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A Framework for Assessing Pedestrian Exposure Using GPS and Accelerometer Walking Data

Background

In 2022, an estimated 7,522 pedestrians were killed by vehicles, the highest number in 40 years (NCSA, 2024). To support safe active transportation, research on pedestrian exposure is needed to understand and reduce risks. Pedestrian exposure is defined as the number of potential opportunities for a pedestrian to be involved in a crash or other harmful situation with a moving vehicle on or near the roadway environment (Greene-Roesel et al., 2007; Ryus et al., 2014). Understanding and measuring pedestrian exposure is critical to implementing a safe system approach to eliminate serious and fatal injuries for pedestrians (U.S. DOT, 2022).

Quantifying safe travel requires a better understanding of the likelihood that a pedestrian will be involved in a potentially harmful pedestrian-vehicle interaction. This is achieved by obtaining a good pedestrian exposure metric, which will allow traffic safety experts and policymakers to differentiate between emerging risks and changing patterns of exposure. From this exposure metric countermeasures can be tailored for different pedestrian walk patterns. However as discussed in the full report, pedestrian exposure is challenging to measure accurately and efficiently. This study provides a framework quantifying pedestrian exposure that can be used by transportation researchers to capture pedestrian exposure.

Method

The primary objectives of this project were to develop an operational definition of pedestrian exposure and create a representative pedestrian exposure measure that can be modeled analytically. Time segments of physical activity during which walking was measured to have occurred, referred to as "walking bouts," provided the foundation for measuring pedestrian exposure and can be aggregated to the individual, trip, and intersection level. Walking bouts are naturalistic observations of pedestrian walk patterns over various locations and times. For this study, walking bouts were used to capture pedestrian volumes at intersections (the point location) in Seattle and surrounding King County, Washington.

The study team first examined pedestrian exposure metrics used in past studies. The team then used data collected from two previous longitudinal studies on walking in King County. This project builds an estimate of pedestrian exposure based on individual walking activity captured using accelerometers and GPS devices. Estimates of pedestrian exposure were built on time segments of physical activity during which walking is measured to have occurred ("walking bouts"). Explanatory variables included geospatial locations, individual-level characteristics, micro-environmental factors, and macro-environmental factors (see Table 1).

Framework Development

The first step in developing the pedestrian exposure model combined all data into a format defined at the intersection level. The project team used TIGER/Line spatial databases (data.census.gov) to identify over 14,000 intersections in King County.

A framework was developed to combine all environmental variables and walking bouts at the intersection level. Separate analytic models were developed for two different datasets: the first comprised all intersections in Seattle regardless of whether a walking bout was observed, and the second analyzed intersections where 10 or more walking bout counts were observed.

The first dataset examined the likelihood of observing any amount of walking. The second analyzed the environmental factors that impact the frequency of observed walking.

Table 1. Examples of Explanatory Variables Modeled

Individual-Level Variables (derived from King County longitudinal studies)	Micro-Environmental Variables	Macro-Environmental Variables
Pedestrian average age	Average roadway width	Residential and job density
Pedestrian female ratio	Median roadway class	Population and residential census density
Pedestrian non-white race ratio	Maximum posted speed limit	White population percentage (census)
Pedestrian employment ratio	Total sidewalk length	Median household income
Pedestrian median household income	Total crosswalk count	Public school presence and enrollment count
Pedestrian single household ratio	Presence of traffic signs or signals	Residential, manufacturing, transportation, trade, and service land use percentage

Results

The number of walking bouts (the outcome variable) was associated with multiple variables. The first model showed that several variables increased the number of walking bouts; they included:

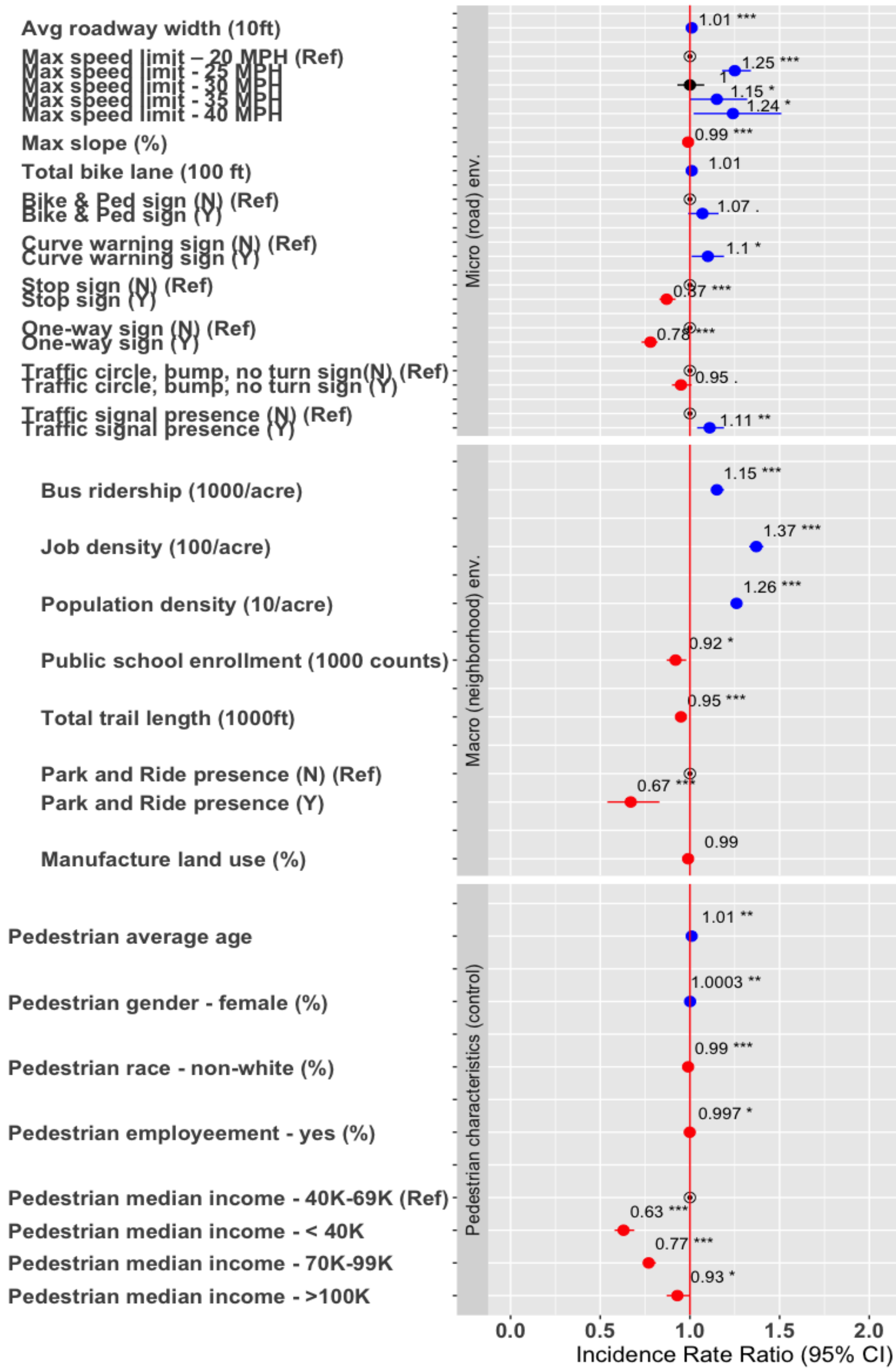
- longer bike lane length,
- presence of crosswalk warning sign,
- presence of bike and pedestrian sign,
- presence of traffic signal,
- higher bus ridership density,
- higher population density,
- park presence,
- longer trail length, and
- higher job density.

Variables that were associated with a decrease in walking bouts included:

- higher maximum roadway slope,
- presence of one-way signs, and
- presence of a park and ride facility.

As shown in the figure below, many of the same indicators of increased walking frequency were found using the second dataset (10+ walking bouts).

Figure 1. Model Results for Intersections With 10+ Walking Bouts (Dataset 2)



Our results also identified environmental predictors that may be useful for pedestrian exposure analyses. These variables were identified as significant either during variable selection or modeling. Significant micro-environment (location-based) variables of interest include:

- average roadway width,
- maximum speed limit,
- total sidewalk length (feet), and
- the presence of various pedestrian- and vehicle-related control signs and devices (one-way signs, stop signs, crosswalk signs, and traffic signals).

Significant macro-environment (population-based) variables of interest include:

- total trail length (feet),
- public school enrollment count,
- bus ridership density,
- job density, and
- various land uses (manufacturing, service, transportation).

Many of these variables are available at the local and state level. For example, one of the most significant variables was maximum slope percentage, a variable available in most localities.

Conclusions

This study provides a framework for using environmental predictors to estimate pedestrian exposure that can be used by other localities. The use of electronic device data to measure pedestrian exposure was shown to be useful, providing information on relative frequency of pedestrian activity at a highly disaggregated level. Walking bouts can also be aggregated up to the person-, trip-, and intersection-level to estimate exposure patterns and can be used with crash data to estimate risk of pedestrian-vehicle crashes or severe injuries accounting for variation in pedestrian exposure. The framework can be adapted to different levels of analysis. While not fully exhaustive, the list of predictor variables provided in this report serve as a starting point for other localities to examine pedestrian behavior. Additional environmental factors that exist within a specific locality can easily be incorporated.

References

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Download a copy of the final report, *A Framework for Assessing Pedestrian Exposure Using GPS and Accelerometer Walking Data* (Report No. DOT HS 813 583), https://rosap.ntl.bts.gov.

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