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TITLE: Performance Metrics for Visualizing Interdependent Regional Traffic Congestion Using Aggregated Probe Vehicle Data

by

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INTRODUCTION

Analysis of the performance of expansive road transportation networks requires copious quantities of pertinent data. Traditional data sources for roadway performance measures are traffic counts, spot-speed studies and travel-time studies, which provide very limited data in terms of temporal and spatial coverage. In contrast, anonymous probe vehicles are currently acquiring big data repositories that are rich in spatial and temporal coverage over the vast majority of the nation's roadways. These big data repositories are increasingly being used in transportation analytics and in the development of key performance measures. For example, the Texas A&M Transportation Institute (TTI) incorporates probe vehicle data in the annual publication of the Urban Mobility Report, which ranks urban congestion levels throughout the United States (1). Probe vehicle data has been used in national mobility reports (2, 3) and statewide mobility reports of interstates as well as pre-defined commuter corridors using different performance measures (4, 5, 6, 7, 8, 9,10). Recent research has used this type of data to develop quantified regional performance measures along with visually intuitive graphical representation of large data sets (11, 12). Probe data has also been used to evaluate the impact on the roadway network after a natural disaster (12, 13). Collective congestion performance measures on a regional level provide a means to determine the impact of planning, operation decision, and overall resiliency to better determine future decisions regarding construction, detours, and may provide insight as to how to focus capital improvement funds to better manage the system as a whole. Visualization methods are necessary to convey meaning of large data sets. The importance of "information visualization" is well characterized by the following quote (14):

"Most data analysis involves searching for and making sense of relationships among values and making comparisons that involve more than just two values at a time. To perform these operations and see relationships among data, which exhibit themselves as patterns, trends, and exceptions, we need a picture of the data." (Page 30.)

While probe vehicle data is currently being adopted due to its expansive and continuous nature, it only responds as a symptom of existing problems, and it is not well understood how it responds to different stimuli.

This paper evaluates how the archived anonymous probe vehicle speed data reacts to the I-276 bridge closure between New Jersey and Pennsylvania. Approximately 90-million speed records covering three adjacent counties in New Jersey were analyzed in the study. The research methods build on previously defined performance measures (11, 12, 15, 16) to demonstrate how aggregated probe data can be used to assess the congestion due to, and recovery from, a major impact on the roadway network across a region. The performance measures developed quantify the increase in travel time experienced by the motoring public in a visually intuitive manner.

DATA

The evaluation of commercially available anonymous probe vehicle speed data requires a cross reference between spatially defined Traffic Message Channels (TMC) and temporal speed data sets. These data are collected by a commercial provider who tracks vehicle telematics over predefined TMCs. Each TMC is geo-located and assigned a corresponding unique roadway ID. The format of this data has been defined in previous research (11, 12, 15). Each speed record is accompanied by a time stamp, c-value, and confidence score. A confidence of 30, along with a c-value of 100, indicates that the speed is directly based, not calculated, on probe vehicle measurements with a high confidence that the speed represents the actual roadway conditions. For this research, only records with a score of 30 and c-value of 85 or greater, which is an 85% confidence that the actual roadway conditions is represented, were included.

The study region is defined by selecting all TMCs within three New Jersey counties, namely Mercer, Camden, and Burlington counties, located in the close proximity of the Pennsylvania (PA)/New Jersey (NJ) Turnpike Bridge crossing (I-276), shown in Figure 1. The I-276 Bridge was abruptly closed on Friday January 20, 2017 (17) due to a failure in a structural member, leaving six of the seven regional bridges open for traffic. The study area (Figure 1) is comprised of 1,765, or about 10.8% of the state's 16,256 TMCs. The regional analysis was broken out to include the New Jersey Department of Transportation (NJDOT) maintained roads (Interstates and Arterials) and local roads that are not maintained by NJDOT. The data was collected between January 1, 2017 and March 31, 2017 to cover the bridge closure and subsequent reopening. The data employed in the big data analytics for this research included over 90 million unique speed records.

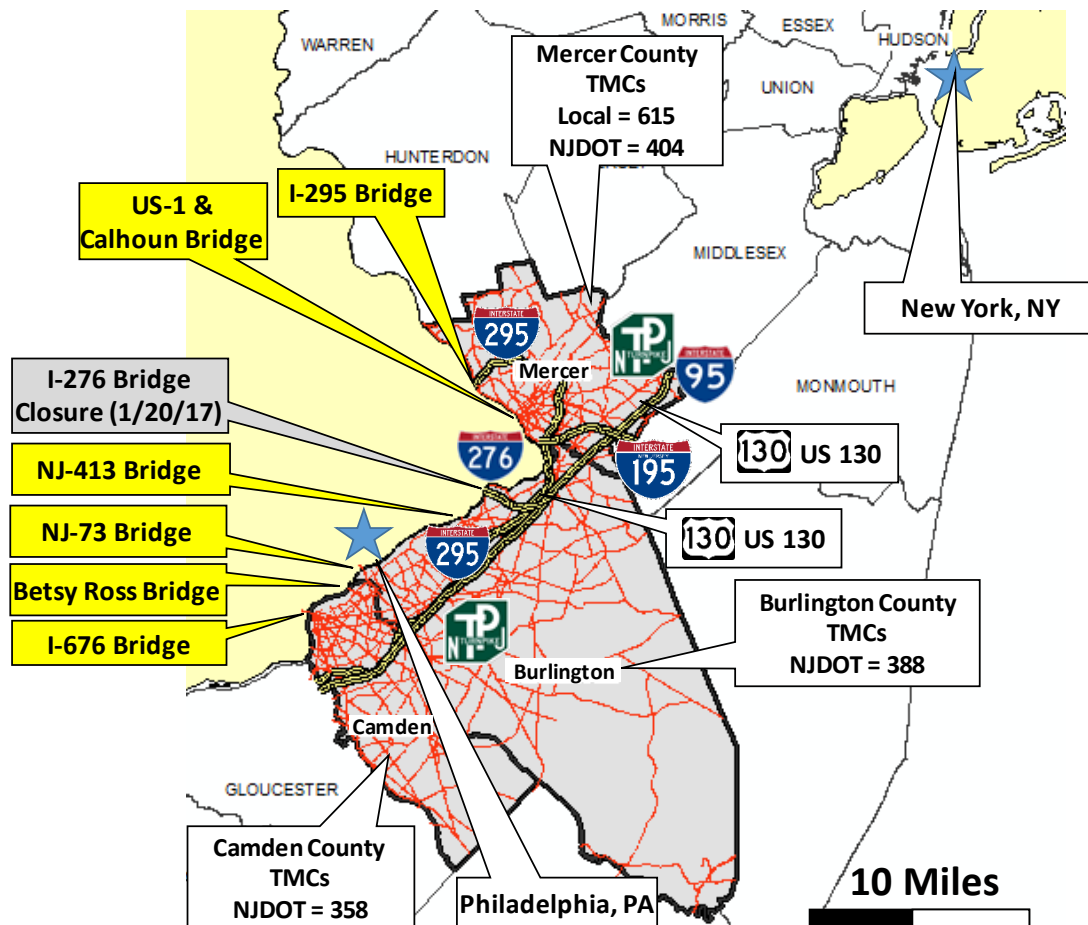


Figure 1. Three-county study area (New Jersey, USA) around the I-276 Bridge closure with 1,765 TMC segments.

MEASURES OF CONGESTION

The *MTT* provides a means to evaluate and compare the impact of traffic related events traversing regional transportation network boundaries. The I-276 Bridge was abruptly closed on Friday January 20, 2017, when a structural member was found to be cracked (17). To determine the impact on the three adjacent counties, the *MTT* was applied. The visualization of *MTT* is provided in Figure 2a for all NJDOT maintained roadways in Mercer, Burlington, and Camden County, NJ. The graph shows the

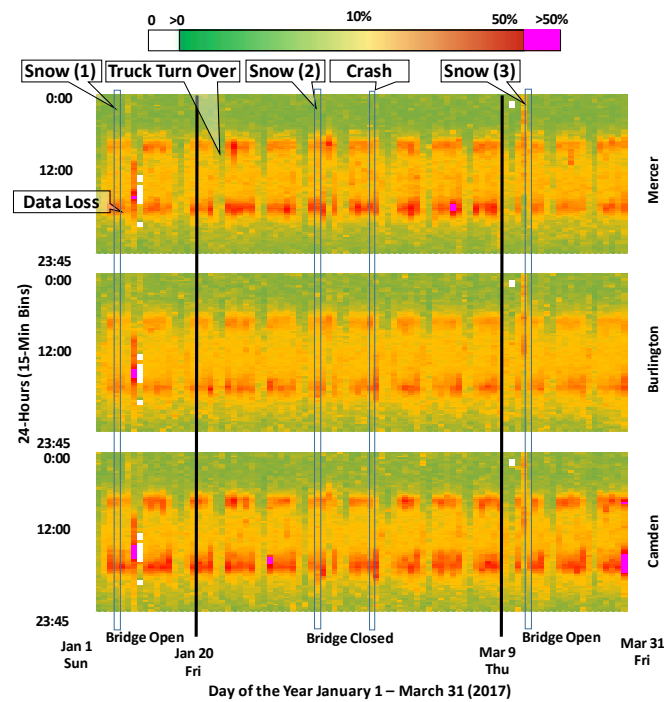
juxtaposing of the counties, each with a 24-hour y-axis in 15-minute increments. There are a number of observations that can be derived from this graph, some impacting a single county, while other impacted each of the counties.

- All counties: Three snow days are observed in all counties
- All counties: Areas shown to be ‘white’ are locations when no-data was available.
- All counties: The weekend traffic versus the weekday traffic.
- All counties: AM Peak and PM Peak travel times are identified.
- All counties: Road Closure on US-130 due to crash incident (18)
- Mercer County: Dump Truck Turn over on I-195 (19)

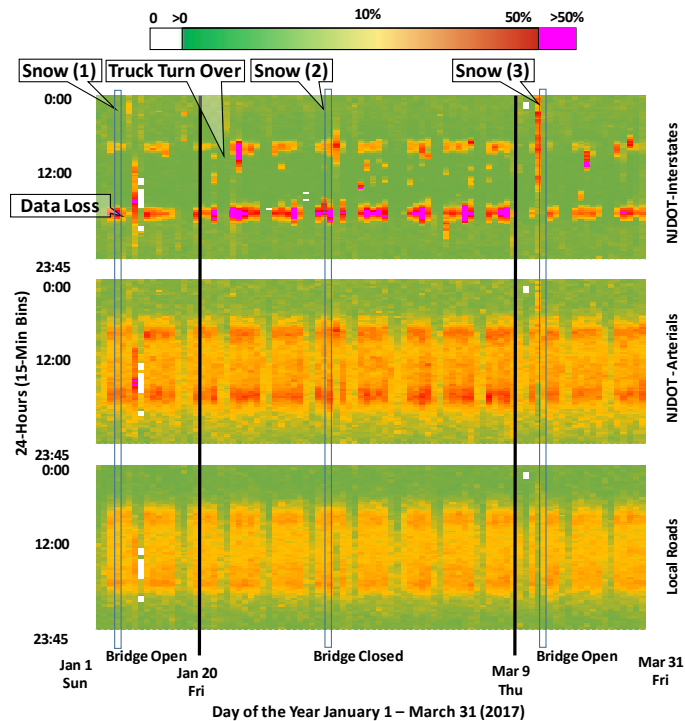
Most of the observations were noted to be recurring traffic patterns that are consistent across the counties. As would be expected, the snow days did show an impact across all the counties. One crash incident occurring on February 17, 2017 resulted in the closure of US-130 in both directions. US-130 runs parallel to both the New Jersey Turnpike and Interstate 295 and traverses each of the counties. The incident appeared to impact roadways in all three counties. The illustrative shows the county transportation systems’ resiliency by its return to recurring congestion systems the following day. A similar observation is made during the Saturday January 7, 2017 snow storm (Storm 1), where not only the resiliency of the transportation system is show, but the resiliency of the data collection systems whose data was missing of the region immediately following the snow. Following the snow, the transportation system as well as the data collection returned to pre-storm conditions.

With respect to the start and end date of the bridge closure, it appears that Mercer County had an increase in *MTT* while the bridge, located in Burlington County, was closed. Detours in the region had travelers directed to I-95/I-295 in Mercer County instead of the bridge. Figure 2a shows a change in the *MTT* coinciding with the bridge closure did occur. Thus, the *MTT* measure clearly captures the impact of the I-276 bridge closure on Mercer County, as seen by the minimal impact on Camden and Burlington Counties. It also captures Mercer County’s ability to recover from the detour after the bridge re-opened.

With Mercer being identified as the most impacted county, the *MTT* data can be disaggregated to better observe the interdependency of the congestion on the interstate roadways verses the arterial as well as the non-NJDOT maintained local roads. The NJDOT roadways were disaggregated into NJDOT maintained arterials and interstates as shown in Figure 2b. An additional analysis of 615 TMCs representing roadways in Mercer County that are not maintained by NJDOT are also shown in Figure 2b. By disaggregating the roadways, it appears that the interstates incurred the brunt of the increase in *MTT* due to the bridge closure. However, the measures for arterials also show that they were impacted by the bridge closure. The measures for local roads show that they were not necessarily impacted by the I-276 bridge closure, at least not directly. One incident identified in Figure 2a as a truck turn over on an I-195 on-ramp, had more of an observable impact when shown only on the interstate heat map shown in Figure 2b. It should be pointed out that Interstate 195 only traverses Mercer County, and the incident occurred in a relatively rural part of New Jersey.



a) NJDOT Maintain Roadways - Mercer, Burlington, and Camden, NJ (1,150 TMCs)



b) Mercer County, NJ (1,019 TMCs)

Figure 2. MTT for Roadways

CONCLUSIONS

This research applied a scalable Mean Percent Increase in TMC Travel Time (MTT) performance measure that quantifies the increase in base free flow travel time (BTT). This performance measure was used to visualize the complexities of the interdependent roadway networks within Mercer, Burlington, and Camden, counties New Jersey, USA using a heat map visualization methodology. The *MTT* was specifically applied to 90 Million probe vehicle speed data points to measure the changes, and eventual recovery, in regional travel time resulting from the abrupt closing of the I-276 Bridge near Philadelphia, PA. The performance metric allowed a comparison of the relational impact among three counties before, during, and after the bridge closure. The research demonstrated that a graphical ‘heat map’ representation of the bridge closures can be derived directly from probe vehicle data. When the bridge was closed, there was a notable increase in *MTT* for Mercer County that returned to near pre-closure *MTT* once the bridge re-opening. The visualized data illustrated the regional resiliency of Mercer County during the closure.

The methods used, and performance measures and visualization tools developed in this research help determine the local and regional impact of incidents, weather events and the potential outcome of planned disruptions. The application of methods presented in this study on probe vehicle data in real time can help improve the efficiency the management of regionally distributed traffic systems and network disruptions unfold. Further research can explore the need for determining data driven regional boundaries, instead of arbitrary boundaries, which may inadvertently gerrymander congestion out of an agency’s situational awareness. Ultimately, the ability to visualize interdependencies among and with a region’s transportation network can help in the planning for temporary or permanent infrastructure investment.

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