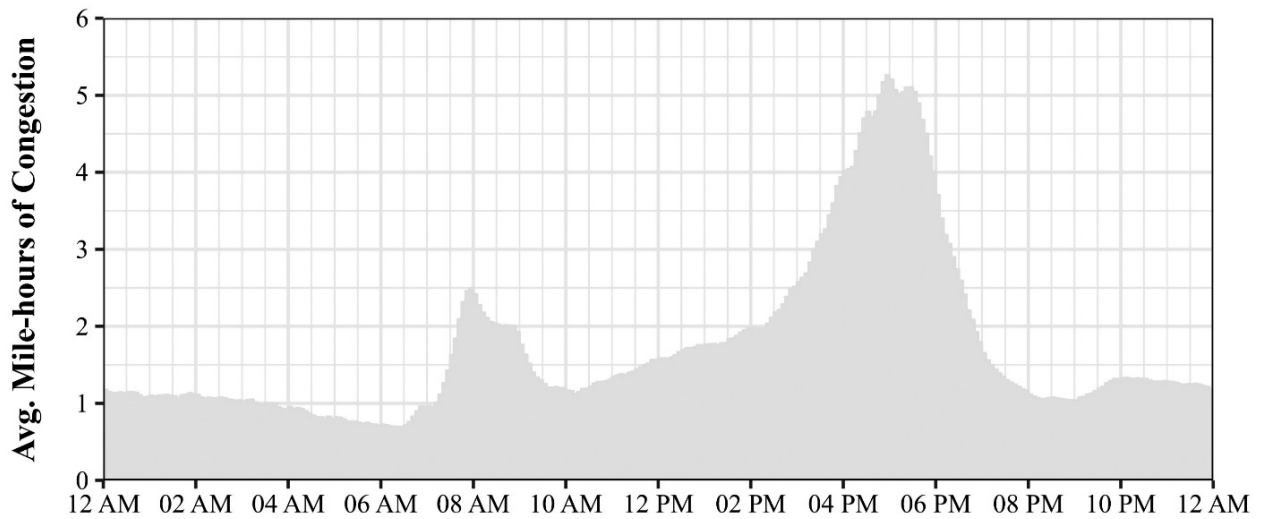


Figure 3.5 Average Mile-Hours of Congestion Per 5-Min Period By Time of Day (April–June 2024).

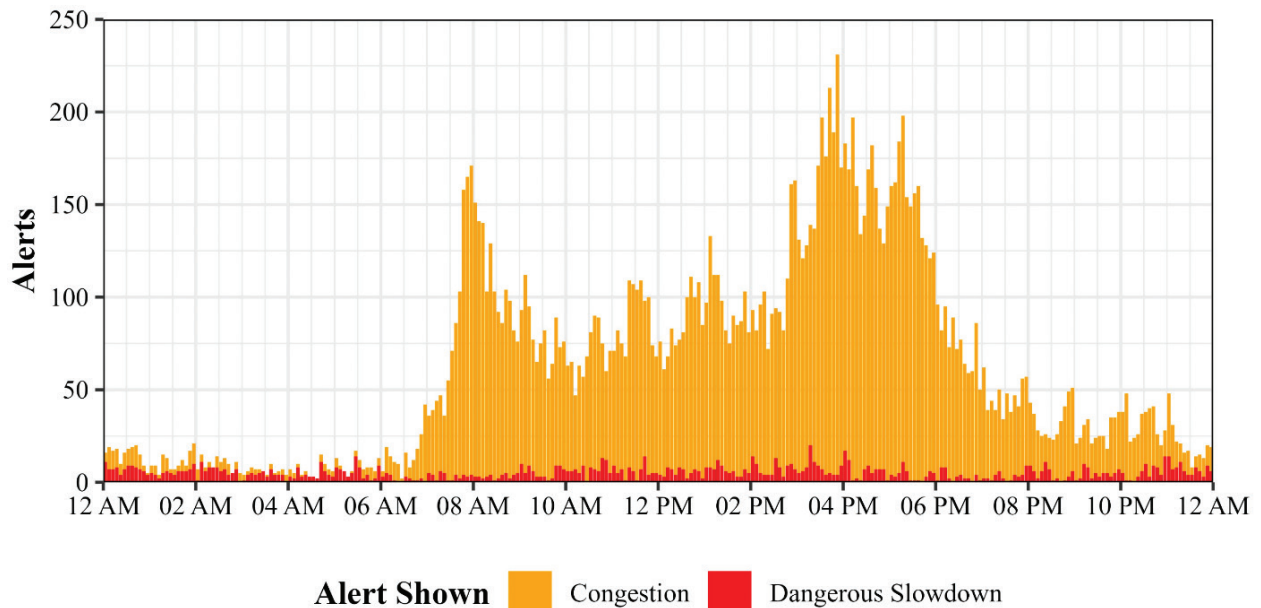


Figure 3.6 Alert Counts Per 5-Min Period By Time of Day (April–June 2024).

Figure 3.6. Figure 3.5 shows the average interstate mile-hours of congestion observed for every 5-min period of the day between April and June 2024 with clear peaks visible during the morning and evening commuting times around 6:30–10:00 a.m. and 4:00–6:00 p.m., respectively. These peaks align near identically with times for which the highest Congestion alert counts are seen in Figure 3.6. Due to the nonrecurring nature of Dangerous Slowdown events, their corresponding alert counts are dispersed throughout the day with no clear trends emerging. For the morning peak periods, 7:55–8:00 a.m. showed the highest alert counts and correspondingly, the same time also showed the highest overall average mile-hours of congestion on Indiana interstates. For the evening peak periods, 3:50–3:55 p.m. showed the overall highest number of alerts being sent out for the three-month analysis period

from April to June 2024. Correspondingly, 4:55–5:00 p.m. showed the overall highest average mile-hours of congestion on Indiana Interstates for the 3-month analysis period.

While the visuals shown herewith represent in-cab alerts and congestion summaries at a statewide level, practitioners could easily replicate these visualizations down to the route or even local level to determine if alert timing trends align with their local observations of congested roadways. The close alignment seen between times of day with heavy congestion and corresponding higher Congestion alert counts further inspires confidence in the timeliness and validity of these in-cab alerts.

Figure 3.7 depicts a summary visualization of the total number of alerts sent categorized by the Indiana corridor they were

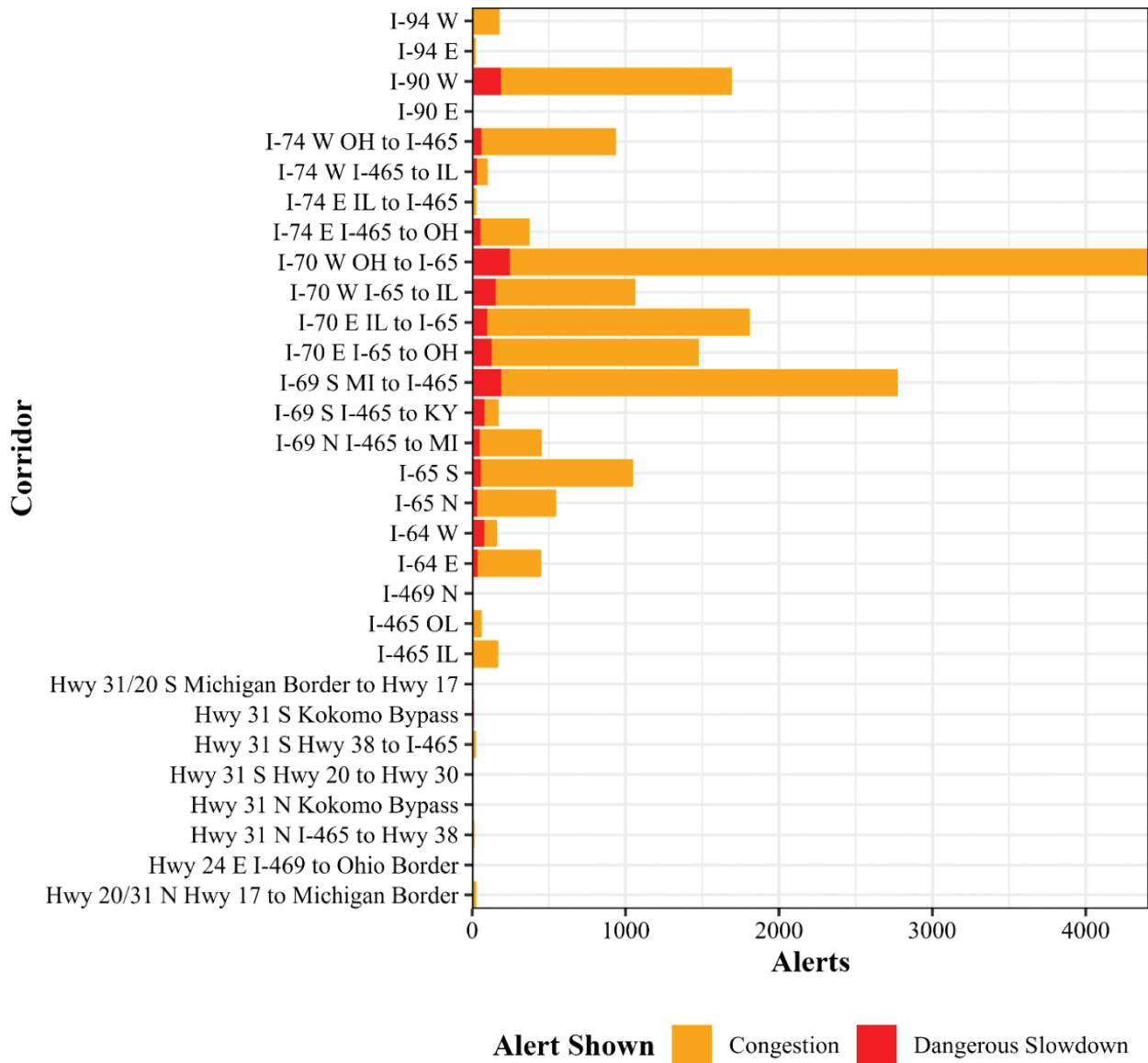


Figure 3.7 Summary of Alerts Sent By Corridor.

sent on. I-70 westbound from the Ohio state line to I-65 in downtown Indianapolis witnessed the highest number of alerts being sent (24.5% of total) followed by I-69 southbound from the Michigan state line to I-465 near north-east Indianapolis (15.4%) and I-70 eastbound from the Illinois state line to I-65 in downtown Indianapolis (10.0%). Overall, interstate corridors in Indiana accounted for 99.5% of all alerts that were sent, with the remaining 0.5% occurring on US routes. A number of roadway construction-related closures on I-465 around Indianapolis this summer of 2024 have seen significant traffic diversions onto sections of I-65 and I-70 passing through downtown Indianapolis that might be the cause for the I-70 corridor seeing a high number of Congestion alerts. Directional impacts of corridors on alert counts are also discernible from Figure 3.7. Alert counts are higher on corridors leading into Indianapolis than their complementary directional corridor leading out of

Indianapolis. For example, I-70 W OH to I-65 sees significantly higher alert counts than its complementary corridor I-70 E I-65 to OH. This may be indicative of daily commuter traffic in the greater Indianapolis region’s road network causing high numbers of Congestion alerts.

While the analysis focuses on alerts for the period of April to June 2024, the Indiana Department of Transportation (INDOT) as well as the research team were provided with access to a live dashboard by the data provider that documented statistics on the in-cab alerts that were sent in a granular fashion. Figure 3.8 shows a snapshot of this dashboard showing overall statistics on Indiana’s in-cab alerts deployment program with more than 78,000 alerts sent to more than 36,000 vehicles at the time of this writing.

The preceding text presented a high-level summary of the in-cab alerts deployment in Indiana beginning in spring 2024

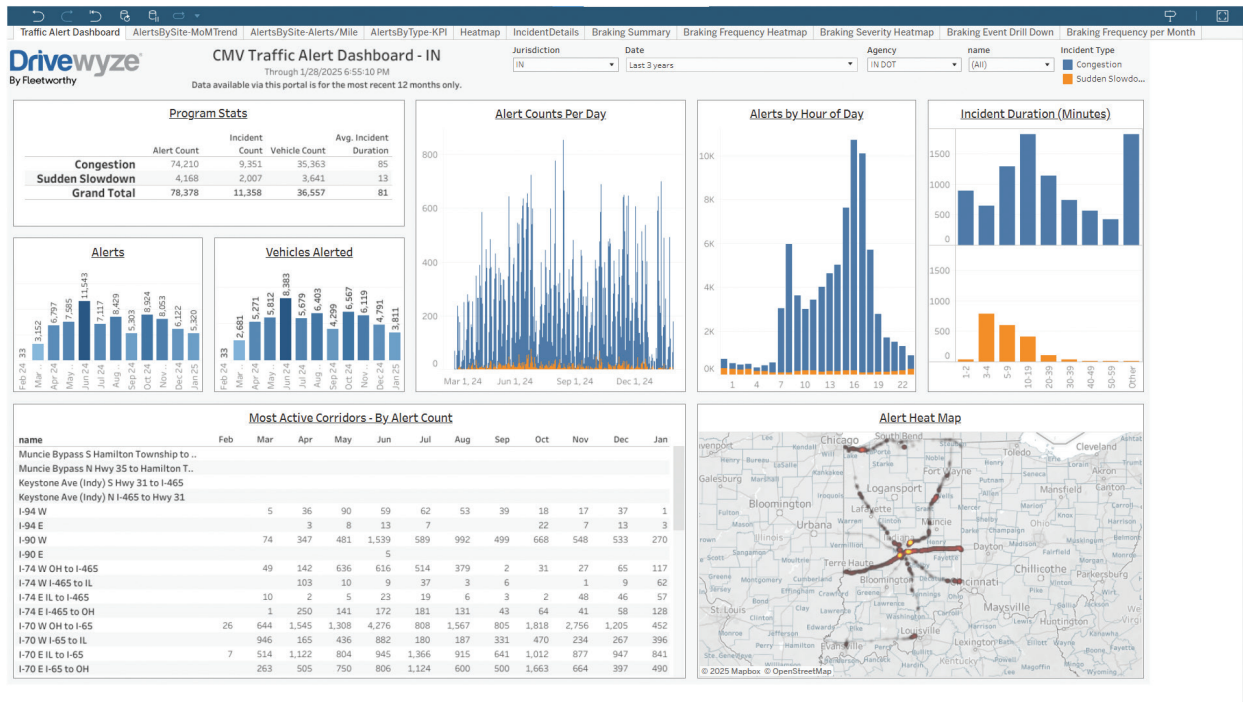


Figure 3.8 Dashboard Showing Overall Statistics on Indiana’s In-Cab Alerts Program.

at a statewide and corridor level along with time of day and day of week trends. The text that follows documents the analysis of nearly 18,000 alerts and corresponding waypoints in further detail to observe driver response to alerts as well as driver experience in the immediate aftermath of an alert.

#### 4. RESULTS

Using the raw waypoint data from each truck that received either a Congestion or Dangerous Slowdown alert, the speed at which a truck received an alert was documented, as well as the change in speed with reference to the speed at alert for every truck waypoint before and after the alert using established methodologies (Desai, Mathew, & Bullock, 2024). This allows for a longitudinal system-level analysis of the percentage of trucks operating above or below the speed at which they received the alert from 30 s prior to almost 5 min after receiving the alert. Summary statistics are derived as the change in truck speed compared to speed at the time of alerting (henceforth referred to as delta speed). Due to gaps in data reporting, there are instances when a truck does not report waypoint information every second. For the results that follow, data from only those alerted trucks are utilized where the speed at alert (T = 0) is available. This filter brings down the total number of analyzed alerts from 18,031 for April through June 2024 to 14,585 (19.1% reduction).

- Figure 4.1 includes a summary visual for 13,525 (out of 14,585) unique Congestion alerts.
- Figure 4.2 includes a similar summary visual for the remaining 1,060 unique Dangerous Slowdown alerts.

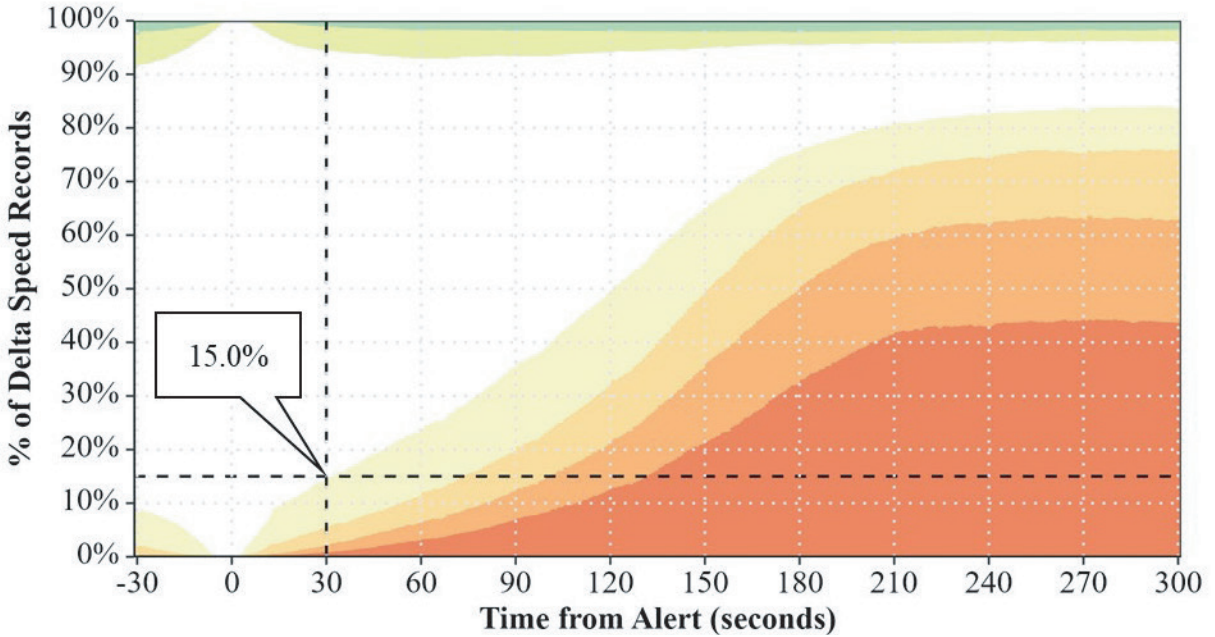
Both Figure 4.1 and Figure 4.2 show second-by-second percentage summaries of observed speed reductions compared to the speed at the time of alerting for all alerted trucks. The horizontal axis represents the time from alerting, ranging from 0.5 min before the alert to 5 min after the alert. The vertical axis represents a stacked percentage visualization of the distribution of truck delta speeds for alerted trucks with an available data point in that second. Delta speeds of -5 to +5 mph are colored by a white band as a control group to account for minor braking or data outliers and are not considered as a significant change in truck speeds. Positive delta speeds are grouped into two broad bands of 5 to 15 mph and more than 15 mph. Negative delta speeds are grouped into four bands of -5 to -15 mph, -15 to -30 mph, -30 to -45 mph, and under -45 mph. As a reference, the 0 s slice will have 100% of records in the -5 to 5 mph band to represent speeds at the time of alerting (hence zero delta speed).

Approximately 2 min after receiving a Congestion alert, most trucks were observed operating at speeds lower than 5 mph of the speed at which they received the alert, with these numbers increasing to nearly 80–85% at 3 min after the alert. Of particular note are the following:

- Approximately 15% of trucks receiving a Congestion alert had reduced their speeds by at least 5 mph 30 s after receiving an alert (Figure 4.1).
- Approximately 21.2% of trucks receiving a Dangerous Slowdown alert had reduced their speeds by at least 5 mph 30 s after receiving an alert (Figure 4.2).
- However, following the 30-s mark, each alert type shows distinctive characteristics of driver experience.

**Delta Speed Bins**

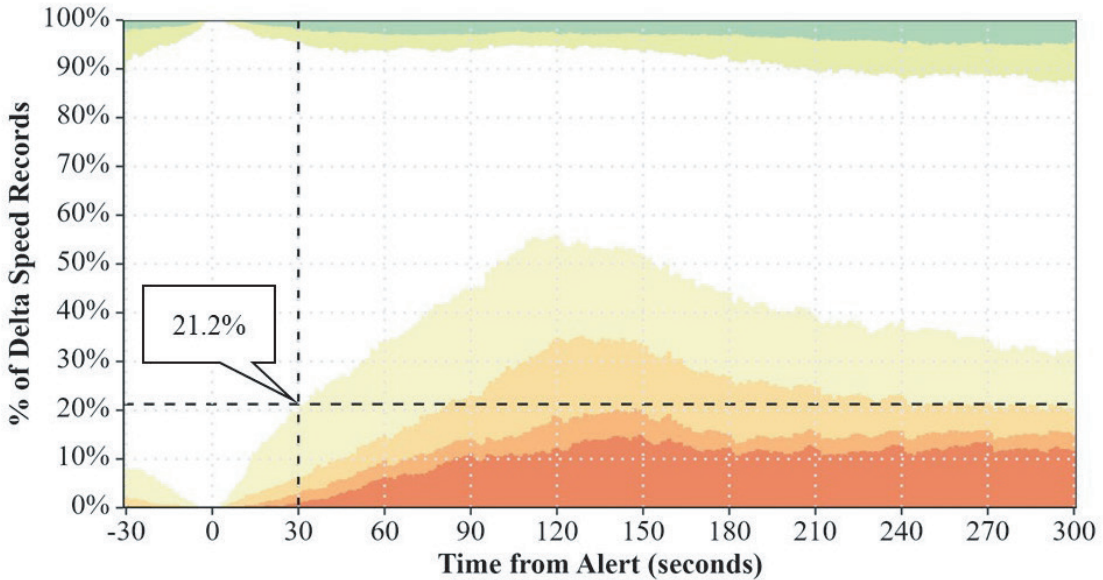
- $\leq -45$  mph
- $> -45$  mph and  $\leq -30$  mph
- $> -30$  mph and  $\leq -15$  mph
- $> -15$  mph and  $\leq -5$  mph
- $> -5$  mph and  $< 5$  mph
- $\geq 5$  mph and  $< 15$  mph
- $\geq 15$  mph



**Figure 4.1** Observed Speed Reductions for Congestion Alerts From 0.5 Min Prior to 5 Min After Alert (13,525 Unique Alerted Trucks).

**Delta Speed Bins**

- $\leq -45$  mph
- $> -45$  mph and  $\leq -30$  mph
- $> -30$  mph and  $\leq -15$  mph
- $> -15$  mph and  $\leq -5$  mph
- $> -5$  mph and  $< 5$  mph
- $\geq 5$  mph and  $< 15$  mph
- $\geq 15$  mph



**Figure 4.2** Observed Speed Reductions for Dangerous Slowdown Alerts From 0.5 Min Prior To 5 Min After Alert (1,060 Unique Alerted Trucks).

- The percentage of Congestion alerted trucks who reduce their speed by at least 5 mph consistently increases and stabilizes up to about 80–85% within 5 min.
- The percentage of Dangerous Slowdown alerted trucks who reduce their speeds by at least 5 mph increases to a maximum of about 55% by 2 min after the alert and then steadily decreases to about 30% at the 5-min mark after receiving an alert.

Traditional methods of gauging driver response to such in-cab alerts such as driver surveys lack the continuous monitoring capability provided by granular 1-s data obtained from in-cab alerted trucks. This lookahead period allows for a detailed analysis of the type of prevailing traffic speeds truck drivers experience after receiving these alerts and will help stakeholders finetune alerting algorithms to determine if the alerts are being sent too far out in advance of congested traffic or too late after trucks encounter congested traffic. A speed threshold of 45 mph has been widely used to indicate roadway congestion (Cambridge Systematics, Inc. & Texas Transportation Institute, 2005; Day et al., 2016). This same threshold was utilized to test the number of occurrences for which alerts were delivered at a time when their speeds were below this congestion threshold, indicating that the truck was already driving in congested conditions and the in-cab alert may have been redundant in warning the driver of upcoming congestion. This analysis found that 8.1% of Congestion alerts and 8.3% of Dangerous Slowdown alerts were received by trucks when they were operating at speeds of less than or equal to 45 mph, indicating they were already in congested conditions. While not ideal, these are relatively low percentages of redundant alerts and provide a performance metric for agencies to monitor alert relevance in contrast to prevailing roadway conditions. Route-by-route level analysis of this metric may yield different results as this 45-mph congested speed threshold for freeways and US routes may not hold true for state or local routes.

Summary visualizations such as these can be utilized to monitor the effectiveness of in-cab alerts at reducing truck speeds on a monthly, weekly, or even daily basis and at the systemwide or individual route level to see if alerts sent on a particular corridor (or a particular construction zone) are more effective at reducing speeds than at other locations (or corridors). Although more than 14,000 alerts were analyzed by this study, these alerts are broadly distributed across the entire state and do not present any concentrated clusters in particular locations. With enough alerting history built up in specific locations or corridors, statistical analysis may be performed to derive insights into localized factors on alert effectiveness at reducing speeds.

## 5. DETAILED ANALYSIS OF ALERTS USING INDIVIDUAL TRAJECTORIES

The following subsections demonstrate detailed analysis of in-cab alerts and their impacts using individual commercial vehicle trajectories.

### 5.1 Congestion Alerts

Figure 5.1 shows the recorded geolocations for one truck traveling eastbound on I-70 that received a Congestion alert around mile marker (MM) 74.4 (Callout i). The recorded speed as it travels through this location is shown by the color of each waypoint with free flow speeds shown in green and congested speeds (below 45 mph) indicated by the orange, red, and purple colors. Figure 5.2 shows a speed profile visualization of this truck pivoted off the timestamp at which the truck received an alert ( $T = 0$  on the horizontal axis). The vertical axis indicates the corresponding speed for each second. Callout i indicates the alert location, and callout ii indicates a time instance 30 s after the alert when the truck had traveled about half a mile and was still operating at near free flow speeds (Figure 5.2). Callout iii indicates the position of the truck 165 s after the alert when its speed had just dipped below 45 mph (entering congestion). Callout iv indicates a time instance 3.5 minutes after the alert when the truck had fully entered the zone of congestion with traffic operating at speeds under 15 mph.

Using an independently available dataset of commercial vehicle dash camera images (Sakhare, Desai, Mathew, & Bullock, 2024), images of prevailing traffic conditions at each of the locations of Callouts i, ii, iii, and iv in Figure 5.3 were obtained from a commercial vehicle that passed through the same zone within 8–10 min of the Congestion alerted truck passing through. Images i and ii in Figure 5.3 clearly indicate no visible queues at the location where the truck received an alert as well as half a mile downstream. However, image iii in Figure 5.3 shows the first signs of slow-moving traffic, aligning well with the alerted trajectory's speeds dipping below 45 mph in the same vicinity. At the location shown by image iv in Figure 5.3, fully congested traffic is visible in the images, indicative of speeds under 15 mph. This independent validation provides further confidence in the observation that most trucks receiving a Congestion alert appear to end up in slow moving traffic within 2–3 min after receiving an alert. Future research in this space will involve the use of such dash camera images and ITS camera images among others to provide validation on traffic conditions when an alert is delivered and to isolate false positives to improve the accuracy of alerts.

### 5.2 Safety Impact of a Dangerous Slowdown Alert on Hard Braking Instances

Out of a total of 1,060 Dangerous Slowdown alerts represented in Figure 4.2, only 604 alerts recorded a minimum speed of less than or equal to 45 mph (threshold for indicating congestion like prior sections). The remaining 43% of alerts associated with trucks whose speeds never dipped below 45 mph may be indicative of slowdowns that either may not have required significant driver response in terms of speed reductions when passing through or false positives wherein the connected vehicle data driving the alerts was overrepresenting slow traffic speeds and thus flagging a Dangerous Slowdown alert. Using the reduced set of 604 alerted trucks that entered the congested

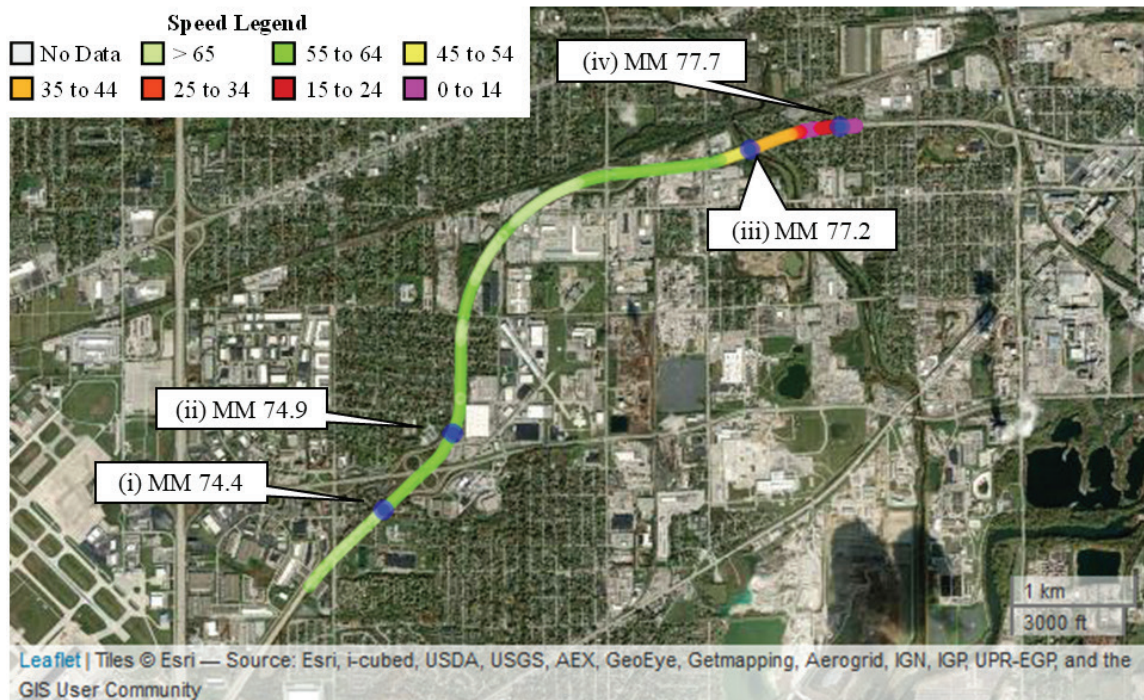


Figure 5.1 Recorded Geolocations for Eastbound Truck on I-70 Corresponding to Figure 5.2 and Figure 5.3.

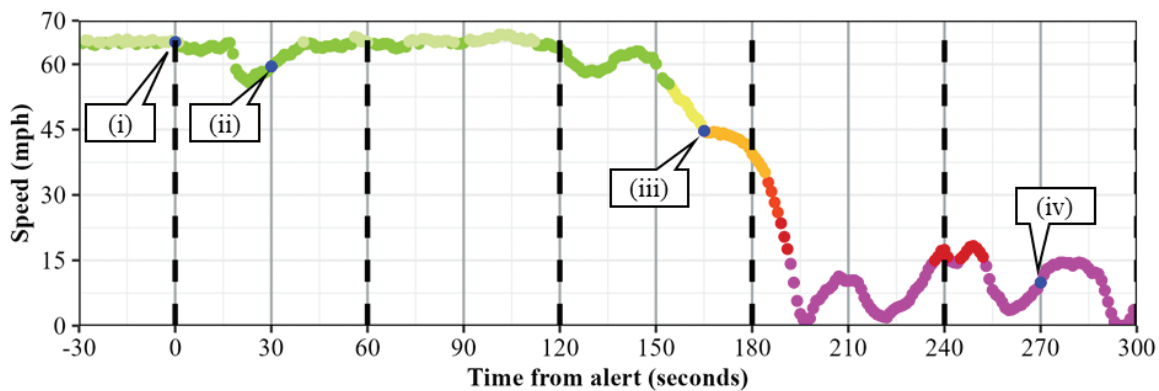


Figure 5.2 Speed Profile of Sample Alerted Truck on I-70 Corresponding to Figure 5.1 and Figure 5.3.

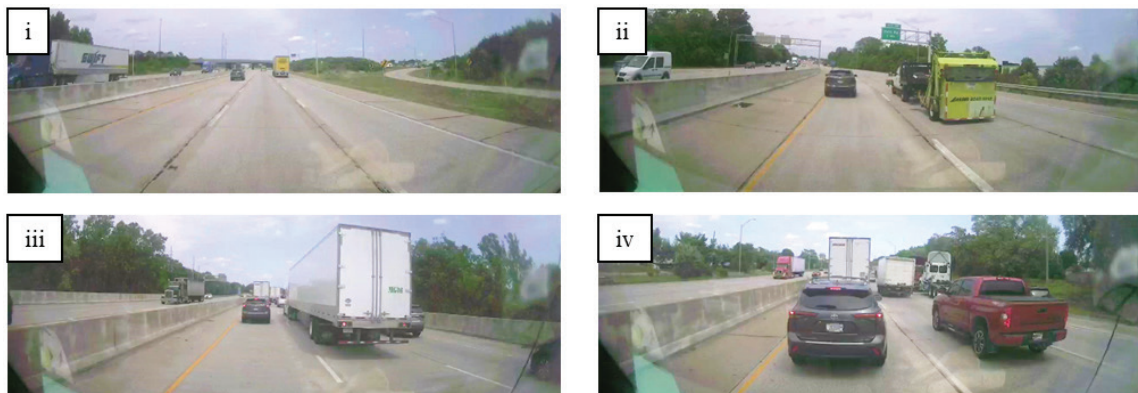
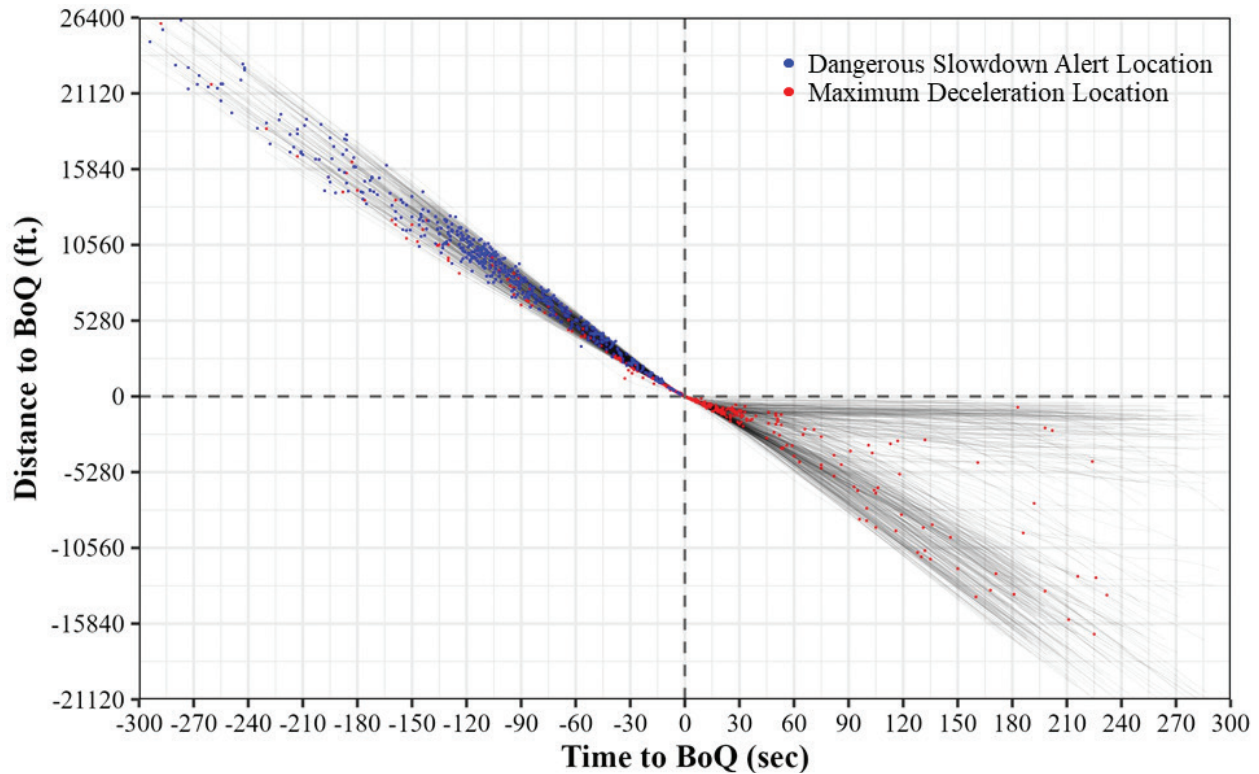


Figure 5.3 Independent Commercial Vehicle Dash Camera Images to Validate Roadway Conditions Corresponding to the Time and Location of a Congestion Alert (Figure 5.1 and Figure 5.2).

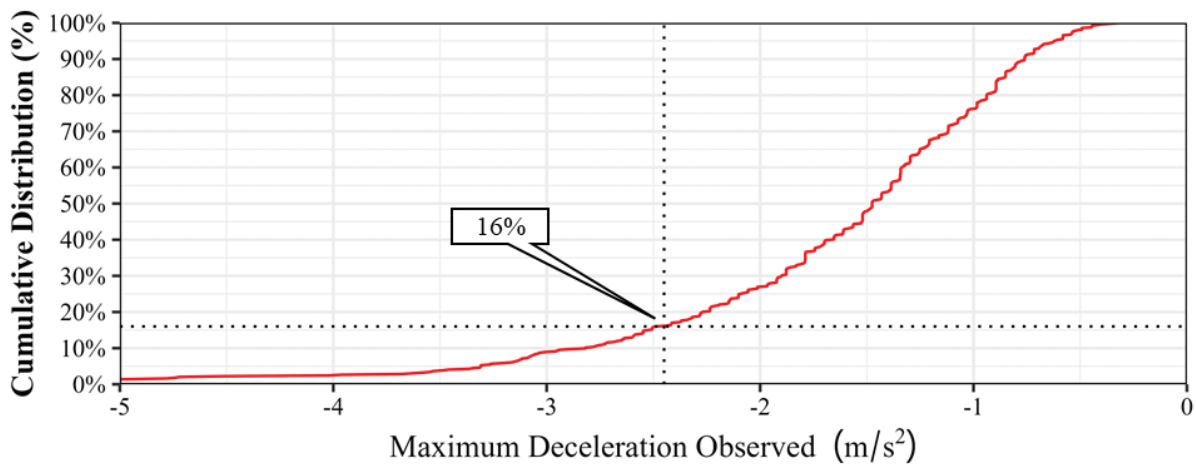
zone at one point in their trajectory, further refining was conducted to only analyze trucks that arrived at the back of queue (BoQ) only after receiving an alert. As indicated earlier, there were instances when Dangerous Slowdown alerts were received by trucks when they were traveling at or under 45 mph (already in congested conditions). By removing such trucks where the alert could have been assumed to be redundant, a final count of 494 alerted trucks was prepared for further analysis.

Figure 5.4 depicts a time-space diagram of the 494 trucks that received a Dangerous Slowdown alert, pivoted off of the location

when the truck was assumed to have reached the BoQ, chosen as the point where the truck's speed first dips below 45 mph. The time at which a truck receives an alert is indicated by a solid blue circle, while the time at which the maximum deceleration event for the entire truck trajectory is recorded (computed using pairwise speed differentials between waypoints that are generally 1-s apart) is indicated by a solid red circle along the trajectory. The vertical axis is limited to only span from about 5 mi (26,400 ft) upstream to 4 mi (21,120 ft) downstream of the BoQ location while the horizontal axis is limited to span from 5 min prior to about 5 min after BoQ.



**Figure 5.4** Summary Visualizations of Time-Space Trajectories of Trucks Receiving a Dangerous Slowdown Alert Pivoted From Timestamp at Which Truck Speeds First Dip Below 45 mph (494 Alerted Trucks).



**Figure 5.5** Cumulative Distribution of Maximum Deceleration Observed Across All Alerted Trucks.

Using this time-space trajectory level visual, which is extensively used in evaluating traffic signal performance measures (Leitner et al., 2022; Saldivar-Carranza et al., 2023; Waddell et al., 2020), the corresponding locations and times (both with respect to BoQ) where the maximum deceleration was recorded for each truck were obtained. Negative values of time to BoQ and positive values of distance to BoQ indicate times and locations upstream of BoQ, respectively. A number of truck trajectories in Figure 5.4 indicate red dots close to and preceding BoQ representing trucks that possibly received the alert but did not heed it in time and had to brake just before hitting the BoQ. Red dots downstream of BoQ possibly indicate trucks having to hard-brake due to the congested queue dynamics they are in (stop-and-go traffic). Overall, 49% of all maximum deceleration events are observed to have occurred downstream of the BoQ (pointing to queue dynamics causing braking rather than the in-cab alerts themselves) while 34% of maximum deceleration events are observed within a quarter mile upstream of BoQ, pointing to queue visibility resulting in hard-braking activity. Most of the blue circles (indicating alert locations) in Figure 5.4 are observed to be within 2 mi of the BoQ, a sufficient advance warning to trucks before they arrive at the BoQ.

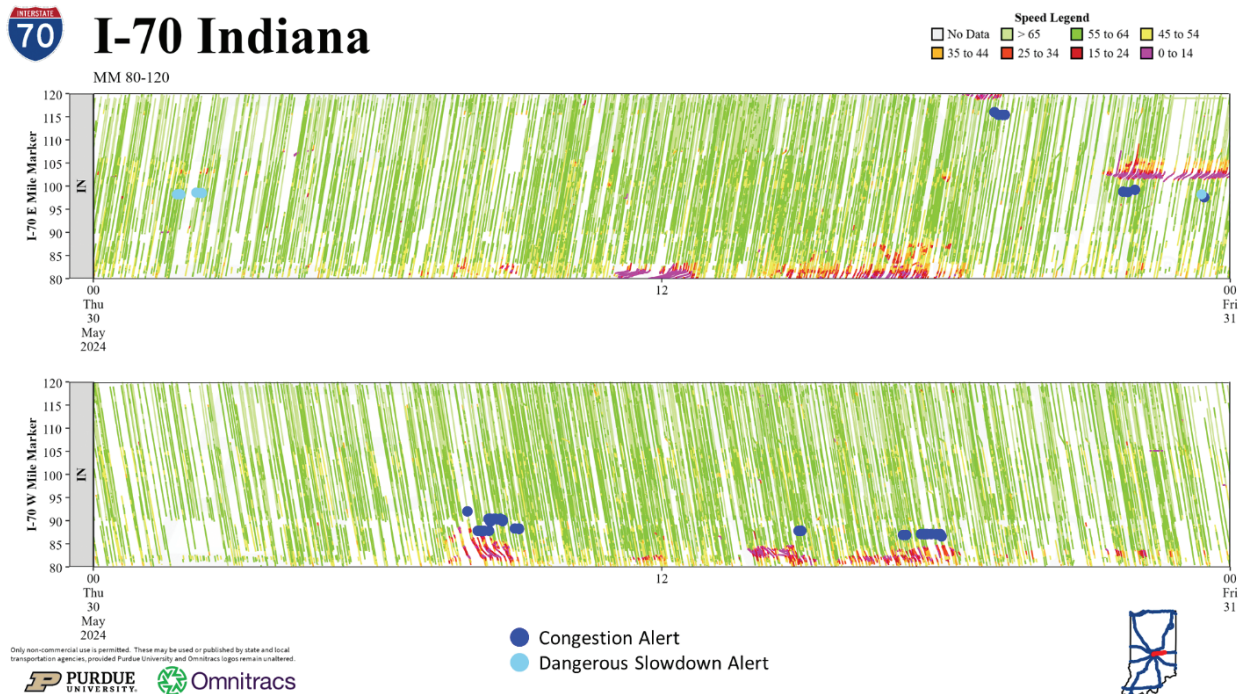
Figure 5.5 shows a cumulative frequency distribution of the actual values of maximum deceleration across all 494 alerted trucks. The emerging consensus among various stakeholders seems to be that acceleration events with values lower than  $-0.25g$  or  $-2.45 \text{ m/s}^2$  constitute a hard-braking event, which may point to a possible safety concern. The callout in Figure 5.5 clearly shows that only 16% of trucks recorded a maximum deceleration value exceeding  $-0.25g$ . In contrast, 84% of truck trucks did not have to hard-brake during their entire trajectory.

Such trajectory level analysis methodologies, accompanying visuals, and performance measures will be vital for agencies for continuous monitoring of in-cab alert deployments to ensure the alerts are having a desired impact on calming deceleration profiles as trucks approach a congested BoQ to ultimately reduce hard-braking and back of queue crashes and thus improve road safety.

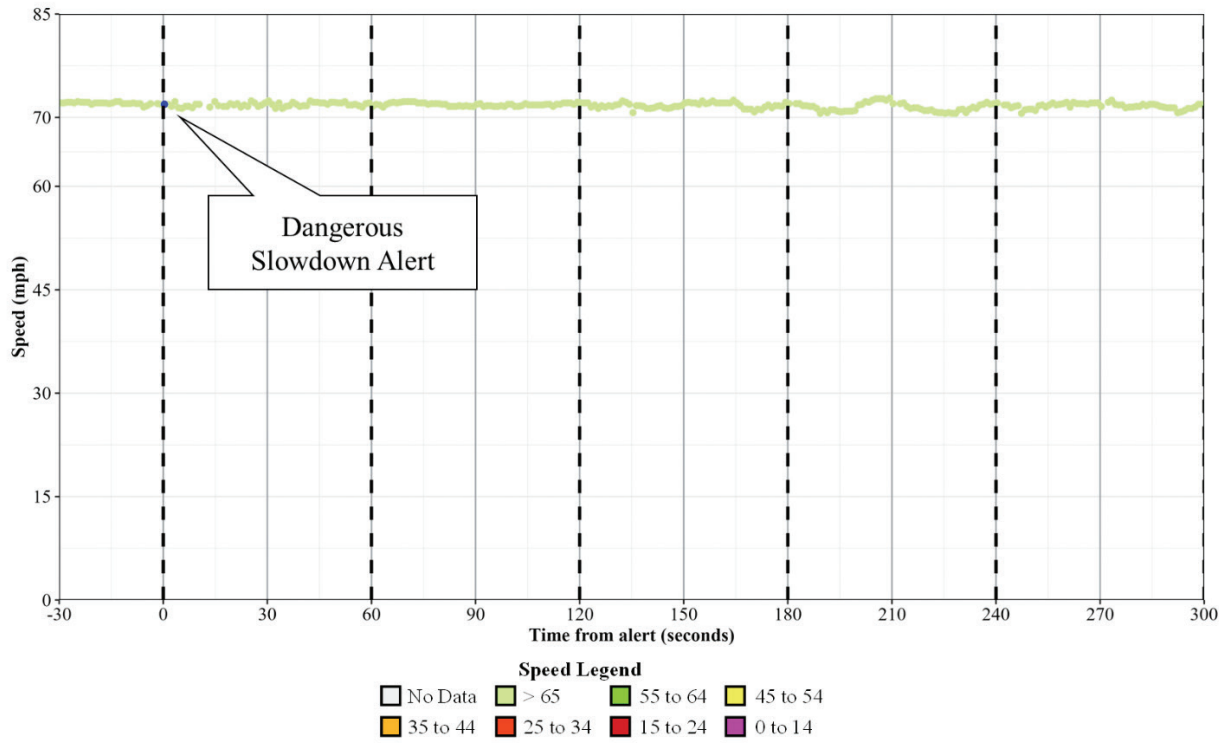
## 6. DETAILED ANALYSIS OF SPATIAL AND TEMPORAL ALERT LATENCY

### 6.1 Incorporating Connected Vehicle Data into Analysis of Alert Impacts

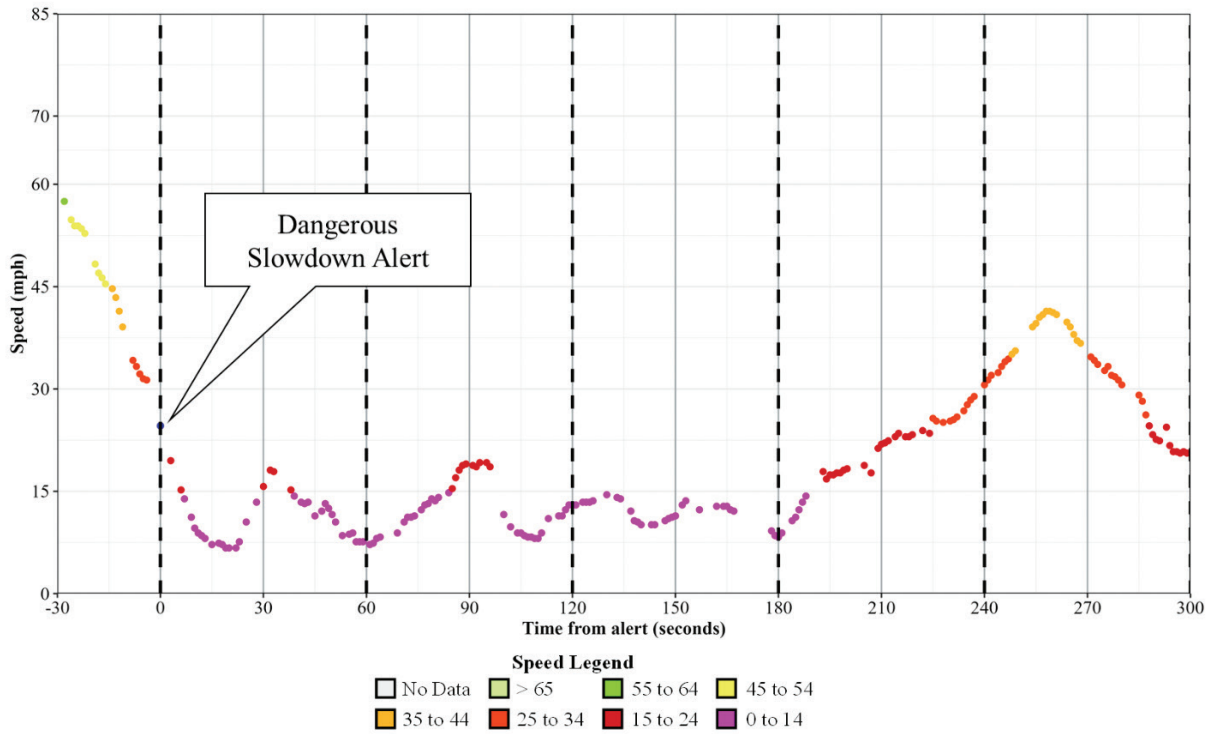
Independent sources of connected vehicle data and connected truck data can be incorporated into the analysis of alert effectiveness to validate how surrounding traffic reacted in the vicinity of an alert. Figure 6.1 shows a spatiotemporal traffic speed heatmap, a widely used graphic to visualize roadway traffic conditions (Sakhare, Desai, Mathew, McGregor, et al., 2024), for I-70 in Indiana from MM 80–120 for 30 May 2024. Locations where commercial vehicles received in-cab alerts (Congestion or Dangerous Slowdown) are shown by solid blue and solid sky-blue circles on the graphic, respectively. This overlay clearly shows that Congestion alerts were being sent to trucks well in advance of their approaching queues visible by the near constant spatial separation between Congestion alert locations and the back of the queue downstream on the roadway. Dangerous Slowdown alerts refer to nonrecurring instances of sudden slow traffic evidenced by the alert locations visible in the eastbound direction in the early morning hours around MM 95–100.



**Figure 6.1** Sample Connected Truck Data Heatmap With In-Cab Alert Locations Highlighted By Solid Circles (Blue and Sky Blue For Congestion and Dangerous Slowdown Alerts, Respectively).



**Figure 6.2** Example Speed Profile of a Truck Trajectory That Received a Dangerous Slowdown Alert But Whose Speeds Never Dropped Below 45 mph.



**Figure 6.3** An Example Speed Profile of a Truck Trajectory That Received a Dangerous Slowdown Alert When it Was Already Operating at Congested Speeds (< 45 mph).

Furthermore, granular CV data available at 3-s frequency with low latency levels offers in-cab alert providers the opportunity to fine tune their alerting algorithms to be more responsive and accurate with respect to prevailing traffic conditions, in turn helping improve driver confidence in these alerts.

## 6.2 Longitudinal Monitoring of False Alerting Rates

Although the results of this analysis are encouraging, the study also found that 8.1% of Congestion alerts and 8.3% of Dangerous Slowdown alerts were received by trucks when they were operating at speeds of less than or equal to 45 mph, indicating they were already in congested conditions. An example truck trajectory encountering such a situation is shown by Figure 6.3. The study also found that 43% of trucks that received Dangerous slowdown alerts never reduced their speed below 45 mph, as demonstrated by another example truck trajectory in Figure 6.2. Persistent monitoring of these performance measures over time will be crucial to evaluating alert impacts and improving stakeholder confidence in this technology.

This will, in turn, provide quantitative evidence and monitoring procedures allowing for continuous improvement of these systems to further increase driver and fleet provider confidence in these alerting systems and performance measures such as these that are essential to provide independent evaluations of in-cab alert deployments. These observed percentages may be attributable to a number of contributing factors including but not limited to latency and accuracy of connected vehicle data powering the alerts, rapidly changing traffic conditions, driver response, or compliance to alert notifications. Future scope of research should cover analysis to flag such cases to improve alerting accuracy.

## 7. CONCLUSION

This study reported on the observed impacts of deployment of in-cab alerts to commercial vehicle drivers along 44 limited access corridors in Indiana for the months of April through June 2024 (Figure 3.3 and Figure 3.4). Approximately 20,000 alerts were sent out with 92% of them being Congestion alerts and the rest being Dangerous Slowdown alerts.

This study looked at driver response (change in speed) and driver experience (did they encounter a slowdown) to evaluate the effectiveness of these alerts. Driver experience from 30 s prior to receiving an alert to about 5 min after receiving an alert was analyzed for this study. The study found:

- 21.2% of drivers receiving a Dangerous Slowdown alert reduced their speeds by at least 5 mph within 30 s of receiving an alert (Figure 4.2).
- 15% of drivers receiving a Congestion alert had reduced their speed by at least 5 mph within 30 s of receiving an alert (Figure 4.1).

Table 7.1 and Table 7.2 compare these driver responses across identical studies conducted in both Indiana and Ohio. This table shows the percentage of trucks that reduced their speeds by at least 5 mph 30 s after an alert for a prior study on Ohio corridors in 2023 (Desai, Mathew, & Bullock, 2024) as

TABLE 7.1  
Summary Comparisons of In-Cab Congestion Alerts and Truck Speed Reductions in Indiana and Ohio.

State	Study Period	Total Congestion Alerts	% Showing $\geq$ 5 mph Speed Reduction 30 s After Alert
Ohio	Sep 28–Nov 13, 2023	2,350	19.1
Indiana	Apr 1–Jun 30, 2024	13,525	15.0

TABLE 7.2  
Summary Comparisons of In-Cab Dangerous Slowdown Alerts and Truck Speed Reductions in Indiana and Ohio.

State	Study Period	Total Dangerous Slowdown Alerts	% Showing $\geq$ 5 mph Speed Reduction 30 s After Alert
Ohio	Sep 28–Nov 13, 2023	599	21.9
Indiana	Apr 1–Jun 30, 2024	1,060	21.2

well as this Indiana study for summer 2024. These comparable results across states demonstrate the scalability and repeatability of the methodologies and performance measures developed by this study to other states and corridors to observe the effectiveness of in-cab alerts in reducing truck speeds.

While the study only reports on data received from trucks that received an in-cab alert, these observed speed reductions potentially carry inherent traffic calming impacts for the mix of traffic operating in the same vicinity as an in-cab alerted truck, thus helping increase overall driver awareness to upcoming roadway hazards such as a congestion or dangerous slowdown event.

## 8. FUTURE RESEARCH

Although the results shown in Table 7.1 are promising, the study authors believe there are further opportunities to improve the fidelity of these systems to more accurately predict slowdowns and improve driver’s trust in these alerts. The study also found that 8.1% of Congestion alerts and 8.3% of Dangerous Slowdown alerts were received by trucks when they were operating at speeds of less than or equal to 45 mph, indicating they were already in congested conditions. The study also found that 43% of trucks that received Dangerous slowdown alerts never reduced their speed below 45 mph, suggesting that drivers may lose confidence in the alerts if they do not encounter a significant slowdown in traffic after receiving the alerts. It will be important to improve these systems to further increase driver and fleet provider confidence in these systems and performance measures such as these that are essential to provide independent evaluations of in-cab alert deployments.

As the area of in-cab alerts continues to evolve, it will be important to converge on a shared vision and common targets for the safety and mobility performance measures—possibly including metrics on spatial and temporal latency of alerts as well as false positive alerting rates—so that public agencies, in-cab alert providers, and trucking companies can work closely together to agilely improve these systems and increase driver confidence.

## REFERENCES

- Bullock, D., Desai, J., Mathew, J. K., Saldivar-Carranza, E. D., & Sakhare, R. S. (2024, October 3). Do In-Vehicle Alerts Work? *Roads and Bridges*. <https://www.roadsbridges.com/technology/article/55140124/do-in-vehicle-alerts-work>
- Day, C., McNamara, M., Li, H., Sakhare, R., Desai, J., Cox, E., Horton, D., & Bullock, D. (2016). 2015 Indiana mobility report and performance measure dashboards. *Indiana Mobility Reports*. <https://doi.org/10.5703/1288284316352>
- Desai, J., Mathew, J. K., & Bullock, D. M. (2024). Quantifying the impact of in-cab alerts on truck speed reductions in Ohio. *Journal of Transportation Technologies*, 14(3), 273–288. <https://doi.org/10.4236/jtts.2024.143017>
- Desai, J., Saldivar-Carranza, E. D., Sakhare, R. S., Mathew, J. K., & Bullock, D. M. (2024). Impact of in-cab alerts on connected truck speed reductions in Indiana. *Vehicles*, 6(4), 1857–1871. <https://doi.org/10.3390/vehicles6040090>
- Goodall, N., & Lan, C. -L. (2023). Evaluation of a truck in-cab alert system [Research in progress]. Virginia Transportation Research Council. <https://rip.trb.org/View/2239598>
- Federal Motor Carrier Safety Administration. (2024a). FMCSA 2024 safety research forum. <https://www.fmcsa.dot.gov/research-and-analysis/fmcsa-2024-safety-research-forum>
- Federal Motor Carrier Safety Administration. (2024b). *Large truck and bus crash facts 2021*. <https://www.fmcsa.dot.gov/safety/data-and-statistics/large-truck-and-bus-crash-facts-2021#A2>
- Howell, B., Walton, J., & Koo, J. (2021). In-cab alert system for commercial motor vehicle drivers (Kentucky Transportation Center Report No. KTC-21-28/RSF19-73-1F). University of Kentucky. [https://uknowledge.uky.edu/ktc\\_researchreports/1736](https://uknowledge.uky.edu/ktc_researchreports/1736)
- Katsikides, N., Gick, B. N., Parab, S., Hwang, W., Lee, D., de Oca, J. R. M., Farzaneh, R., Kong, X. J., Srisan, T., Bell, S., Alden, A. S., Warner, J., & Schrank, D. (2022). *Connected vehicle information for improving safety related to unknown or inadequate truck parking* (Safe-D University Transportation Center Report No. TTI-06-01). <https://safed.vti.vt.edu/projects/4610-2/>
- Kwigizile, V., Oh, J. -S., Alkhatni, F., Jorge, R., Ceifetz, A., & Yassin, J. (2015). Evaluating Michigan commercial vehicle enforcement strategies and facilities. (Transportation Research Center for Livable Communities Report No. RC 1622). Western Michigan University. <https://rosap.ntl.bts.gov/view/dot/28753>
- Lamb, E. (2017). Arizona installs Driveway PreClear system to save truckers' time, costs at weigh stations. *Transport Topics*. <https://trid.trb.org/View/1481731>
- Leitner, D., Meleby, P., & Miao, L. (2022). Recent advances in traffic signal performance evaluation. *Journal of Traffic and Transportation Engineering (English Edition)*, 9(4), 507–531. <https://doi.org/10.1016/j.jtte.2022.06.002>
- Sakhare, R. S., Desai, J., Mathew, J. K., & Bullock, D. M. (2024). Assessing the interstate coverage of commercial trucks capable of providing roadway imagery via on-vehicle dash camera in the United States. *IEEE Access*, 12, 173517–173529. <https://doi.org/10.1109/ACCESS.2024.3503368>
- Sakhare, R. S., Desai, J., Mathew, J. K., McGregor, J., Kachler, M., & Bullock, D. M. (2024). *Measuring and visualizing freeway traffic conditions: Using connected vehicle data* (Joint Transportation Research Program Report No. TPF-5[514]). Purdue University. <https://doi.org/10.5703/1288284317751>
- Saldivar-Carranza, E. D., Li, H., Mathew, J. K., Desai, J., Platte, T., Gayen, S., Sturdevant, J., Taylor, M., Fisher, C., & Bullock, D. M. (2023). *Next generation traffic signal performance measures: leveraging connected vehicle data*. Purdue University. <https://doi.org/10.5703/1288284317625>
- Cambridge Systematics, Inc., & Texas Transportation Institute. (2005). The nature of traffic congestion and reliability: Causes, how they are measured, and why they matter. In *Traffic congestion and reliability: Trends and advanced strategies for congestion mitigation*. Federal Highway Administration. [https://ops.fhwa.dot.gov/congestion\\_report/chapter2.htm](https://ops.fhwa.dot.gov/congestion_report/chapter2.htm)
- Waddell, J. M., Remias, S. M., Kirsch, J. N., & Young, S. E. (2020). Scalable and actionable performance measures for traffic signal systems using probe vehicle trajectory data. *Transportation Research Record*, 2674(11), 304–316. <https://doi.org/10.1177/0361198120941847>

APPENDICES

**Appendix A: List of Acronyms**

## Appendix A. List of Acronyms

CV	Connected Vehicle
DOT	Department of Transportation
INDOT	Indiana Department of Transportation
GDOT	Georgia Department of Transportation
VDOT	Virginia Department of Transportation
FMCSA	Federal Motor Carrier Safety Administration
KYTC	Kentucky Transportation Cabinet
KTC	Kentucky Transportation Center
BoQ	Back of Queue
MM	Mile Marker

## About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1 — evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at <https://docs.lib.purdue.edu/jtrp/>.

Further information about JTRP and its current research program is available at <https://engineering.purdue.edu/JTRP>.

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