Georgia DOT Variable Speed Limit Analytics Help Solve Traffic Congestion

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When the Georgia Department of Transportation (GDOT) wanted to optimize the use of big data and advanced analytics to gain insights into transportation, it worked with Teradata to develop a proof of concept evaluation of GDOT's variable speed limit (VSL) pilot project.

The VSL concept has been adopted in many parts of the world, but is still relatively new in the U.S. As GDOT explains: "VSLs are speed limits that change based on road, traffic, and weather conditions. Electronic signs slow down traffic ahead of congestion or bad weather to smooth out flow, diminish stop-and-go conditions, and reduce crashes. This low-cost, cutting edge technology alerts drivers in real time to speed changes due to conditions down the road. More consistent speeds improve safety by helping to prevent rear-end and lane changing collisions due to sudden stops."

Quantifying the customer service, safety, and efficiency benefits of VSLs is extremely important to GDOT. This fits within a wider need to understand the effects of investments in intelligent transportation systems as well as other transportation systems and infrastructures.

VSL Pilot Project on I-285 in Atlanta

GDOT conducted a VSL pilot project on the northern half, or "top end," of I-285 that encircles Atlanta. This 36-mile stretch of highway was equipped with 88 electronic speed limit signs that adjusted speed limits in 10 mph increments from 65 mph to a minimum 35 mph. The objectives were twofold:

- Analyze speeds on the highway, before vs. after implementation of VSL.
- Measure the impact of VSL on driving conditions.

This paper showcases the results from the first 90 days of VSL operations at the end of 2014. GDOT had a variety of data sources available for examining highway speeds. However, a new type of data, privately-sourced INRIX speed data, was used because it offered comprehensive, detailed information. INRIX provided data for all of 2013 and 2014, including the period when VSL was operational.

INRIX data, collected every minute at approximately half-mile intervals along each direction of the highway, provided more than 133 million data points. This became the "ground truth" of what was happening on the highway.

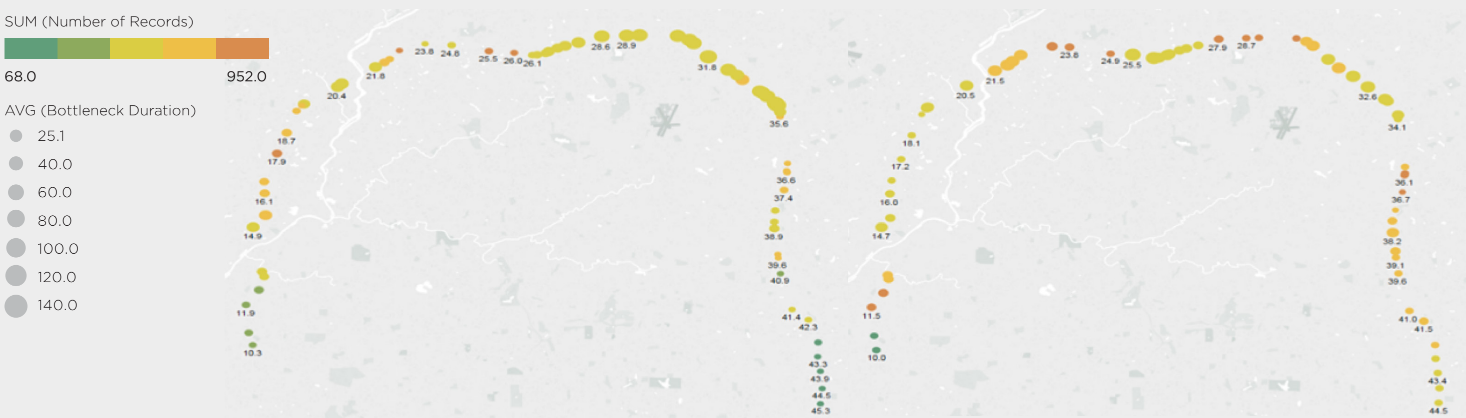

Figure 1 shows locations of persistent top end slowdowns on the highway by duration in minutes (size of circle), frequency (intensity of color), and direction of travel.

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To obtain an initial view of traffic, Teradata data science solutions identified the locations and durations of "persistent slowdowns." When highway speeds are above "reference speed," then traffic is considered freely flowing. When they fall below the reference speed at any point on the highway, it's considered a slowdown. When slowdowns persist across multiple consecutive minutes, a persistent slowdown can be defined.

Finding Slowdown Patterns on Highways

By creating an analytic definition of slowdowns, it is possible to convert voluminous, and highly variable speed data into patterns to support closer investigation. In Figure 1, we show the slowdowns in clockwise and counterclockwise directions. This revealed that the frequency and duration of slowdowns are very different by direction.

To better understand how slowdowns affect highway traffic, it is useful to take our new definition and zoom in on a specific situation. In Figure 2, we show a specific, but typical Atlanta afternoon on the I-285, at a section of highway where traffic is moving clockwise, from the west to east, between mile markers MM10 in the west to the east end at MM46.

The first significant slowdown occurred at 3:00 pm near MM32. The size of the circles represents duration (measured in minutes). The slowdown at MM32 is nearly four hours long. As that slowdown "persists," traffic is slowed down behind it. The slowdown formed at MM32 becomes a bottleneck that causes traffic behind it to slow down as well.

The "comet trail" of backed up traffic at the top left of the Figure 2 illustrates the sequential formation of slowdowns at MM32 and then further west, each starting later in the afternoon and not lasting as long.

Measuring Highway Speed Variability

Seeing the patterns of slowdowns on the highway, their different timings and locations, led us to question their impact on drivers. If VSL could help drivers better anticipate the stop-and-go nature of slowdowns, then being able to quantify the impact would be of interest to GDOT.

We were particularly concerned about what happens when a driver first encounters a slowdown. While we do not know what causes a slowdown, we do know that drivers have to make speed adjustments. If the slowdown was caused by an accident, then the speed reduction could be quite sudden; alternatively, if the slowdown was just caused by growing volumes of traffic, then the speed reduction might be much more gradual.

We took a clue about the impact of this variability and potential impact of VSL signs from a comment by the GDOT Assistant Traffic Engineer, Mark Demidovich, "When you drive the I-285 top end during an incident, your subjective impression is that the traffic is more tranquil."

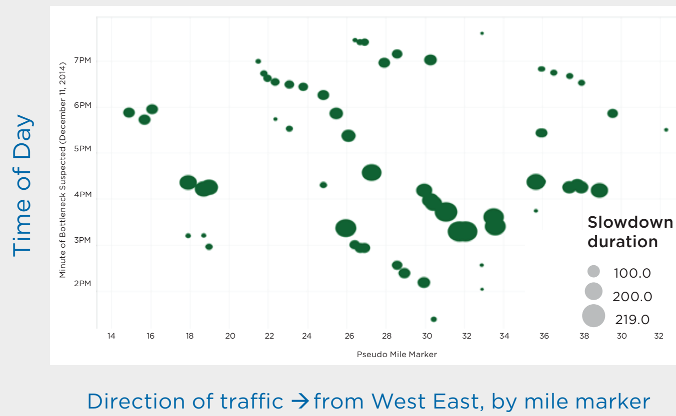

Figure 2: Traffic Moving Clockwise During the Afternoon

Since the opposite of tranquility can be defined as turbulence, we adopted the search for traffic turbulence as the primary evaluation parameter and created a line of exploration around specific definitions of turbulence, such as rate of speed change between consecutive lengths of highway segments.

The places of most interest were the comet trails, because that was where slowdowns were occurring in great numbers, for long periods of time. We specifically focused on locations where drivers were decelerating, and this led to the second new analytic definition, which was that of a bottleneck.

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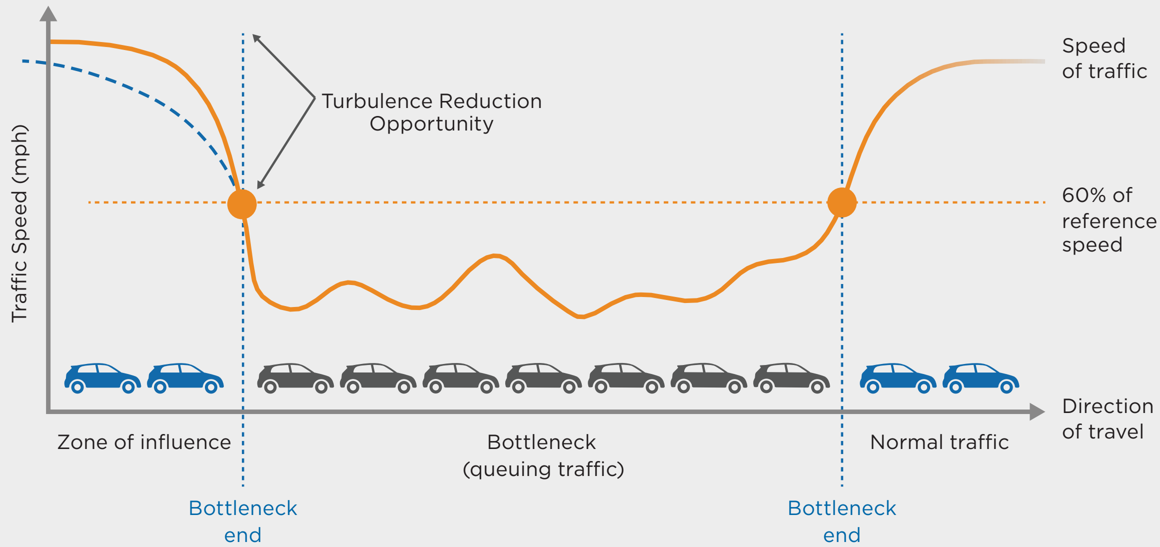

Figure 3: Bottleneck on a Highway

Identifying Bottlenecks and Traffic Turbulence

A bottleneck starts as a slowdown at a particular location. Something like "pinch point" occurs on the highway. Then, over a period of time, traffic slows down behind the original pinch point. A bottleneck is a length of highway where traffic falls below 60 percent of reference speed and can stay at that level for miles. Figure 3 shows a conceptual representation of a bottleneck.

While bottlenecks are initiated by a pinch point, or slowdown, that forms the head of the queue, it is the end of the queue that is the most interesting. The area at the back of a queue is where traffic encounters a transition from free flow to slowly moving congested conditions.

In the worst conditions, the end of queue can experience a rapid transition. Drivers moving at highway speed may unexpectedly encounter slower traffic. This condition is ripe for accidents and is the place where VSLs can deliver real value.

By detecting the slower speeds in a bottleneck ahead, VSL signs upstream can warn drivers by posting speed limit reductions well in advance of reaching the back end of the queue (see the "zone of influence" in Figure 3). With advance warning from a VSL, we expect that drivers approaching a bottleneck would decelerate at a more gradual rate than without that warning.

We measured deceleration in the approach to a bottleneck at three locations and then calculated the average turbulence across the zone of influence. We did find compelling evidence of smoother, more "tranquil" speed reductions. Figure 4 shows how over a distance of one mile, drivers reduce their speed from almost 60 mph to 30 mph. By comparing 4Q2013 to 4Q2014, we see that when VSL was present, it had a measurable reduction in average and total turbulence in the approach to the bottleneck.

Powerful New Insights on Highway Congestion

The availability of new big data sources that describe the "ground truth" of traffic conditions on the highways provide rich new opportunities for developing and analyzing highway performance metrics. Using just a single data source on detailed highway speeds, we produced two new and distinctive metrics using Teradata advanced data science capabilities.

First, by defining and measuring persistent slowdowns, we helped traffic engineers understand the frequency and duration of slow speed locations on a highway. The distinction of measuring a persistent slowdown vs. a fleeting one is uniquely challenging and requires data science. Data science provides the ability to compare the number, duration, and location of slowdowns in a way that's more informative and compelling than simple averages, variances, and outliers in highway speeds.

	Speed in the "Zone of Influence"						Average Zone Turbulence	Count of Bottlenecks	Total Zone Turbulence	Avg Queue Length
	1 mile from queue		0.5 mile from queue		end of queue					
	actual	posted	actual	posted	actual	posted	(mph/minute)	(#)	(mph/minute)	(miles)
4Q2013	56.6	-	49.0	-	30.1	-	(20.8)	81,218	(1,686,757)	3.9
4Q2014	55.9	47	48.9	43	29.9	39	(18.9)	80,627	(1,521,833)	4.3
	Lower		Lower		Lower		Lower		Lower	

Figure 4: Bottleneck Turbulence in the Zone of Influence

The second metric was the ability to measure turbulence caused by bottlenecks. By identifying where bottlenecks occur, and then by narrowing in on their very critical zones of influence, we can make measurements of speeds and traffic deceleration turbulence within those zones. Data science and analytic capabilities demonstrated reduced turbulence when VSL is active in the critical zone of a bottleneck.

There is much more that could be explored within this context. For example, it is natural to assume that because most traffic is on the road during rush hours, VSL provides the most benefits during these high traffic periods. However, the opposite may be true, which could provide a very important benefit of the VSL program.

During rush hours, drivers may be more attuned to expect congestion. Conversely, during off-peak hours, drivers may not be. So if a chance, unexpected, bottleneck were to appear, there is the risk of an accident. Sometimes it is an accident that causes the bottleneck in the first place, and then a second accident occurs as a result of the bottleneck. Preventing these secondary accidents in the zone of influence may be one of the most visible use cases for the VSL program. Combining analytics and ground truth data can bring clarity to these new opportunities.

Creating Sustainable Improvements for Transportation

Teradata has experience across smart transportation solutions and related applications, deep industry knowledge, and broad expertise with complex analytics at scale. Our proven capabilities span technologies, people, and methodologies to deliver high-value, sustainable business outcomes for smart cities. Our multi-industry consulting expertise, advanced analytic capabilities, and intellectual property make us uniquely qualified to connect and enable smart cities.

We help companies evolve from standalone or narrowly-focused smart city projects to tightly integrated, business-driven operations. Using Smart Data Management as a focal point, we drive projects to success through data acquisition and a proven strategy that optimizes analytics.

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