

# Virtual Queue Protection Corridors



By Pennsylvania Department of Transportation  
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## Benefits Statement

PennDOT's (Pennsylvania DOT) virtual queue protection system reduced crashes by 11% annually, and cut truck-related fatal crashes by 50%. The system saved 72,116 vehicle hours and \$53.4 million annually by improving traffic flow and reducing delays. It's a cost-effective solution using existing data, covering 600 miles of roadway with minimal costs, and delivering vehicle operation cost savings of nearly \$300,000 per year, including \$100,000 for trucks. This project significantly enhances safety, efficiency, and cost savings on Pennsylvania roads.

## In this case study you will learn:

1. How PennDOT addressed 7,000 annual congestion-related crashes by implementing an automated queue protection system using GPS data.
2. How virtual queue protection corridors provided automated protection for over 10,000 work zones and traffic incidents, reduced crashes by 11% and led to significant decreases in fatal and injury crashes.
3. How the system saved \$53.4 million annually through crash reductions, travel time, and operational savings.



## Case Study #186

Version Number: 1



## BACKGROUND



Data analysis from PennDOT's TSMO Performance Program identified crashes that occur in existing congestion as a significant issue on PennDOT's core roadway network. Annually, roughly 7000 crashes occur in pre-existing congestion. Most of these crashes are rear end crashes or hit fixed object crashes that occur when motorists unexpectedly encounter a queue and either run into the back of it or swerve to avoid the queue and hit a median/guardrail instead. Each year, approximately 1000 of these crashes are secondary crashes, and a similar amount occur in work zone related congestion. Further analysis showed that in most cases (over 90%), a changeable message sign (CMS) was present in a location that could have warned motorists of the impending queue prior to encountering it.

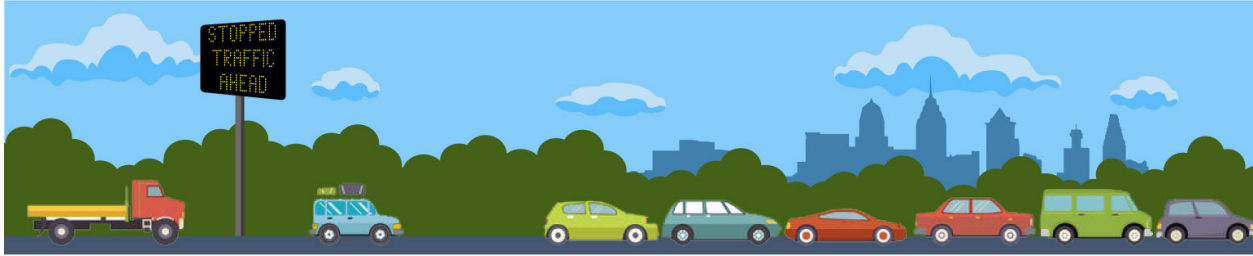
A solution was needed which allowed motorists to be warned of an impending queue, without relying on traffic management center operators to detect queues and constantly be updating message signs. Traditional queue warning systems have been shown to reduce crashes in work zone areas by 18-45%. These solutions however are costly (often adding over \$200K in costs to protect a single work zone) and rely on the deployment of physical detectors, which makes them impractical for deployment on a wide scale. A solution that was more cost effective and easily replicable across the state was required.

## TSMO PLANNING, STRATEGIES AND DEPLOYMENT

PennDOT has been procuring statewide GPS probe-based speed and travel time data since 2015. This data was already integrated into PennDOT's ATMS for the purpose of displaying real-time travel times on CMS. Real-time speeds are provided 24/7 on the core network, with updates every minute. There is typically latency of about 3 to 5 minutes between when conditions occur on the road and when they are reflected in the data. The data was originally used as a supplement to physical detector data when implementing the automated variable speed limit (VSL) and queue protection corridor on I-76 in Philadelphia. Based on the success of that implementation, the decision was made to use this data independently to allow for the implementation of virtual queue protection corridors in any area where CMS were present to alert motorists of upcoming queueing.



Design conversations began with PennDOT's ATMS vendor, and a corridors module was developed for the system. The corridors module allows for a given section of a route to be geofenced to define the extent of the corridor and the message boards to be included in the corridor. Once a corridor is active, traffic speeds within the corridor are monitored on a segment by segment basis. When detected speeds drop below a defined threshold, messages warning of queuing ahead are automatically posted to upstream message boards within the corridor. The module also automatically calculates the distance between the back of the queue and each message board and informs motorists how far ahead to expect the queue. Speed thresholds can be configured to alert users to slow traffic as opposed to stopped traffic



ahead, and those thresholds also determine the priority with which the automated messages post to signs.

After initial testing, the Traffic Operations Office began sharing the new capability during statewide presentations and meetings with PennDOT's Engineering Districts. A few construction projects immediately wanted to pilot this new technology due to safety concerns. Growing out of these initial successful implementations, the program has grown to the point where PennDOT has implemented 18 automated queue detection corridors statewide, with the majority of these corridors being implemented between Q4 of 2022 and throughout 2023. These corridors provide automatic queue protection that covers 600 miles of roadway, at virtually no additional cost beyond the initial investment to develop and build the functionality in ATMS. Through April 2024, queue protection corridors had provided automated protection for over 5,700 work zones and over 4,400 traffic incidents.

## COMMUNICATIONS PLANNING AND EXECUTION

Coordination between PennDOT's Central Office Traffic Operations Office and the various Engineering District Traffic Units and Traffic Management Centers has been critical to its success. As referenced above, once the capability was available, the communications process began by presenting it in statewide meetings and meetings with individual Districts.

As construction projects and other areas of concern were identified, close coordination

between Central Office, the appropriate District Traffic Unit, and the ATMS vendor occurred to appropriately design and implement a corridor in a way that met the needs of the location, including the extents, assigned signs, and appropriate speed thresholds.

As corridors have been implemented, coordination has continued, as feedback from the Districts has been needed to refine and improve the system. For instance, there was a concern that the automated messages for slow traffic were overriding critical messages regarding commercial vehicle restrictions during winter operations, so the priority of the queue warning messages were adjusted to allow the restriction messaging to take precedent.



## OUTCOME, BENEFITS AND LEARNINGS

As of April 2024, PennDOT had sufficient crash/safety data to share from 11 queue protection corridors. Across those 11 corridors, total crashes were reduced from 1,808 crashes per year prior to activation of queue protection, to 1,625 crashes per year following activation—a decrease of 183 crashes, or just over 11 percent. The 183 yearly crash-reduction included an average reduction of 96 rear-end crashes, 86 injury crashes, and 7 fatal crashes each year. Crash injury severity reduction was targeted by providing better location information of dangerous traffic conditions. The result was fatal and injury crashes dropping by over 20 percent in one-third of the corridors. Most installations focused on long-term work zones on high traffic volume routes, so any reduction is an emphasized success.

Unsurprising, when isolating truck crashes, the safety benefits are even more dramatic. The advance queue detection can help truck drivers slow their heavier vehicles in a timely fashion. Within the safety analysis described above, rear-end crashes involving trucks were reduced by 13 percent and fatal crashes involving trucks were reduced by nearly 50 percent (13 to 7 fatal crashes). By comparison, passenger vehicles only saw a slight reduction in fatal crashes. Keeping more trucks operational and the economy moving is a core staple of PennDOT's operations strategies.

Additionally, drivers in these corridors recouped an estimated 72,116-hour vehicular travel time in the year post-activation, or 109,088 person-hours when accounting for passenger vehicle occupancy rates. This includes 10,075 hours of travel time savings for trucks. The travel time savings were particularly significant along two major non-Interstate corridors in Eastern and Western Pennsylvania—SR 28 near Pittsburgh and

US 22 near Allentown, both of which are subject to heavy use by local residents and commuters.

Using FHWA's recommended monetized values, the 183 per year-crash and associated injury severity reduction represents an estimated total annual savings of \$53.4 million to drivers in Pennsylvania. Monetizing the resultant travel time savings, motorists saved \$2.2 million in the year following deployment across these corridors. Meanwhile, operational savings associated with keeping traffic moving (e.g., fuel, oil, tires, maintenance and repair, and vehicle depreciation) totaled nearly \$300,000 a year, including over \$100,000 for trucks.