Accident Analysis and Prevention 43 (2011) 769–781

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Does street network design affect traffic safety?

Wesley Earl Marshall[a,*], Norman W. Garrick[b]

[a] University of Colorado Denver, Department of Civil Engineering, 1200 Larimer Street, Campus Box 113, Denver, CO 80217, United States
[b] University of Connecticut, Center for Transportation and Urban Planning, Civil & Environmental Engineering, U-37, Storrs, CT 06269-2037, United States

ARTICLE INFO

Article history:
Received 18 September 2009
Received in revised form
28 September 2010
Accepted 24 October 2010

Keywords:
Road safety
Street network
Connectivity
Density
Negative binomial
Sustainable infrastructure
Community design

ABSTRACT

Negative binomial regression models were used to assess the effect of street and street network characteristics on total crashes, severe injury crashes, and fatal crashes. Data from over 230,000 crashes taking place over 11 years in 24 California cities was analyzed at the U.S. Census Block Group level of geography. In our analysis we controlled for variables such as vehicle volumes, income levels, and proximity to limited access highways and to the downtown area. Street network characteristics that were considered in the analysis included street network density and street connectivity along with street network pattern.

Our findings suggest that for all levels of crash severity, street network characteristics correlate with road safety outcomes. Denser street networks with higher intersection counts per area are associated with fewer crashes across all severity levels. Conversely, increased street connectivity as well as additional travel lanes along the major streets correlated with more crashes. Our results suggest that in assessing safety, it is important to move beyond the traditional approach of just looking at the characteristics of the street itself and examine how the interrelated factors of street network characteristics, patterns, and individual street designs interact to affect crash frequency and severity.

1. Introduction

Around the world, 1.2 million people are killed and approximately 50 million people are injured in road crashes (World Health Organization, 2004). In the United States alone, the economic cost of road crashes and injuries exceeds $230.6 billion annually (World Health Organization, 2004). Given the impact of road crashes on the economy and quality of life, it is surprising to note that the road fatality rate in terms of the number of fatalities per population and per miles traveled in the United States continues to fall further and further behind that of other comparable industrialized counties. Less than 40 years ago, there were a dozen major countries with road fatality rates exceeding that of the United States (International Traffic Safety Data and Analysis Group, 2005). As of 2004, every single one of the 29 Organisation for Economic Co-operation and Development (OECD) countries reporting statistics has a lower road fatality rate per population than the U.S., and ten of those countries have rates less than half the U.S. road fatality rate (OECD, 2006). One of those countries, the Netherlands, has brought their road fatality rate over the last 40 years from 25 fatalities per 100,000 population per year to under five, which is less than a third of the current U.S. fatality rate per 100,000 population.

There are a many possible reasons as to why the U.S. is lagging behind the rest of the world when it comes to road safety. One possible explanation that this research will focus on is that we often fail to pay enough attention to overall community design when it comes to safety. For instance, various researchers have shown that street widening projects, typically proposed in order to improve safety and relieve congestion, actually result in a reduction in safety (Noland, 2000; Sawalha and Sayed, 2001; Huang et al., 2002; Dumbaugh, 2006; Swift et al., 2006). In this case, the focus has been too much on assessing how the changes affect individual street segments rather than how those changes might impact the community as a whole. A second example of failing to regard overall community is in how we often attempt to improve safety on residential streets by minimizing the opportunities for through traffic. What is missing is the sense that limiting street connectivity in residential neighborhoods can impact safety elsewhere (Ewing et al., 2002; Ewing and Dumbaugh, 2009).

Hence in this paper, we probe beyond the street, corridor, and neighborhood levels of analyses to determine how aspects of overall community design might affect road safety. More specifically, the goal is to find out more about how characteristics of the street network – in terms of features such as street connectivity, street network density, and street network patterns – are associated with road safety outcomes.

In this research we carry out a spatial analysis of 11 years of crash data in 24 medium-sized California cities. The cities were

* Corresponding author. Tel.: +1 303 352 3741; fax: +1 303 556 2368.
E-mail addresses: wesley.marshall@ucdenver.edu, wesleyemarshall@gmail.com (W.E. Marshall).

0001-4575/$ – see front matter
doi:10.1016/j.aap.2010.10.024

selected from an initial database of over 150 California cities to best represent a geographically diverse collection of 12 medium-sized cities with good safety records and 12 with poor safety records with respect to the number of road fatalities per capita in the transportation system. Street network measures were combined with street characteristics, socioeconomic data, traffic flow information, and over 230,000 individual crash records geo-coded in a Geographic Information System (GIS) database. The analysis was conducted at the U.S. Census Block Group level of geography for over 1000 distinctly populated Block Groups. Statistical negative binomial regression crash models were estimated for three response variables: total number of total crashes, severe injury crashes, and fatal crashes.

By characterizing the street networks of these cities and the representative street design characteristics, the goal is to capture the safety implications of different street network patterns and to account for the potential implications of the street design features while controlling for variables such as vehicle volumes, income levels, and proximity to limited access highways and the downtown area.

2. Background

Over the course of the last century, there has been a dramatic shift in American street patterns and community design. In particular, the U.S. experienced a transition from the traditional gridded street layouts of the first part of the twentieth century to increasingly more dendritic, tree-like street networks of the post-1950s period (Taylor, 2001). In describing these changes, many observers focus on the shape and connectivity of the street networks but typically ignore another factor – street network density – that has progressively decreased over the last half of the century. Despite their fall from favor, connected street networks are widely considered to have some advantages, including directness of travel, more route choice options, and higher network reliability. The trade-off for these advantages – as touted despite the lack of technical evidence by entities such as the Federal Housing Authority (FHA) in the late 1930s with Technical Bulletins No. 5 and 7 (Tunnard, 1963) and the Institute of Transportation Engineers (ITE) with their "Recommended Practice for Subdivision Streets" in 1965 (Southworth and Ben-Joseph, 1997) – is commonly believed to be increased through traffic on local roads and a reduction in safety (Lerner-Lam et al., 1992).

The result was that from the 1950s through the late 1980s, very few new developments in the United States featured a gridded street pattern; instead, hierarchical layouts became the standard (Southworth and Ben-Joseph, 1997). By 1992, this pattern of building hierarchical street networks had started to change with over 50 neo-traditional neighborhood design projects either in the planning stages or in construction (Lerner-Lam et al., 1992). With this influx of more traditional street designs came a small but growing body of research on the pros and cons of different street network structures. Thus far, much of the prevailing research related to street network measures has concentrated on issues such as mode choice, physical activity, and obesity (Ewing and Cervero, 2001). While the explicit relationship between street networks and road safety is beginning to garner more interest, the subject still has not been extensively studied.

An early road safety study from the 1950s by Marks is one of the first to address the perceived safety problems of grid street patterns compared to hierarchical designs (Marks, 1957). Based on 5 years of crash data for 86 residential areas, Marks found almost 8 times more crashes on the gridded streets and 14 times more crashes at the four-way intersections in a grid design than at the T-intersections found in dendritic arrangements. The reason purported for these results was the relationship between increased residential street connectivity and the probability of increased through traffic at higher speeds. Although this study continues to be influential, the researchers paid little attention to some very important considerations such as actual street patterns, the density of these street networks, the potential for crash migration, or the observed levels of crash severity.

Kim et al. (2006) found that the parts of Hawaii with higher populations and more jobs were associated with more crashes when controlling for vehicle volumes. And in a set of papers from a recent 3-year study of street networks and safety in Calgary that also controlled for vehicle volumes, Rifaat and Tay found that street networks comprised of loop and lollipop-type designs were safer than gridded street networks (Rifaat and Tay, 2009, 2010; Rifaat et al., 2009). Conversely, Noland and Quddus found that wards in England with densely populated areas had fewer traffic fatalities and that increased minor street length densities were associated with decreases in slight injuries. In a Virginia study, Lucy and Lewis (2009) found the safest jurisdictions to be those with the highest population density. Ladron de Guevara et al. (2004) found that higher intersection densities in Tucson, Arizona were correlated with fewer fatal crashes and injury crashes but more property damage only (PDO) crashes.

Overall, the work that has been reported has shown inconsistent results. One set of studies associates more crashes with street networks that exhibit more urban qualities such as more centerline miles of streets, more connectivity, higher populations, and higher population densities (Marks, 1957; Ladron de Guevara et al., 2004; Hadayeghi et al., 2006; Kim et al., 2006; Lovegrove and Sayed, 2006; Rifaat and Tay, 2009). On the other hand, another strand of existing research associates urban places, and the attributes also linked to more urban places (such as increased street network density, street connectivity, mixed land uses, more transit use, and increased population density), with increased safety (Ossenbruggen et al., 2001; Surface Transportation Policy Project (STPP), 2002; Ewing et al., 2003; Environmental Protection Agency, 2004; Pawlovich et al., 2005; Dumbaugh, 2006; Hansen et al., 2007).

Yet another set of studies tended to combine large geographic areas into general categories labeled with terms such as "sprawl" or "smart growth," and a common limitation of road safety studies focusing on an area-wide geographic level is the failure to adequately control for vehicle volumes. For instance in a county-level study, Ewing et al. (2003) found that the 10 counties exhibiting sprawl development were the least safe with respect to the number of traffic deaths per 100,000 population. Similarly, the Environmental Protection Agency issued a report finding that out of 13 metropolitan areas, those more representative of smart growth principles had lower traffic fatality rates (Environmental Protection Agency, 2004). To combat the issue of failing to control for vehicle volumes, some studies have used population and employment as a proxy for this vehicle exposure (Ladron de Guevara et al., 2004). These proxy variables are intended to account for vehicle volumes based on the premise that demand for travel is derived, and traffic flows arise from factors such as people and jobs (Noland and Quddus, 2004). The key problem with this conceptualization is that it fails to sufficiently account for the fact that travel patterns and community design patterns are interrelated, which means that vehicle miles traveled (VMT) is not simply a function of population and employment. For instance, variables such as land use, population density, and street network design have been shown to affect how much driving people do (Cervero and Radisch, 1995; Ewing and Cervero, 2001). Thus, proxy variables based on the relative concentration of population and employment may actually be a better measure of the level of overall activity associated within an area rather that a proxy for vehicle volumes. As a result, our study accounts for *both* actual vehicle volumes as well as a proxy for the