JOINT TRANSPORTATION
RESEARCH PROGRAM
INDIANA DEPARTMENT OF TRANSPORTATION
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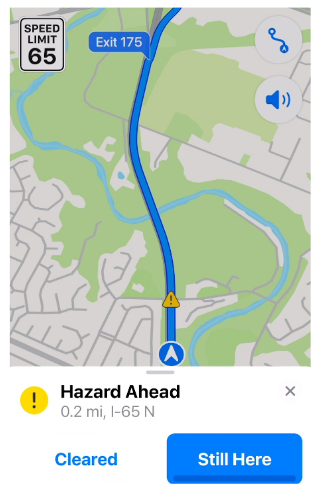
Impacts to Traffic Behavior from Queue Warning Truck: Current Pilot Project



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JOINT TRANSPORTATION RESEARCH PROGRAM

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NOTICE

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16. Abstract

The Indiana Department of Transportation (INDOT) started deploying queue warning trucks ahead of interstate work zones toalert motorists of queued traffic. Along with visually alerting the motorists, digital alerts were integrated with navigational applications such as Apple Maps, Waze, and the in-vehicle infotainment system of Stellantis vehicles. More than 16,000 hours of alerting was provided to motorists across various interstates in Indiana over a 26-month period. This report evaluated the impact of queue warning trucks on traffic using hard braking events and traffic speeds provided by granular connected trajectory vehicle data. Evaluation of over 370 hours of queuing with the presence of queue trucks and 52 hours of queuing without the queue trucks indicated a decrease in hard braking events by 80% when trucks were present with digital alerts. It was also observed that traffic speeds started to reduce approximately 1,500 to 2,000 ft in advance of deployed queue trucks. These encouraging results support the further deployment of queue trucks and integration of alerts for enhancing the safety for motorists approaching work zone queues.

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EXECUTIVE SUMMARY

Motivation

Work zone activities often result in slow traffic and/or forming a queue on interstates, which can increase crash risk for inattentive drivers. Back of queue crashes, particularly on high-speed interstates in advance of construction zones experiencing queuing, are a significant concern for all transportation agencies. In 2020, the Indiana Department of Transportation (INDOT) began deploying queue warning trucks ahead of work zones. Besides alerting the motorists visually, these queue trucks were also equipped with digital alerts that were transmitted to navigation systems. This study was initiated to evaluate the Indiana queue truck warning program.

Study

Telematics data from queue warning trucks and digital alerts was first deployed in May 2020. As of July 2022, a total of 53 trucks and 40 other emergency response vehicles have been deployed and alerting motorists in Indiana. Digital alerts covering more than 16,726 truck-hours were provided across Indiana interstates over a 27-month period. This study analyzed the impact of queue trucks with digital alerts on hard braking events. It also evaluated traffic speed reductions relative to the location of trucks.

Findings

- INDOT construction records (site manager) indicated 3,957 days of queue truck deployment since 2020. Telematics data however was broadcasted for 16,726 truck-hours from a total of 2,927 unique truck days. This discrepancy is most likely explained by gaps in telematics records provided by one of the newer digital alert providers that is still developing protocols for interfacing with transportation agencies.
- Hard-braking events (defined as any vehicle decelerations with a magnitude greater than 8.76 ft/s^2) is used as a measure for crash risk. These events were found to decrease by approximately 80% when queue warning trucks were used to alert motorists of impending queues.
- Traffic speeds were observed to gradually reduce from about 1,500 to 2,000 ft behind the deployed queue truck location. This suggests that queue trucks were alerting the drivers and reducing the traffic speeds ahead of the work zone.

Recommendations

These encouraging results support the further deployment of queue trucks and the integration of alerts for enhancing the safety of motorists behind work zone queues. It is important to note that queue truck drivers are a first line of defense and limiting their exposure is a challenge that will be a factor in future research. To increase the impact of in-vehicle digital alerts, particular attention should be devoted to strengthening relationships with automotive OEMs, navigation software companies, and truck fleets.

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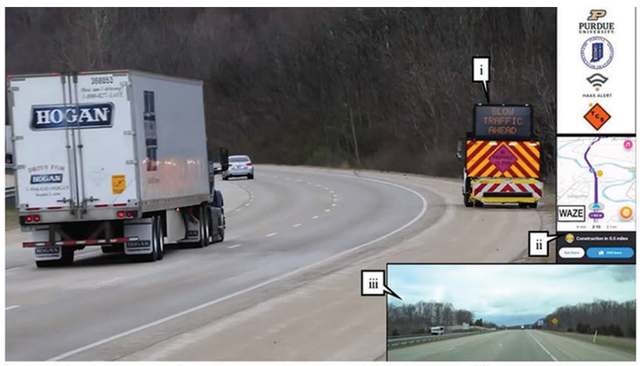
1. INTRODUCTION

Identifying opportunities for continuous improvement in roadway safety is a priority for all transportation agencies. Work zone activities often result in slow traffic and/or forming queues. The boundary between free-flow conditions and queued traffic results in rapid speed reductions (also called shockwaves) on interstates that can increase crash risk for inattentive drivers. In 2020, Indiana begins deploying queue warning trucks ahead of the work zones for alerting motorists of the slow traffic ahead. These queue trucks are also equipped with digital alerts that could be transmitted to navigation systems. In-vehicle navigation alerts provide an additional opportunity to improve communication to drivers of modern vehicles.

This report summarizes the alerts from deployed queue trucks and evaluates its impact on the traffic behavior using traffic speeds and hard braking events from connected vehicle data. Several studies in the past have used the connected vehicle data to evaluate the performance in wide variety of applications relating to work zones (Desai, Sakhare, Rogers, et al., 2021; Sakhare, Desai, et al., 2022; Sakhare, Desai, Mathew, et al., 2021), winter operations (Desai, Mahlberg, et al., 2021; McNamara et al., 2017), intersections (Li et al., 2018) and roadways (Day et al., 2016; Mahlberg et al., 2021; Mathew et al., 2021) in general showing the effectiveness of such datasets.

Figure 1.1 and the YouTube video that can be viewed via the hyperlink in the caption, illustrate alerts from queue truck (callout i) on Indiana Interstate 65 (I-65). Callout ii points to alert shown on the Waze navigation application whereas callout iv shows the in-vehicle infotainment system of Stellantis vehicle. The motorists' view is shown in callout iii. Callout v points to alert shown on Apple Maps.



(a) Waze navigation application (Purdue Traffic Lab, 2022b).

(b) Stellantis in-vehicle infotainment system (Purdue Traffic Lab, 2022a).

(c) Apple Maps (Purdue Traffic Lab, 2022c).

Figure 1.1 Alerts to motorists from queue warning truck demonstration along I-65.

2. SUMMARY OF QUEUE TRUCK DEPLOYMENT IN INDIANA

Telematics data from queue warning trucks and its digital alerts were first deployed in May of 2020. Since then, total of 53 queue warning trucks and with 40 other emergency response vehicles have been deployed and alerting motorists as of July 2022 in Indiana. Cumulative monthly counts of queue warning trucks and other emergency vehicles from May 2020 to July 2022 are shown in Table 2.1. Comments column in the table provides additional details on the inclusion of truck providers and telematics data providers during this period.

Queue trucks are managed by various subcontractors throughout the state such as RoadSafe Traffic Systems, Traffic Control Specialist, The Hoosier Company, Site-Safe, Safe-Ti-Co, and PK Contracting etc. Digital alert transponders are installed on these vehicles to capture the telematics data. The truck's location information along with alerting status (telematics data) is currently provided by only two commercial data providers, HAAS Alert and iCone products.

Analysis of telematics data included only the queue warning trucks deployed ahead of the work zones. Telematics data from other emergency response vehicles such as Hoosier Helpers, fire department trucks, and so on have been excluded. Any telematics data received in regions with no INDOT contracted deployment of the queue trucks were also filtered. Digital alerts covering more than 16,726 truck-hours were provided across Indiana interstates over the 27-month period from May 2020 to July 2022. Figure 2.1 shows total number of hours of alerts broadcasted along different interstates and direction of travel stacked by the two different data providers. Hours of digital alerts from queue warning trucks were significantly more on I-70 followed by I-65 and I-74. Other interstates, such as a I-69, I-94, and I-64 saw a few hours of alerting. Most of the queue trucks on I-65 were equipped with HAAS Alert system whereas in case of I-74, it was majorly iCone. Trucks along I-70 construction projects were divided between the two data providers.

Table 2.2 shows monthly hours of alerting (both data providers combined) by interstates. It can be observed that the queue truck alerts were sparce in 2020, increased in the later part of construction season in 2021 and significantly higher usage in 2022. Most alerts (1,345.1 hours) were distributed in November of 2021 along I-70 westbound. Monthly more than 1,200 hours of alerts combined across all the interstates were issued from September through November in 2021 and from April through July in 2022.

TABLE 2.1
Summary of growth of queue warning trucks since May 2020

Month	Queue Warning Trucks	Other Emergency Response Vehicles	Total	Comments on Addition of Truck/Data Providers
May-20	0	14	14	Lafayette Fire Department
Jun-20	0	14	14	–
Jul-20	4	17	21	RoadSafe Traffic Systems
Aug-20	4	22	26	–
Sep-20	4	22	26	–
Oct-20	4	22	26	–
Nov-20	4	22	26	–
Dec-20	4	22	26	–
Jan-21	5	22	27	–
Feb-21	5	22	27	–
Mar-21	8	22	30	Traffic Control Specialists
Apr-21	10	22	32	The Hoosier Company
May-21	12	23	35	The Hoosier Company
Jun-21	13	38	51	INDOT Hoosier Helpers
Jul-21	21	38	59	–
Aug-21	23	38	61	Site-Safe
Sep-21	35	38	73	Safe-Ti-Co
Oct-21	37	38	75	–
Nov-21	45	38	83	iCone
Dec-21	46	38	84	–
Jan-22	48	38	86	–
Feb-22	48	38	86	–
Mar-22	49	38	87	–
Apr-22	52	39	91	Site-Safe
May-22	53	40	93	PK Contracting
Jun-22	53	40	93	–
Jul-22	53	40	93	–

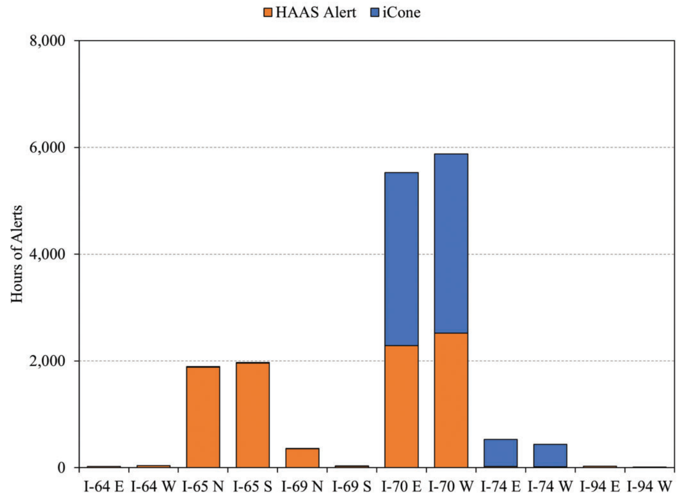


Figure 2.1 Queue trucks hours of alerts by interstate identified from two commercial telematics data providers from May 2020 to July 2022.

TABLE 2.2
Monthly hours of alerts on Indiana interstates from queue warning trucks observed from the telematics data from May 2020 to July 2022

Year	Interstate/ Month	I-64 E	I-64 W	I-65 N	I-65 S	I-69 N	I-69 S	I-70 E	I-70 W	I-74 E	I-74 W	I-94 E	I-94 W	Total
2020	May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Jun	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Jul	0.0	0.0	10.0	3.3	1.5	0.0	20.1	14.3	0.0	0.0	0.0	0.0	49.2
	Aug	0.0	0.0	28.5	22.1	0.8	0.9	7.2	10.8	0.0	0.0	0.0	0.0	70.3
	Sep	0.0	0.0	0.0	0.0	0.0	0.0	4.8	2.8	0.0	0.0	0.0	0.0	7.6
	Oct	0.0	0.0	0.0	22.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.2
	Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dec	0.0	0.0	0.3	0.1	0.0	0.0	0.0	5.2	0.0	0.0	0.0	0.0	5.6
2021	Jan	0.0	0.0	1.5	9.6	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	11.3
	Feb	0.0	0.0	7.4	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
	Mar	0.0	0.0	3.8	148.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	152.1
	Apr	0.0	0.0	164.6	150.3	295.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	610.0
	May	0.0	0.0	137.1	73.5	52.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	263.3
	Jun	0.0	0.0	79.2	119.6	0.0	8.6	530.8	42.5	0.0	0.0	0.0	0.0	780.7
	Jul	0.0	0.0	212.5	310.4	0.0	0.0	169.0	338.0	35.2	44.9	0.0	0.0	1,109.9
	Aug	0.0	0.0	30.6	35.9	0.0	0.0	40.1	284.9	68.6	97.7	0.0	0.0	557.7
	Sep	4.6	22.0	56.3	37.8	0.0	0.0	530.3	656.1	33.6	79.2	0.0	0.0	1,419.9
	Oct	0.1	3.1	14.7	1.2	7.6	4.5	754.1	1,003.5	180.2	94.5	28.9	11.9	2,104.2
	Nov	16.3	14.7	24.0	78.0	0.0	0.0	409.0	1,345.1	177.9	114.7	0.0	0.0	2,179.6
	Dec	0.0	0.0	37.8	38.2	0.0	0.0	28.1	20.0	35.0	4.1	0.0	0.0	163.3
2022	Jan	0.0	0.0	6.9	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5
	Feb	0.0	0.0	0.1	13.7	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	13.9
	Mar	0.0	0.0	8.2	12.6	0.3	0.0	194.6	32.6	0.0	0.0	0.0	0.0	248.3
	Apr	0.0	0.0	73.8	222.5	0.0	0.0	837.8	131.0	0.0	0.0	0.0	0.0	1,265.1
	May	0.0	0.0	257.9	185.5	0.0	0.0	540.6	601.8	0.0	0.0	0.0	0.0	1,585.8
	Jun	0.0	0.0	288.3	279.5	0.8	12.2	759.9	631.8	1.7	1.1	0.0	0.0	1,975.1
	Jul	0.0	0.0	448.4	189.2	0.0	0.0	704.8	757.5	0.0	0.0	0.0	0.0	2,100.0
	Total	20.9	39.8	1,891.8	1,970.1	358.7	26.3	5,531.1	5,878.1	532.2	436.2	28.9	11.9	1,6726.0

Note: Lowest values in black text, 75% percentile in gold text, and highest values in red text.

In addition to the telematics data, site manager records are maintained with manual entries. These records help agencies in tracking queue truck deployments and respective pay items. Summary of site manager records (Appendix A) provide contract number and corresponding manually recorded total

TABLE 2.3
Comparison of queue warning trucks deployment using telematics data and site manager records for 2020, 2021, and 2022

			Queue Truck Deployment from Telematics Data						
			HAAS Alert		iCone		Total		
District	**Queue Truck Deployment from Site Manager Data (days) [a]**	**Total Amount Paid by Agency (USD)**	**Hours of Alerting (hours)**	**Unique Days (days)**	**Hours of Alerting (hours)**	**Unique Days (days)**	**Total Hours of Alerting (hours) [b]**	**Total Unique Days (days)**	**Average Hours of Alerting per Day [b/a]**
Crawfordsville	1,784	$2,091,069	2,882	486	6,448	808	9,330	1,294	5.2
Greenfield	1,759	$3,225,082	5,271	678	1,069	539	6,340	1,217	3.6
Seymour	383	$330,842	962	374	30	26	992	400	2.6
LaPorte	31	$49,617	64	16	–	–	64	16	2.1
Total	3,957	$5,696,610	9,179	1,554	7,547	1,373	16,726	2,927	4.2

number of queue truck days deployed. INDOT district wide aggregation of records from site manager are compared against the telematics data as shown in Table 2.3.

Crawfordsville district had most days of queue truck deployment followed by Greenfield district. Site Manager records indicated 3,957 days of queue truck deployment across the four districts since 2020. Telematics data indicated 16,726 truck-hours of alerting from total of 2,927 unique truck days. Average daily hours of alerting were observed to be most in Crawfordsville at 5.2 hours per day and least in LaPorte at 2.1 hours per day. Table 2.3 also shows total amount paid by agencies to subcontractors over 3-year period for queue truck deployment. The difference in the number of days of deployment in telematics data compared to the site manager records can be attributed to the following various factors.

- Queue truck operations that did not have alert transponders present on-board or were not turned on for alerting.
- Related activities such as transporting from one location to other or present on non-interstate regions (such as ramps, state routes, etc.) are filtered from telematics data aggregation.
- Site manager records were summarized annually and included period from 2020 up until July 2022 whereas telematics data ingestion started only after July 2020.

In the future, agencies might consider including pay item based on the received telematics data to enforce the seamless and consistent delivery of digital alerts and avoiding billing for non-essential activities.

3. IMPACT OF QUEUE TRUCKS ON HARD BRAKING EVENTS

In 2020, Indiana DOT began deploying queue warning trucks with message boards, flashers and digital alerts that could be transmitted to navigation systems such as Waze and Apple Maps. A novel analysis of queue warning trucks equipped with digital alerts was conducted during the months of May through July in 2021 using connected vehicle (CV) data. This data set reports locations of anonymous hard-braking events from connected vehicles on the interstate. Recent study has shown CV data penetration around 6.3% on Indiana interstates (Sakhare, Hunter, et al., 2022). The provider of this data defined hard-braking events as any vehicle decelerations with a magnitude greater than 8.76 ft/s^2 (0.272 g). Hard-braking events were tabulated for when queueing occurred with and without the presence of a queue warning truck. Approximately 370 hours of queueing with queue trucks present and 58 hours of queueing without queue truck present were evaluated. Hard-braking events were found to decrease approximately 80% when queue warning trucks were used to alert motorists of impending queues (Sakhare, Desai, Mahlberg, et al., 2021).

TABLE 3.1
Summary of hard braking events without any queue warning trucks or navigation alerts

Date	I-65 MM, Direction of Travel	Start Time of Queues	Duration (hours) [a]	Number of Trajectories Approaching Queues [b]	Hard-Braking Events Approaching Queues [c]	Hard-Braking Events per Hour of the Queue [c/a]	Hard-braking Events per Trajectories (%) [c/b]
5/21/2021	165, SB	21:00	1	47	10	10	21.3
5/27/2021	176, SB	18:00	5	235	29	5.8	12.3
5/28/2021	177, SB	6:30	4.5	283	33	7.3	11.7
6/2/2021	131, NB	15:00	5	386	16	3.2	4.1
6/4/2021	125, SB	19:00	2	76	10	5	13.2
6/10/2021	103, NB	16:00	1	179	19	19	10.6
6/10/2021	131, SB	16:00	1	149	15	15	10.1
6/11/2021	178, NB	13:30	2.5	131	33	13.2	25.2
6/11/2021	190, NB	12:30	8	91	55	6.9	60.4
6/11/2021	189, SB	12:30	6	407	41	6.8	10.1
6/18/2021	128, SB	18:00	1.5	152	14	9.3	9.2
6/25/2021	158, SB	14:00	2.5	219	37	14.8	16.9
7/1/2021	151, NB	13:00	1.5	138	21	14	15.2
7/1/2021	190, NB	14:30	1.5	154	33	22	21.4
7/2/2021	161, NB	17:30	1	110	46	46	41.8
7/2/2021	166, SB	15:00	2	172	26	13	15.1
7/5/2021	177, NB	12:30	2	206	45	22.5	21.8
7/5/2021	176, SB	12:30	3	238	53	17.7	22.3
7/9/2021	176, NB	14:00	2	305	41	20.5	13.4
7/9/2021	181, NB	19:00	2	106	13	6.5	12.3
7/16/2021	134, SB	14:00	1.5	220	16	10.7	7.3
7/23/2021	167, SB	13:00	1.5	191	14	9.3	7.3
Total			*58*	*4,195*	*620*	*10.7*	*14.8*

Table 3.1 summarizes the hard-braking events during 58 hours of observed queuing with no queue trucks. 620 hard-braking events occurred in the 4,195 trajectories approaching the queue, i.e., 14.8% of the motorists experienced hard braking while approaching the queue. Table 3.2 summarizes the hard-braking events for 370 hours of queues when queue warning trucks were deployed with digital alerts. The trucks were deployed for ongoing work zone activity at MM 145 on I-65 during the evening hours. Only 2.6% of the trajectories experienced hard braking out of 6,240 trajectories.

Figure 3.1 shows the scatter plot between hard-braking events and trajectories approaching queue without and during the presence of queue warning trucks and navigation alerts. Hard-braking events without and during the presence of queue warning trucks are denoted by hollow black circles and purple cross marks respectively on the scatter plot. Hard-braking events during the presence of queue trucks with digital alerts seem to have shifted towards the lower side and grouped tightly. Linear regression estimates are shown by dotted lines for each of the groups with respective line equations and coefficient of determination (R^2) values. Every 100 trajectories approaching the queue without any alerts has approximately 12.73 hard-braking events compared to only 2.66 hard-braking events if the queue warning trucks with alerts was present.

Previous study that analyzed 196,215 hard braking events over a 2-month period for the 23 interstate work zones in Indiana had shown that there was approximately 1 crash/mile for every 147 hard braking events in and around a construction site (Desai, Li, et al., 2021). Hence, the clear reduction in hard-braking events for queue warning trucks with alerts is anticipated to reduce crashes by a similar proportion.

TABLE 3.2
Summary of hard braking events during the presence of queue warning trucks and navigation alerts

Date	I-65 MM, Direction of Travel	Start Time of Queues	Duration (hours) [a]	Number of Trajectories Approaching Queues [b]	Hard-Braking Events Approaching Queues [c]	Hard-Braking Events per Hour of the Queue [c/a]	Hard-Braking Events per Trajectories (%) [c/b]
5/18/2021	144, NB	18:30	10.5	126	1	0.1	0.8
5/19/2021	144, NB	18:30	10	134	2	0.2	1.5
5/20/2021	144, NB	19:00	10	134	9	0.9	6.7
5/21/2021	144, SB	19:30	9.5	178	5	0.5	2.8
5/24/2021	144, SB	18:30	11	147	5	0.5	3.4
5/25/2021	144, SB	19:00	8.5	123	5	0.6	4.1
5/26/2021	144, SB	18:30	11	180	4	0.4	2.2
6/1/2021	144, SB	18:30	9.5	123	2	0.2	1.6
6/3/2021	144, SB	18:30	11.5	195	6	0.5	3.1
6/4/2021	145, SB	19:00	11	310	4	0.4	1.3
6/7/2021	144, NB	20:00	10	110	4	0.4	3.6
6/7/2021	142, SB	19:00	11	129	3	0.3	2.3
6/8/2021	144, NB	19:00	6	95	0	0.0	0.0
6/11/2021	144, NB	20:00	9	150	4	0.4	2.7
6/21/2021	146, NB	19:00	9	146	3	0.3	2.1
6/22/2021	146, NB	20:00	9	101	4	0.4	4.0
6/23/2021	146, NB	22:00	7	47	0	0.0	0.0
6/28/2021	145, SB	20:30	8	108	0	0.0	0.0
6/29/2021	145, NB	20:00	5	77	2	0.4	2.6
7/1/2021	144, SB	19:00	10.5	279	9	0.9	3.2
7/8/2021	146, NB	19:00	8	178	4	0.5	2.2
7/8/2021	144, SB	19:00	11	204	5	0.5	2.5
7/9/2021	147, NB	20:00	8	182	4	0.5	2.2
7/9/2021	144, SB	20:00	8	208	8	1.0	3.8
7/12/2021	147, NB	19:00	9	145	0	0.0	0.0
7/12/2021	144, SB	21:00	7	82	0	0.0	0.0
7/14/2021	147, NB	19:00	9.5	142	1	0.1	0.7
7/19/2021	147, NB	19:00	10.5	150	5	0.5	3.3
7/19/2021	146, SB	18:30	11.5	193	4	0.3	2.1
7/20/2021	146, NB	19:00	6	89	1	0.2	1.1
7/20/2021	146, SB	19:00	10.5	167	5	0.5	3.0
7/20/2021	141, SB	20:00	6.5	122	4	0.6	3.3
7/21/2021	147, NB	19:00	10	140	4	0.4	2.9
7/21/2021	147, SB	19:30	9	174	4	0.4	2.3
7/21/2021	141, SB	19:30	4	155	5	1.3	3.2
7/22/2021	145, NB	18:30	11	195	11	1.0	5.6
7/22/2021	146, SB	19:30	10.5	240	8	0.8	3.3
7/23/2021	146, NB	20:00	7	150	5	0.7	3.3
7/23/2021	146, SB	20:30	9	182	4	0.4	2.2
7/26/2021	146, SB	19:00	10	126	4	0.4	3.2
7/27/2021	146, SB	19:00	7	124	5	0.7	4.0
Total			*370*	*6,240*	*163*	*0.44*	*2.6*

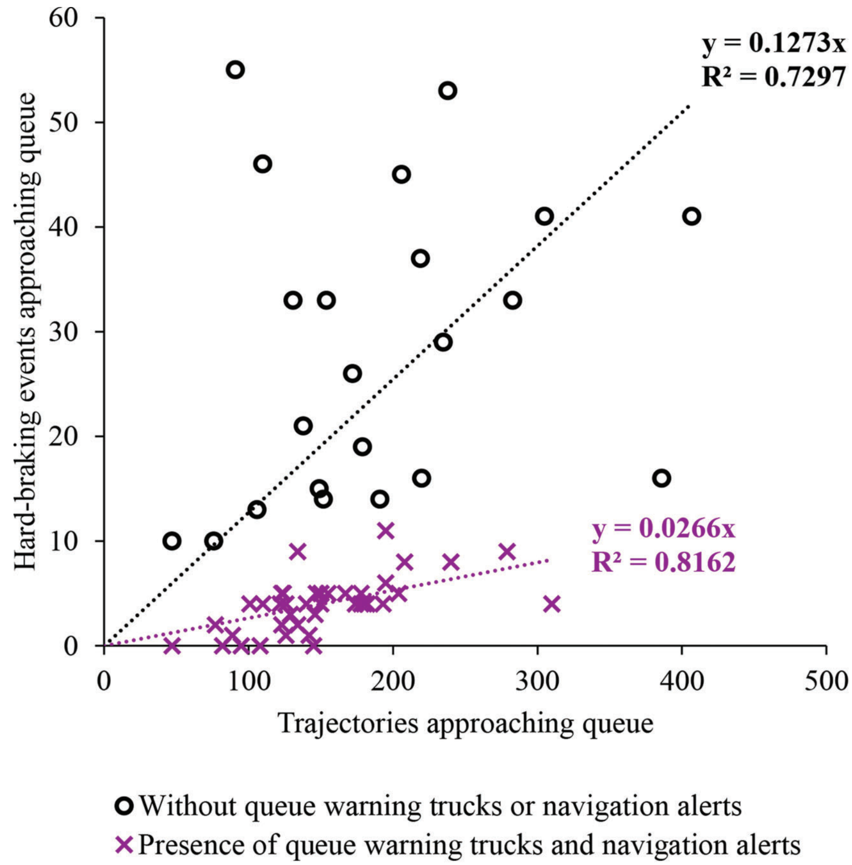
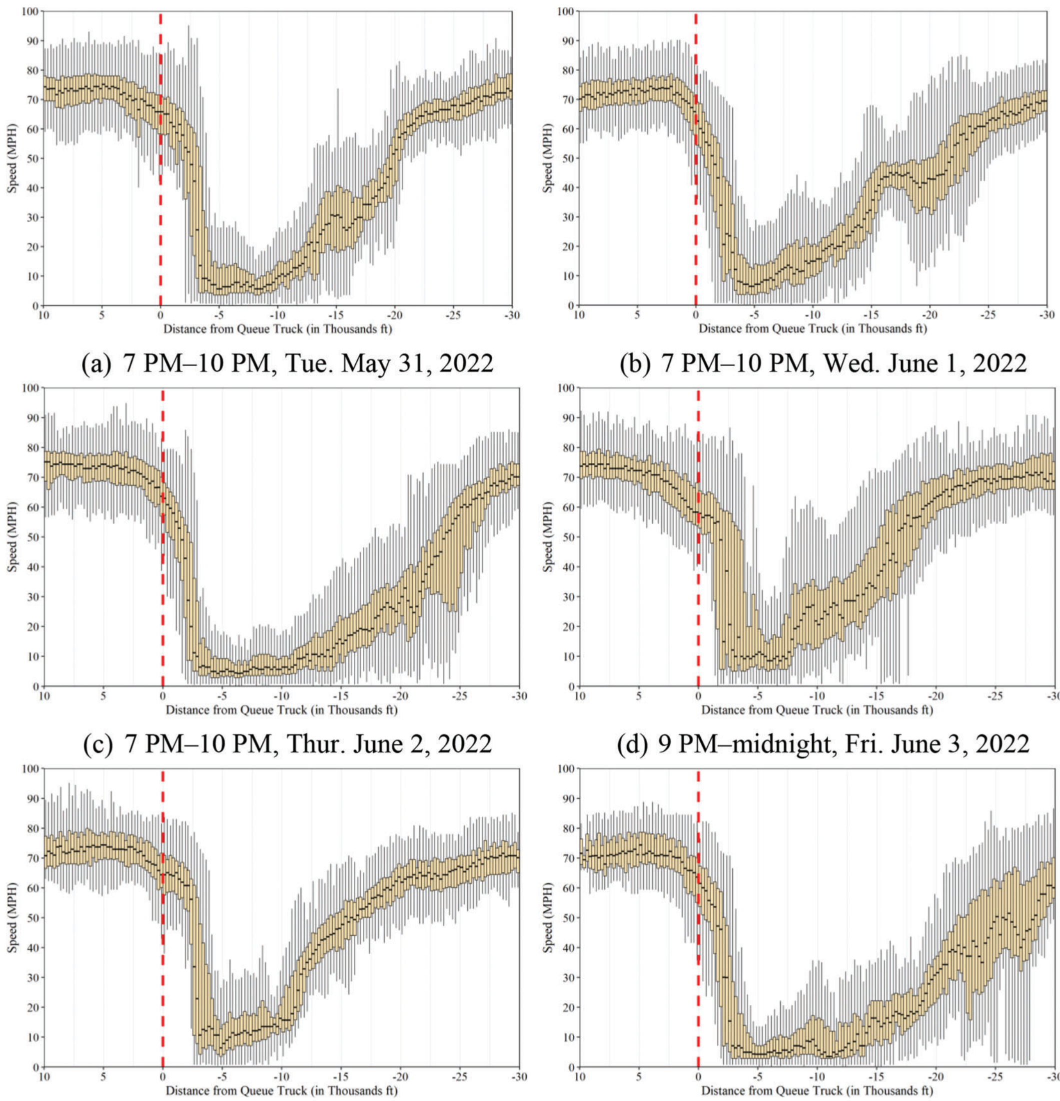


Figure 3.1 Scatter plot comparing the hard braking events and trajectories of approaching queues without the presence and during the presence of queue warning trucks or navigation alerts.

4. IMPACT OF QUEUE TRUCKS ON TRAFFIC SPEEDS

The boundary between free-flow conditions and queue traffic results in rapid speed reductions on interstates that can increase crash risk for inattentive drivers. Queue trucks are placed ahead of the work zones to alert motorists of the slow traffic ahead. The impact of queue trucks on approaching traffic speeds was also analyzed over several days in May and June of 2022 along the I-65 northbound work zone around mile marker 178.

Figure 4.1 shows box whisker plots of traffic speeds 10,000 feet (1.9 miles) downstream and 30,000 ft (5.7 miles) upstream of queue truck location covering the work zone area. The traffic speeds were analyzed for three-hour period in the evening when queue truck was present and were broadcasting digital alerting behind the work zone. The queue trucks adjust their position as the location of queue boundary changes. The queue trucks are adjusting behind the queue and hence the horizontal axis shows distance with respect to the truck location. Positive distance represents location behind the queue (downstream) and negative distances show distances ahead of the truck (upstream). The red vertical dotted line represents the location of the queue truck. Figure 4.2 shows similar traffic speeds within 5,000 ft (0.95 miles) vicinity of truck location on either side (zoomed in view of Figure 4.1). It was observed that the speeds started to reduce gradually about 1,500 to 2,000 ft (0.28 to 0.38 miles) behind the queue truck location before joining the queue boundary caused due to the work zone. This suggests that queue trucks were having impact in alerting the drivers and reducing the traffic speeds ahead of the work zone.



(a) 7 PM–10 PM, Tue. May 31, 2022

(b) 7 PM–10 PM, Wed. June 1, 2022

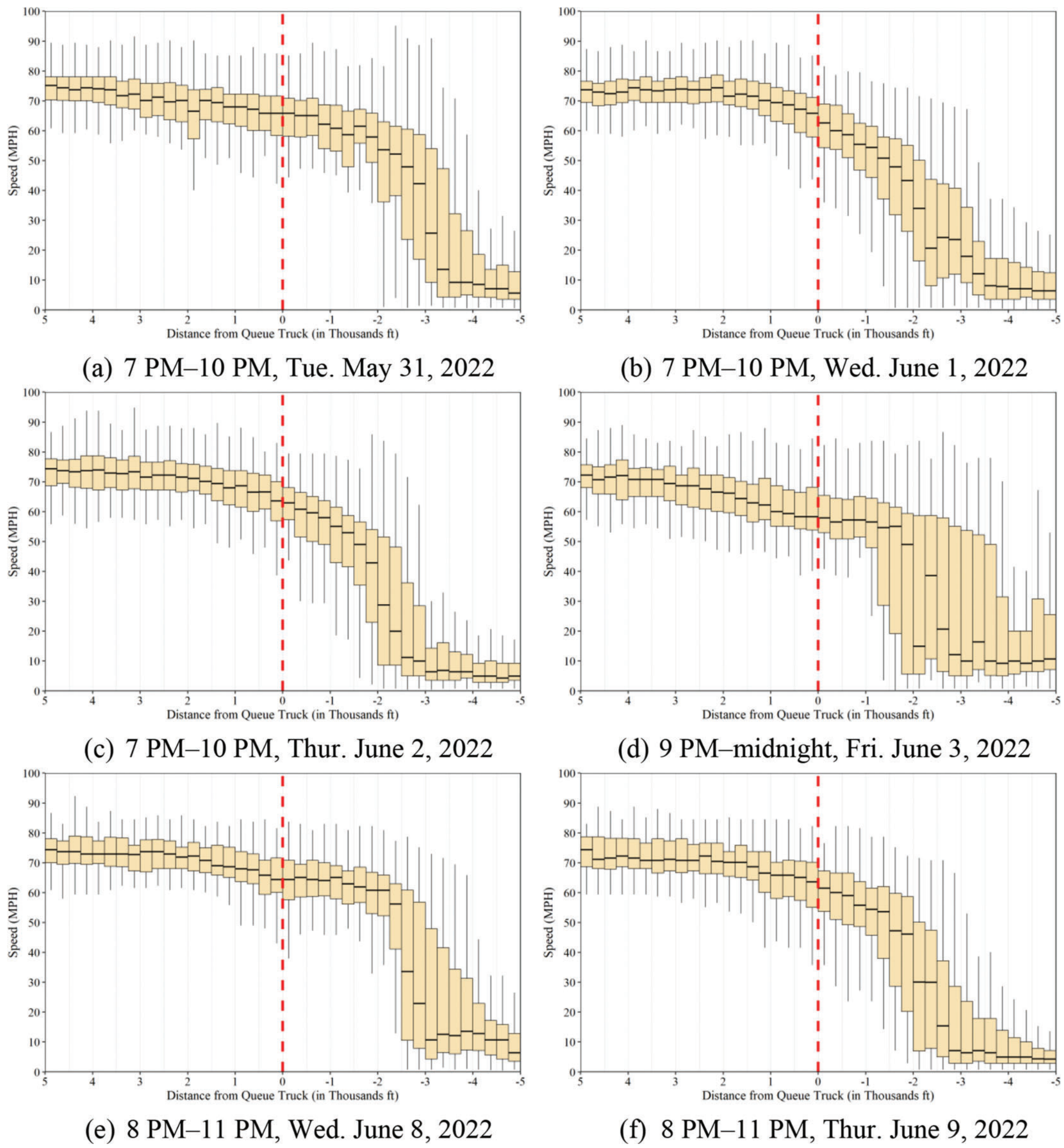
(c) 7 PM–10 PM, Thur. June 2, 2022

(d) 9 PM–midnight, Fri. June 3, 2022

(e) 8 PM–11 PM, Wed. June 8, 2022

(f) 8 PM–11 PM, Thur. June 9, 2022

Figure 4.1 Traffic speeds with respect to the locations of queue trucks from 10,000 ft (1.9 miles) behind up to 30,000 ft (5.7 miles) ahead covering the work zone area.



(a) 7 PM–10 PM, Tue. May 31, 2022

(b) 7 PM–10 PM, Wed. June 1, 2022

(c) 7 PM–10 PM, Thur. June 2, 2022

(d) 9 PM–midnight, Fri. June 3, 2022

(e) 8 PM–11 PM, Wed. June 8, 2022

(f) 8 PM–11 PM, Thur. June 9, 2022

Figure 4.2 Traffic speeds with respect to the location of queue trucks within 5,000 ft (0.95 miles).

5. SUMMARY

Alerting data from queue warning trucks is currently provided by two commercial data providers HAAS and iCone. Published alerts by HAAS are currently ingested and distributed by Waze, Apple Maps, and Stellantis in-vehicle infotainment system. However, iCone currently broadcasts to the Waze navigation application only. Queue trucks issuing digital alerts have grown to total of 53 in Indiana over 27 months since its initial inception in May 2020 (Table 2.1). Figure 1.1a and Figure 1.1b, along with the YouTube video links in those captions, illustrate how digital alerts are provided to motorists. More than 16,000 truck-hours of alerting was provided to motorists across various interstates (Table 2.2). A longitudinal comparison of queueing for 370 hours with the presence of trucks and 58 hours without trucks was conducted during the months of May–July in 2021. Hard-braking events were found to decrease approximately 80% when queue warning trucks were used to alert motorists of impending queues (Figure 2.1). Traffic speeds were observed to gradually reduce around 1,500 to 2,000 ft (0.28 to 0.38 miles) behind the queue truck location (Figure 4.2).

Encouraging results support the further deployment of queue trucks and integration of alerts for enhancing the motorists' safety behind the work zone queues. It is also important to note that queue truck drivers are first line of defense and limiting their exposure is a challenge and will be a consideration factor. This presents future research opportunity for assessing the impact on human factor involved. Further the framework for policies on systemwide deployment of queue warning trucks needs to be developed.

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APPENDICES

Appendix A. Queue Truck Deployment Summary Data Extracted from Site Manager

APPENDIX A. QUEUE TRUCK DEPLOYMENT SUMMARY DATA EXTRACTED FROM SITE MANAGER

Data extract produced by JNOVAK@indot.IN.gov on 07/21/2022 13:34
Filters applied on data:
ITEM_DESCRIPTION = queue truck

LETTING _FISCAL _YEAR	CONTRACT _NUMBER_ 5_DIGITS	DISTRICT	UNIT	ORIGINAL QUANTITY	QUANTITY _PLACED_ TO_DATE	AMOUNT_PAID TO_DATE
2020	39272	Greenfield	Day	0	171	$315,506.97
2020	41978	Crawfordsville	Day	0	27.75	$42,061.50
2020	42554	Greenfield	Day	0	5	$26,907.94
2021	40506	Greenfield	Day	180	431	$624,950.00
2021	40616	Greenfield	Day	190	1,088.241	$2,154,717.18
2021	40643	Laporte	Day	28	8	$8,800.00
2021	40973	Seymour	Day	270	45	$21,375.00
2021	40978	Seymour	Day	16	16	$11,200.00
2021	41197	Greenfield	Day	40	50	$75,000.00
2021	41206	Laporte	Day	196	0	$0.00
2021	41841	Crawfordsville	Day	300	470	$117,500.00
2021	41849	Seymour	Day	0	251	$236,413.32
2021	41849	Seymour	Day	56	60	$52,328.64
2021	41865	Laporte	Day	360	8	$20,392.00
2021	42652	Crawfordsville	Day	200	71	$78,100.00
2021	42673	Seymour	Day	0	5.5	$8,525.00
2021	42676	Laporte	Day	0	13	$18,525.00
2022	41501	Greenfield	Day	200	14	$28,000.00
2022	42043	Crawfordsville	Day	189	72.5	$202,093.75
2022	42100	Seymour	Day	30	0	$0.00
2022	42170	Laporte	Day	50	2	$1,900.08
2022	42463	Ft. Wayne	Day	420	0	$0.00
2022	42491	Laporte	Day	30	0	$0.00
2022	42901	Seymour	Day	30	5	$1,000.00
2022	42909	Crawfordsville	Day	300	78.042	$53,813.86
2022	43717	Crawfordsville	Day	810	1065	$1,597,500.00
2022	44070	Crawfordsville	Day	216	0	$0.00
			Total	*4111*	*3,957.033*	*$5,696,610.24*

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 http://docs.lib.purdue.edu/jtrp.

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