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Use of different exposure metrics for understanding multi-modal travel injury risk

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ABSTRACT

The objective of this work is to identify characteristics of different metrics of exposure for quantifying multi-modal travel injury risk. First, a discussion on the use of time-based and trip-based metrics for road user exposure to injury risk, considering multiple travel modes, is presented. The main difference between a time-based and trip-based metric is argued to be that a time-based metric reflects the actual duration of time spent on the road exposed to the travel risks. This can be proven to be important when considering multiple modes since different modes typically different speeds and average travel distances. Next, the use of total number of trips, total time traveled, and mode share (time-based or trip-based) is considered to compare the injury risk of a given mode at different locations. It is argued that using mode share the safety concept which focuses on absolute numbers can be generalized. Quantitative results are also obtained from combining travel survey data with police collision reports for ten counties in California. The data are aggregated for five modes: (i) cars, (ii) SUVs, (iii) transit riders, (iv) bicyclists, and (v) pedestrians. These aggregated data are used to compare travel risk of different modes with time-based or trip-based exposure metrics. These quantitative results confirm the initial qualitative discussions. As the penetration of mobile probes for transportation data collection increases, the insights of this study can provide guidance on how to best utilize the added value of such data to better quantify travel injury risk, and improve safety.

1. Introduction

Travel injury risk, defined as the number of injuries (or deaths) per unit of exposure, is often used to report on the safety of traveling on roadways. Commonly available metrics for quantifying exposure to travel injury risk include total distance traveled; total number of trips made; and total population. Additional exposure metrics such as travel time are sometimes available too, but are not commonly used. When considering travel injury risk of a single mode for a single jurisdiction with a homogeneous population, the choice of exposure metrics is often irrelevant due to the similar travel speeds, travel distances and mode share. However, when considering multiple modes, multiple jurisdictions, or regions with very heterogeneous population profiles, there is a lack of understanding of the implications of using different exposure metrics. The speed difference between modes, and the different travel characteristics, can significantly alter the relative magnitudes of different

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exposure metrics. This in turn may change the comparison of risk between different travel modes. Also, the mix of modes at different regions can change how different modes interact with each other, changing the travel injury risk of a given mode.

The data for these exposure metrics are typically obtained using household transportation surveys administered by a combination of mail and telephone data collection instruments. In addition to being costly, such surveys are also limited in their ability to capture valuable exposure metrics such as travel time. While some countries and regions are able to reliably collect travel time as part of their surveys, many other countries and agencies have to resort to focusing on distance traveled, number of trips, and population as exposure metrics. Recent technological advances in mobile technology provide the opportunity of using mobile probes for transportation data collection. As the penetration rate of these mobile probes increases, more accurate data on travel behavior of individuals, including travel times and mode choices, will become available in many locations around the world.

While there is some literature investigating different exposure metrics, these studies commonly focus on a single location or a single mode, but no study has investigated exposure across modes and locations. Hence, there is no comprehensive study on identifying metrics to quantify differences in travel injury risk for different modes or locations. In light of this, in order to maximize the opportunities of using mobile probes, there is a need to investigate the use of different metrics of exposure for comparing travel injury risk across modes or across locations. Specifically, time-based and trip-based exposure risks are qualitatively and quantitatively analyzed. The discussion specifically focuses on a time-based metrics ability to provide more insights into different modes' travel characteristics. The remainder of the paper is organized as follows. Section 2 presents a discussion of the different metrics used in the literature to compare travel injury risk of different modes for a single location (comparison across modes), or a single mode at different locations (comparison across locations). Following this literature review, in Section 3 a discussion on the results of using time-based or trip-based exposure metrics for comparing travel injury risk across different modes and locations, respectively, is presented. Section 4 discusses the data used to quantitatively analyze these arguments. In Section 5 the analysis on associations between exposure and risk is shown. Section 6 presents some concluding remarks along with future research directions.

2. Literature review

Though papers investigating different exposure metrics exist in the literature (Chu, 2003; Chipman et al., 1992, 1993; McAndrews, 2011; McAndrews et al., 2013), these studies focus on a single location, or single mode to highlight the difference between exposure metrics. Chu (2003) identified three exposure metrics: population-based, time-based and distance based; and across these three metrics compared the risk of travel by walking and motor vehicles in the United States. As a result of this comparison, the authors concluded that a time-based metric better captured the difference in speeds between the modes. Chipman et al. (1992) explored the differences in time versus distance as exposure metrics. Chipman et al. (1993) looked at the use of number of drivers, total distance traveled and total time traveled as the exposure metric for identifying crash rates using data collected in Ontario, Canada. These two studies concluded that the resulting crash rates obtained using these different metrics are not comparable and hence, the exposure metric to be used should be chosen carefully. However, these works only considered car users and did not look at multiple modes. McAndrews (2011) compared the traffic death rates in San Francisco and Stockholm using population, total distance traveled and total time traveled as the exposure metrics. The author reviewed three different modes: motor vehicle occupants, pedestrians, and bicyclists. The results showed that the three different exposure metrics can lead to significantly different results when comparing risk across modes.

While multi-modal analysis also exists in the literature (Beck et al., 2007; Kweon and Kockelman, 2003), these studies use only a pre-determined exposure metric. A multi-modal analysis which used person-trips as the exposure metric was employed in Beck et al. (2007) which compared the nonfatal injury rates for different modes in the United States. The authors found that motorcyclists had the highest fatality rate, followed by vehicle occupants, bicyclists and pedestrians. However, this study is limited in that it only used the number of trips as its exposure metric. Another study looked at understanding the difference in travel injury risk across different vehicle types using vehicle miles driven for each mode as the exposure metric (Kweon and Kockelman, 2003). That research provided travel injury risk of different vehicle types and crash categories. McAndrews et al. (2013) looked at using person-trips, person-minutes and person-miles as the explanatory variable to evaluate multi-modal travel injury risk in Wisconsin. The authors compared the different metrics across different demographic groups.

The main body of literature on multi-modal injury risk analysis is conducted under the topic of safety in numbers. Safety in numbers is based on the conjecture that people traveling by certain modes, specifically bicyclists and pedestrians, would have lower travel injury risks as the exposure increased. To this end, performance functions to describe the variation in travel injury risk using different explanatory variables are often presented in the literature. The explanatory variables used vary largely are: average distance traveled by a given mode (Jacobsen, 2003; Robinson, 2005; Pucher and Dijkstra, 2003; McAndrews, 2012); total number of users of a given mode (Jacobsen, 2003; Geyer et al., 2006); mode share (Jacobsen, 2003); total time traveled by a given mode (Tin et al., 2010); and conflicting pedestrian and vehicle flows (Leden, 2002). Also while some of these studies looked at comparing travel injury risk across different locations (Jacobsen, 2003; Robinson, 2005; Geyer et al., 2006; Leden, 2002) others looked at time-series analysis for a given location (Jacobsen, 2003; Tin et al., 2010). In these studies, the reason for the choice of the explanatory variable is often missing and could be restricted by the availability of data. The variation in methods and variables used makes it difficult to compare the results of these studies to determine a comprehensive analysis on how to reduce travel injury risk, especially for non-motorized modes. This