Abdullah J. Nafakh

Professor Darcy Bullock, Co-Chair
Professor Samuel Labi, Co-Chair

ABSTRACT

Historically, roadway performance measures have focused almost exclusively on vehicular movement. In most urban settings, pedestrian movements typically outnumber vehicular movements significantly, but there has historically been no way to collect them at scale systematically. With the widespread introduction of cameras for monitoring vehicular flow, there is an opportunity to leverage this infrastructure to acquire insights into the patterns and trends of pedestrian activities at signalized intersections in an automated and systematic manner. Such data and performance measures are critical inputs for detailed analysis of pedestrian movements. Overall, addressing this issue is a vital component of transportation agencies that seek to develop equitable treatment of all transportation system users including vulnerable road users. This dissertation addresses the gap in the literature regarding detailed characterization of pedestrian movement patterns and trends. The dissertation leverages data from signalized intersection cameras to (1) quantify the required duration for the pedestrian walk-interval based on pedestrian volume and geometric features of the intersection, (2) carry out time series analysis to acquire insights on pedestrian demand patterns and the impacting variables, and (3) build machine learning algorithms to accurately predict pedestrian volumes and tie it to signal timing, to enhance service for all roadway users.

The first study provides quantitative guidance for walk time interval selection. This part reports on 1,500 pedestrian movement observations from 12 signalized intersections with varying pedestrian demand, pedestrian storage areas, and pedestrian push-button locations. That data were used to develop a model predicting start-up time with an R^2 of 0.89. The study concludes by presenting a quantitative table with four timing categories ranging from negligible volume to high volume and corresponding appropriate durations for the pedestrian walk interval time, based on the demand per cycle, storage area for pedestrians, and offset of the pedestrian push-button from the crosswalk.

The second study describes several scalable techniques for measuring and analyzing the movement of pedestrians on a typical university campus. Approximately 35.6 million pedestrian movements over 19 months were tabulated in 15-minute counts of pedestrian volumes by intersection. Counts are used in evaluating pedestrian activity dependency on select explanatory variables at both the network and intersection levels at each time step for the entire analysis period. The study reports on time series correlation and cross-correlation and measures the time-dependency between pedestrian activities and influential factors such as the academic calendar, football games, basketball games, and graduation ceremonies. It provided a comprehensive understanding of the factors most impacting pedestrian volumes at intersections.

The third study presents a data-driven approach to predict pedestrian volume per intersection quadrant at 15-minute intervals, and to connect this information to signal timing. Machine learning random forest and XGBoost classification models were trained on a large dataset of pedestrian counts consisting of approximately 2.6 million observations collected through 19 months at 13 exclusive pedestrian service intersections. The predicted pedestrian volumes were then categorized per the pedestrian walk-interval categories to provide optimal signal timing for each intersection quadrant, thus enabling potential dynamic pedestrian signal timing at exclusive service intersections. The results of this study showed that the developed models accurately predict pedestrian volumes per 15-minute intervals for each quadrant of an intersection, with a high degree of precision and a prediction accuracy of 82.3%. Signal timing optimization based on predicted pedestrian volume can significantly improve pedestrian mobility and maximize traffic flow.

The findings of this study provide valuable insights for traffic engineers and planners interested in developing and deploying dynamic pedestrian signal timing systems. It is a practical and effective solution for improving mobility for all roadway users at intersections with exclusive pedestrian service.