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Investigation of pedestrian crashes on two-way two-lane rural roads in Ethiopia

Getu Segni Tulu [a,*], Simon Washington [b,1], Md. Mazharul Haque [c,2], Mark J. King [d,3]

[a] Centre for Accident Research and Road Safety – Queensland (CARRS-Q), Queensland University of Technology, Victoria Park Road, Kelvin Grove 4059, Brisbane,QLD 4059, Australia
[b] Civil Engineering and Built Environment, Science and Engineering Faculty and Centre for Accident Research and Road Safety (CARRS-Q), Faculty of Health, Queensland University of Technology, George St GPO Box 2434, Brisbane, QLD 4001, Australia
[c] Centre for Accident Research and Road Safety (CARRS-Q), Faculty of Health and Civil Engineering and Built Environment, Science and Engineering Faculty, Queensland University of Technology, 130 Victoria Park Rd, Kelvin Grove, QLD 4059, Australia
[d] Centre for Accident Research and Road Safety-Queensland (CARRS-Q), Queensland University of Technology (QUT), K Block K433, Victoria Park Road, Kelvin Grove 4059, Brisbane, QLD, Australia

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ABSTRACT

Understanding pedestrian crash causes and contributing factors in developing countries is critically important as they account for about 55% of all traffic crashes. Not surprisingly, considerable attention in the literature has been paid to road traffic crash prediction models and methodologies in developing countries of late. Despite this interest, there are significant challenges confronting safety managers in developing countries. For example, in spite of the prominence of pedestrian crashes occurring on two-way two-lane rural roads, it has proven difficult to develop pedestrian crash prediction models due to a lack of both traffic and pedestrian exposure data. This general lack of available data has further hampered identification of pedestrian crash causes and subsequent estimation of pedestrian safety performance functions. The challenges are similar across developing nations, where little is known about the relationship between pedestrian crashes, traffic flow, and road environment variables on rural two-way roads, and where unique predictor variables may be needed to capture the unique crash risk circumstances. This paper describes pedestrian crash safety performance functions for two-way two-lane rural roads in Ethiopia as a function of traffic flow, pedestrian flows, and road geometry characteristics. In particular, random parameter negative binomial model was used to investigate pedestrian crashes. The models and their interpretations make important contributions to road crash analysis and prevention in developing countries. They also assist in the identification of the contributing factors to pedestrian crashes, with the intent to identify potential design and operational improvements.

1. Introduction

In developing countries, pedestrian crashes are becoming an increasing public health issue (WHO, 2004). In Ethiopia, pedestrian fatalities are the dominant type of road traffic fatalities, accounting for 55% of total deaths (Tulu et al., 2013a,b; WHO, 2009). This statistic demands attention, however pedestrian safety research in Ethiopia has been relatively rare due to the limitations of resources and institutional capacity in the field, and this shortcoming is shared by other developing countries. Therefore, the existence of critical gaps in current knowledge regarding pedestrian crash problems in developing countries is inevitable. Moreover, developing countries reveal differences in driver and pedestrian behaviours, road design, site characteristics, pedestrian demography, and crossing group effects compared to western countries (Tulu et al., 2013a,b). In general they also lack developed and contiguous pedestrian facilities, have poorly integrated land use and transport planning, are subject to frequent illegal pedestrian crossings, and lack street lighting. The intent of this paper is to fill some of the gaps in knowledge and to gain additional insight into the relationship between frequency of pedestrian crashes and explanatory contributing or causal variables using statistical models.

Considerable research has been conducted to understand the safety performance of road infrastructure as a function of traffic

* Corresponding author. +251911613179.
E-mail addresses: getu.tulu@student.qut.edu.au, getusegne@yahoo.com (G.S. Tulu), simon.washington@qut.edu.au (S. Washington), m1.haque@qut.edu.au (M. M. Haque), mark.king@qut.edu.au (M.J. King).
[1] Tel: +61 7 3138 9990.
[2] Tel: +61 7 3138 4511.
[3] Tel: +61 7 3138 4546; fax: 61 7 3138 0111.

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flow, geometric design parameters, site characteristics, and road environment factors. Much of this research has focused on estimating the safety performance of roads from the perspective of general traffic crashes. For several good reasons, relatively little research has explored pedestrian crashes occurring in less developed countries. Most pedestrian cash prediction models have been developed in the United States, and extensive pedestrian exposure data have been required (Harwood et al., 2008). This is because pedestrian volume is a vital variable, such that the frequency of pedestrian crashes varies with pedestrian crossing volume (exposure) in the roadway environment (Harwood et al., 2008; Zegeer et al., 2000). However, pedestrian crossing volume data are rarely available in road departments and considerable resources and time may be required to gather this information.

The research described in this paper incorporates the collection of exposure data and aims to develop pedestrian crash prediction models for two-way two-lane rural roads in Ethiopia to fill knowledge gaps in developing countries by understanding the complex relationships between pedestrian crash frequency and traffic characteristics, road geometry parameters, and site characteristics. To achieve this aim a count-based statistical model was estimated and assessed for statistical goodness-of-fit, and consistency with the underlying theory of crash process and empirical credibility.

The significance of this study is threefold. First, the prediction of pedestrian crashes is vital to transport planners and professional engineers, as it assists in identifying dangerous locations on existing infrastructure. For instance, similar road segments can be evaluated to identify locations with higher-than-expected pedestrian crashes in the network. The way in which some explanatory variables were uniquely measured and implemented will lead to new insights regarding the role of pedestrian exposure in pedestrian crashes. Second, the models may identify factors that are related to pedestrian crashes and thus may be explored with more in-depth, site-level rigorous study. And third, the study represents a unique effort aimed at quantifying the effect of factors associated with pedestrian crashes in a developing country.

Section 2 presents a review of previous literature with emphasis on modelling pedestrian crashes on two-lane rural roads in developing countries, and is followed by a description of the statistical modelling approach applied in this study. Section 4 describes the data used as potential explanatory variables in the modelling process, and the subsequent sections outline data analysis, model estimation, and contributions to scientific knowledge. Conclusions are presented in Section 8.

2. Literature review

Pedestrian safety on two-lane rural highways is a major concern in developing countries, since much of the road network is constituted by this road type. There are many factors that contribute to pedestrian crashes, including road environment factors, reckless road user behaviour and defective vehicles. In recent years, count models have become popular in modelling crashes, taking into account subsets of these contributing factors. Poisson and negative binomial regression models were first introduced and promoted in the United States (Maher and Summersgill, 1996; Miaou, 1994; Shankar et al., 1995). Building on this formative work, Lord et al. (2005) have reinforced the application of these models by justifying theoretical aspects of assumed crash mechanisms through establishment of their empirical credibility and demonstration of their statistical properties. Before this, most researchers modelled crashes using linear regression by assuming that crashes are normally distributed and homoscedastic in nature.

A number of studies have been carried out to model road traffic crashes starting in the late 1980s, particularly in western countries. Most of this research has focused on general vehicle crashes (Harwood et al., 2000; Hauer, 1989; Vogt, 1999; Vogt and Bared, 1998). A limited number of studies have been undertaken on pedestrian crash modelling, and most of them concentrate on identifying the contributing factors for pedestrian safety at intersections (Bonneson et al., 2011; Hamidun et al., 2013; Miranda-Moreno et al., 2011; Schneider et al., 2010; Turner et al., 2006). However, pedestrian crash models for two-way rural roads are scant, particularly in developing countries. Some studies have been conducted in the United States, New Zealand, Brazil and India (Diogenes and Lindau, 2010; Harwood et al., 2008; Sharma and Landge, 2012; Turner et al., 2006; Wong and Kockelman, 2013). As a part of the AASHTO Highway Safety Manual preparation, a study was conducted by Harwood et al. (2008) that found that average daily pedestrian volume, vehicle volume, and maximum roadway width crossed by pedestrians were statistically significant predictors of pedestrian crashes.

Pedestrian crash prediction models in developing countries are limited to quantifying the crash causing mechanism related to pedestrians. One study in Brazil built a pedestrian crash model for midblocks of one-way and two-way city roads using a Poisson regression model with a variety of explanatory variables (Diogenes and Lindau, 2010). However, the selection of the sample midblock focused on those sites that have comprehensive pedestrian crash records, which makes the developed model biased. Another study was conducted in India for rural roads without taking into consideration pedestrian volume (exposure) and other critical variables (Sharma and Landge, 2012). The incorporated independent variables in the model were traffic volume, lane width, access density, and shoulder width. Likewise, in Ethiopia, one study on crash prediction models for arterial roads in Addis Ababa has been conducted. This study acknowledged that pedestrian crashes were considered as one of the major road safety concerns in cities; however, pedestrian volume counts were not carried out; rather, the density of pedestrians was classified as high, medium, and low (indicator variable) by visual inspection of adjacent land uses (Berhanu, 2004), and thus is a relatively coarse measure of exposure.

In summary, there has been relatively little research focused on identifying causes and contributing factors of pedestrian crashes on two-way two-lane rural roads in developing countries. Although some pedestrian prediction models are available in western countries, they are not applicable to developing countries since there are vast differences in walking culture, road environment characteristics, socioeconomic factors, and road user behaviour. While some scholars have attempted to formulate pedestrian crash models in developing countries, the models do not account for vital explanatory variables, for instance pedestrian volume or exposure. In contrast, this study incorporates into models additional metrics on pedestrian crossing exposure in addition to traffic flow, and road geometric and site characteristics.

3. Statistical modelling techniques

A range of statistical modelling techniques have been used to model the relationships between road geometry, site characteristics, and traffic variables and the expected number of resulting crashes on roadway segments or intersections. Crash data are nonlinear, random, and non-negative (count) data which approximately follow the Poisson distribution (Lord et al., 2005). The inherent nature of the Poisson distribution is a positive skew to the right and a variance equal to its mean. Pedestrian crashes are non-negative count data which show heterogeneity among each member of the population. However, in most practical cases, the