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# ABSTRACT

Advancements in technology have propelled the availability of enriched and more frequent information about traffic conditions as well as the external factors that impact traffic such as weather, emergency response etc. Most newer vehicles are equipped with sensors that transmit its data back to the original equipment manufacturer (OEM) at near real-time fidelity. A growing number of such connected vehicles (CV) and the advent of third-party data collectors from various OEMs have made big data for traffic streams commercially available for use. Agencies maintaining and managing surface transportation are presented with opportunities to leverage such big data for efficiency gains. The focus of this dissertation is enhancing the use of CV data and applications derived from fusing it with other datasets to extract meaningful information that will aid agencies in data driven efficient decision making to improve network wide mobility and safety performance.

One of the primary concerns of CV data for agencies is data sampling, particularly during low-volume overnight hours for getting a systematic overview of the entire roadway network. An evaluation of over 3 billion records from more than 13 million trips of CVs over a 1-week period in May 2022 across 40 continuous count stations in Indiana has shown an overall CV penetration rate of 6.3% on interstates and 5.3% on non-interstate roadways. The average truck penetration was observed to be 3.4% during overnight hours from 1 AM to 5 AM when connected passenger car penetration rate was at its lowest.

Fusion of CV traffic speeds with precipitation intensity from NOAA's High-Resolution Rapid-Refresh (HRRR) data over 42 unique rainy days has shown reduction in the average traffic speed by approximately 8.4% during conditions classified as very heavy rain compared to no rain. The impact of rain on traffic was also shown qualitatively using the spatiotemporal traffic speed heatmaps. Both aggregate analysis and disaggregate analysis performed during this study enables agencies and automobile manufacturers to effectively answer the oft-asked question of the intensity of rain it takes to begin impacting traffic speeds. Proactive measures such as providing advance warnings that improve the situational awareness of motorists and enhance roadway safety should be considered during very heavy rain periods, wind events, and daylight conditions.

Scalable methodologies that can be used to systematically analyze hard-braking and speed data obtained from CVs were also developed. Weekly reports generated using such work zone

monitoring techniques applied over 205 billion records in Indiana were also actively disseminated to stakeholders managing the work zone operations on interstates. This study demonstrated both quantitatively and qualitatively how CV data provides an opportunity for near real-time operational assessment of work zone operations using metrics such as congestion, location-based speed profiles and hard braking. This systematic methodology for integrating CV data into operational decision making was illustrated using case studies on I-65 and I-70 to demonstrate how early warning signs from CV data can be utilized. The availability of data across different states and ease of scalability makes the methodology implementable on a state or national basis for tracking any highway work zone with little to no infrastructure investment. These techniques can provide a nationwide opportunity in assessing the current guidelines and giving feedback in updating the design procedures to improve the consistency and safety of construction work zones on a national level.

CV data was also used to evaluate the impact of queue warning trucks sending digital alerts. Hard-braking events were found to decrease by approximately 80% when queue warning trucks were used to alert motorists of impending queues analyzed from 370 hours of queueing with queue trucks present and 58 hours of queueing without the queue trucks present, thus improving work zone safety. Such CV data was also used to evaluate the impact of presence lighting (PL) and digital speed limit (DSL) trailers on nighttime motorist speeds on a section of I-65 in Indiana. Results showed that median speeds reduced by 4 to 13 mph from 11 PM to 7 AM during the deployment. Increased compliance with the work zone speed limit of 55 MPH was also observed when PL and DSL trailers were deployed.

Emerging opportunities to identify and measure traffic shock waves and their forming or recovery speed anywhere across a roadway network are provided due to the ubiquity of the CV data providers. A methodology for identifying different shock waves was presented, and among the various case studies found typical backward forming shock wave speeds ranged from 1.75 to 11.76 mph whereas the backward recovery shock wave speeds were between 5.78 to 16.54 mph. The significance of this is illustrated with a case study of  a secondary crash that suggested accelerating the clearance by 9 minutes could have prevented the secondary crash incident occurring at the back of the queue. Such capability of identifying and measuring shock wave speeds can be utilized by various stakeholders for traffic management decision-making that provide a holistic perspective on the importance of both on scene risk as well as the risk at the back of the queue. Near real-time estimation of shock waves using CV data can recommend travel time prediction models and serve as input variables to navigation systems to identify alternate route choice opportunities ahead of a driver's time of arrival.

The overall contribution of this thesis is developing scalable methodologies and evaluation techniques to extract valuable information from CV data that aids agencies in operational decision making.