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Analyzing and modeling risk exposure of pedestrian children to involvement in car crashes

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ABSTRACT

This paper analyzes the various variables affecting pedestrian children road crashes, placing emphasis on the effect of daily activity patterns and the built environment, including the children's residential neighborhoods and the land use of the places where they conduct their activities. Two complementary data sources from the case study of an Arab town in northern Israel were used to provide a holistic picture of child-pedestrian road crashes: police files providing detailed analyzes of the reason for each crash, its location, and the characteristics of the driver involved; and a survey of 199 households with both involved and not involved children in road crashes, including a one-day travel diary. The study found that a combination of three groups of variables affects child-pedestrian road crashes: socio-economic status, travel patterns, and land use. Most vulnerable are boys from a low socio-economic group who live in areas of high density and mixed land use near a major road and who tend to walk to and from school and additional activities after school.

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1. Introduction

Pedestrian children's injuries and fatalities in road crashes constitute a world concern and present a major public health burden (Mabunda et al., 2008); indeed, pedestrian road crashes are the second greatest cause of child mortality (Toroyan and Peden, 2007). Overall, pedestrian-vehicle crashes are responsible for more than a third of all traffic-related fatalities and injuries worldwide (Serre et al., 2010). Based on Beterem (2008) reported that 61.8% of children injuries in Israel were injured in road traffic crashes, 29.2% among them in motorized vehicles and 27.3% as pedestrian. Many studies have tried to examine various reasons and factors that affect child-pedestrian involvement in road crashes. This paper focuses on the effect of children's daily activity patterns and travel behavior and the built environment, including urban planning, land use, and the children's residential neighborhoods, on their risk of being involved in pedestrian road crashes.

A large body of literature reports that children belonging to an ethnic minority (Voas et al., 2000; Harper et al., 2000; Lawson and Edwards, 1991; Campos-Outcalt et al., 2002; Department for Transport, 2003), residing in a developing country (Graham and Stephens, 2008; Mabunda et al., 2008; Christie et al., 2007) and

suffering from a low socio-economic level face a high risk of being injured or killed in pedestrian road crashes (Graham and Stephens, 2008; Mabunda et al., 2008; Christie et al., 2007; Department for Transport, 2003). Various studies showed that land use, urban environment and the neighborhoods of children's residences affect children's risk of being involved in pedestrian road crashes (Sideris and Liggett, 2005; Wedagama et al., 2006; Petch and Henson, 2000). Land use is a major factor in the generation and attraction of traffic (Ben-Akiva and Bowman, 1995), as it influences the level of traffic flow, speed, and safety. Wedagama et al. (2006), using data from Newcastle in the UK from 1998–2001, found that retail land use was associated with casualties among adults of working age (16–64). Sideris and Liggett (2005) showed that vacant, medium, and high-density residential and commercial land uses, as well as road density, have an impact on the number of pedestrian casualties. Petch and Henson (2000) pointed out that in order to explain the distribution of child-pedestrian crashes it was necessary to analyze them at the sub-district level and to focus on specific trip attractors, activities, and patterns of conflict, as complicated interactions exist among the various factor groups.

In addition, many studies have pointed to the low standard of transportation facilities, such as narrow roads and the absence of shoulders, pedestrian-crossways, traffic signs, and parking facilities; as well as the relative lack of traffic-law enforcement as factors increasing children's risk of being injured in pedestrian road crashes (Elias et al., 2010; Elias and Shiftan, 2011; Al-Masaeid, 2009; Al-Masaeid and Suleiman, 2004).

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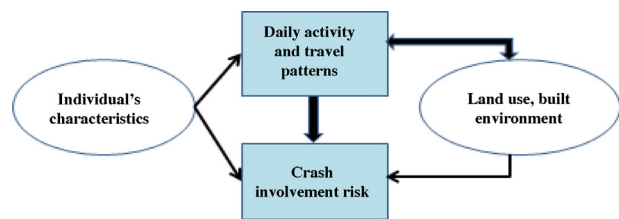


Fig. 1. Theoretical framework of the study (Elias and Shifan, 2011).

Drivers' behavior is also responsible for children's involvement in road crashes (Abdulmajid, 2007). Research by TRL (1997) showed that less than 20% of the drivers in developing countries stop for pedestrians at crosswalks, compared to more than 70% who do so in northern European countries. Abdulmajid (2007) stated that in Libya, it is not unusual for young children on the way to or from school to be knocked down by speeding drivers.

Involvement in road crashes is a by-product of participation in various activities and the travel they require. Thus, a child's risk of involvement in a pedestrian road crash depends not only on the activities in which she takes part, but also on the attributes of the trip undertaken to participate in these activities, such as mode, route, location and time of day/week. A previous paper (Elias and Shifan, 2011) developed a theoretical framework for an activity-based risk model (Fig. 1) that tried to capture individuals' risk of crash involvement as a function of their daily-activity patterns and travel behavior. However, that measure did not take into account the impact of the built environment, including urban planning, land use, and the children's residential neighborhoods on the risk of being involved in road crashes. The present paper extends current knowledge by expanding this framework to account for both daily activity patterns and the built environment in which the children reside and conduct their activities. It is obvious that the more exposure to traffic, the greater is the risk of being involved in a road crash; but the question is how exposure to different types of built environment and land use affects this risk. Participation in certain activities and the child's daily activity pattern become a risk factor only in interaction with the built environment that imposes such risks.

Most pedestrian crash-risk studies employed simple measures of risk exposure, such as walking distance and number of intersections crossed (Thouez et al., 2005). These variables, though, have limited power to explain the risk of pedestrian crash involvement (Janke, 1991; Greenshields and Platt, 1967), since they do not account for trip attributes. For example, Chliaoutakis et al. (1999, 2005) showed that travel distance alone was insufficient to reflect the exposure to risk, since risk levels were affected by trip purpose. Similarly, Thouez et al. (2005) showed that the risk for pedestrians varied with residence location. Spallek et al. (2006) claimed that crash-risk estimates generally did not account for different risk levels in different situations. They attributed this deficiency mainly to the lack of knowledge of a traveller's exposure to various situations (e.g., time of day, type of road, etc.).

This paper tries to develop a child-risk model that captures the combination of three groups of variables affecting child-pedestrian road crashes: socio-economic status, travel patterns, and land use. To the best of our knowledge, the combined effect of these three groups of variables has not been examined.

The study focuses on the Israeli Arab population, which suffers from a high rate of involvement in road crashes, traffic congestion, and a poor public transport system. The town of Shefaram in the Galilee region in the north of Israel is presented as a case study.

As in Arab countries (Al-Masaeid, 2009; Al-Ghamdi, 2001; Jadaan and Bener, 1993; Al-Balbissi et al., 1990; Shbeeb and Salim, 2003), and like minorities in other countries (Voas et al., 2000;

Harper et al., 2000; Campos-Outcalt et al., 2002; Department for Transport, 2003), Israeli Arab pedestrians suffer from a high rate of child-pedestrian involvement in road crashes. Indeed, pedestrians account for about 30% of all Israeli Arab road-crash fatalities, and 60% of this figure are children aged 0–14 – a percentage that is eight times higher than that for Jewish children in Israel (Shifan and Elias, 2011).

The paper is organized as follows: Section 2 presents the methodology, including the case-study town, the survey and the main characteristics of the sample. The results are described in Sections 3 and 4, where Section 3 provides a detailed analysis of pedestrian-car crash records from the police files, and Section 4 analyzes the data collected from the survey. Section 4 starts with a descriptive analysis in Section 4.1 showing differences in injured and uninjured children by socio-economic and demographic characteristics, by travel patterns, and by land use and residential area characteristics. These descriptive analysis helps to define and estimate the risk model estimating the probability that a child will be involved in a pedestrian road crash that is presented in Section 4.1.2. The final section offers conclusions.

2. Methodology

The study is based on a case study of the Arab town of Shefaram in the Lower Galilee region of Israel. Two complementary data sources were used: police files and a survey. The police files of all pedestrian-car crashes in Shefaram from 2008–2012, a total of 115 files, were analyzed to identify the reason for each crash, its location, and the characteristics of the driver involved. The survey conducted for this research included 120 randomly selected households, and was enriched by 79 households whose children had been injured in pedestrian road crashes. The survey of 199 households thus provided the opportunity to compare the characteristics and travel patterns of injured and uninjured children, in addition to arriving at general trends. Finally, a model of the child-pedestrian's risk of being involved in a car crash is developed, based on this data. Details of these various elements are described in the next sub-sections.

2.1. Procedure

We use quantitative statistical methods to explore highly detailed surveys of travel behavior and socio-economic characteristics among involved and not involved children in pedestrian road crashes. We first present some descriptive statistics of mode share, travel tours, travel times and activity participation to identify differences in travel patterns between injured and uninjured children. This initial analysis identifies the daily activity pattern, the built environment and the demographic and socio-economic characteristics as key indicators of child-pedestrian involvement in road crashes; therefore, subsequent analysis focuses on these variables using bivariate correlations.

Finally, a child-pedestrian risk model is developed as a disaggregate binary logit model to estimate the probability of a child's being involved in a pedestrian road crash. This model, based on the theoretical framework presented in Fig. 1, focuses on the direct effect of the various characteristics that affect risk. In the binary logit model, the utility of each alternative response is specified as

$$U_i = V_i + \varepsilon_i \quad (1)$$

where: U_i is the utility of alternative i ($i = 1, 2$) for a given pedestrian; V_i is the systematic component; and ε_i is its random component.

The systematic component of the utility can be written as follows:

$$V_i = \beta' X_i \quad (2)$$

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