ABSTRACT

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Title: Transportation System Performance Measures Using Internet of Things Data
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The transportation system is undergoing a rapid change with innovative and promising technologies that provide real-time data for a variety of applications. As we transition into a technology-driven era and Internet of Things (IoT) applications, where everything is connected via a network of smart sensors and cloud computing, there will be an increasing amount of real-time data that will allow a better understanding of the transportation system. Devices emerging as a part of this connected environment can provide new and valuable data sources in a variety of transportation areas including safety, mobility, operations and intelligent transportation systems. Agencies and transportation professionals require effective performance measures and visualization tools to mine this big data to make design, operation, maintenance and investment decisions to improve the overall system performance. This dissertation discusses the development and demonstration of performance measures that leverage data from these emerging IoT devices to support analysis and guide investment decisions. Selected case studies are presented that demonstrate the impact of these new data sources on design, operation, and maintenance decisions.

Performance measures such as vibration, noise levels and retroreflectivity were used to conduct a comprehensive assessment of different rumble strip configurations in the roadway and aviation environment. The results indicated that the 12 in sinusoidal wavelength satisfied the National Cooperative Highway Research Program recommendations and reduced the noise exposure to adjacent homeowners.

The application of low-cost rumble strips to mitigate runway incursions at general aviation airports was evaluated using the accelerations on the airframe. Although aircraft are designed for significant g-forces on landing, the results of analyzing accelerometers

installed on airframes showed that long-term deployment of rumble strips is a concern for aircraft manufacturers as repeated traversal on the rumble strips may lead to excessive airframe fatigue.

A suite of web dashboards and performance measures were developed to evaluate the impact of signal upgrades, signal retiming and maintenance activities on 138 arterials in the state of Pennsylvania. For five corridors analyzed before and after an upgrade, the study found a reduction in 1.2 million veh-hours of delay, 10,000 tons of CO_2 and an economic benefit of $32 million.

Several billion dollars per year is expended upon security checkpoint screening at airports. Using wait time data from consumer electronic devices over a one-year period, performance dashboards identified periods of the day with high median wait times. The performance measures outlined in this study provided scalable techniques to analyze operating irregularities and identify opportunities for improving service. Reliability and median wait times were also used as performance measures to compare the standard and expedited security screening. The results found that the expedited screening was highly reliable than the standard screening and had a median wait time savings of 5.5 minutes.

Bike sharing programs are an eco-friendly mode of transportation gaining immense popularity all over the world. Several performance measures are discussed which analyze the usage patterns, user behaviors and effect of weather on a bike-sharing program initiated at Purdue University. Of the 1626 registered users, nearly 20% of them had at least one rental and around 6% had more than 100 rentals, with four of them being greater than 500 rentals. Bikes were rented at all hours of the day, but usage peaked between 11:00 and 19:00 on average. On a yearly basis, the rentals peaked in the fall semester, especially during September, but fell off in October and November with colder weather. Preliminary results from the study also identified some operating anomalies, which allowed the stakeholders to implement appropriate policy revisions.

There are a number of outlier filtering algorithms proposed in the literature, however, their performance has never been evaluated. A curated travel time dataset was developed from real-world data, and consisted of 31,621 data points with 243 confirmed outliers. This dataset was used to evaluate the efficiency of three common outlier filtering algorithms, median absolute deviation, modified z-score and, box and whisker plots. The

modified Z-score had the best performance with successful removal of 70% of the confirmed outliers and incorrect removal of only 5% of the true samples.

The accuracy of vehicle to infrastructure (V2I) communication is an important metric for connected vehicle applications. Traffic signal state indication is an early development in the V2I communication that allows connected vehicles to display the current traffic signal status on the driver dashboard as the vehicle approaches an intersection. The study evaluated the accuracy of this prediction with on-field data and results showed a degraded performance during phase omits and force-offs. Performance measures such as, the probability of expected phase splits and the probability of expected green for a phase, are discussed to enhance the accuracy of the prediction algorithm. These measures account for the stochastic variations due to detectors actuations and will allow manufacturers and vendors to improve their algorithm.

The application of these performance measures across three transportation modes and the transportation focus areas of safety, mobility and operations will provide a framework for agencies and transportation professionals to assess the performance of system components and support investment decisions.