Safety Science 62 (2014) 305–311

Contents lists available at ScienceDirect

Safety Science

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

Investigating the safety effects of road width on urban collector roadways

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ARTICLE INFO

Article history:
Received 22 April 2013
Received in revised form 5 September 2013
Accepted 11 September 2013
Available online 8 October 2013

Keywords:
Cross-sectional evaluation
Collision reduction factors
Negative binomial model
Safety performance function
Urban safety

ABSTRACT

Collector roads are designed to provide a balance between traffic safety, mobility, and land access; however, the literature on the effects of collector lane width on safety is generally inconsistent. This study determines the safety implications of oversized collectors by analyzing collisions statistics, traffic-survey data, and roadway-inventory data from the City of Edmonton. The paper adopts a cross-sectional evaluation methodology by developing negative binomial (NB) safety performance functions (SPFs) for total collisions. Based on the NB SPFs, it was found that segment length, traffic volume, access-point density and midblock change was statistically significant and positively related to collisions, while the width was negatively related to collisions and statistically significant. The interaction term of volume and lane width was found to be positively related to collisions. This suggests that the collision rate for oversized collector roads is higher than that for standard-sized roads. It was also found that both standard-sized and oversized roads, with some form of midblock roadway width change, were less safe than those with uniform width. Converting oversized roads to standard size was found to improve safety only for the roads with an average daily traffic (ADT) volume higher than 4000. The maximum crash reduction was estimated to be as high as 28.9%. This study is timely given the contradicting evidence that exists in current literature regarding the relationship between safety and oversized collector roads. For the present data set, this paper provides guidelines on when to convert oversized collector roads to standard-sized collector roads, to improve safety.

1. Introduction

The effect of lane width on traffic collisions has been of major interest to transportation agencies. Though roadway lane widths vary from country to country, normally, 3.75 meters (m) is taken as the maximum lane width for any type of road (Hall et al., 1995). Basic engineering knowledge suggests that wider lanes contribute to safer transportation facilities. This belief could be attributed to general principles of ergonomic theory, which suggest that any action that makes a task easier to perform will make that task safer to perform (Hauer, 2010). However, traffic calming through lane narrowing and road diets has also become a popular and widely used method to effectively slow drivers down and lessen the impact of collisions.

The width of a travel lane greatly influences the safety and speed of driving, as well as the total width of a roadway. In turn, the roadway width determines the pedestrian crossing distance, and the roadway space potentially available for other uses, such as bike lanes, parking lanes, and landscaped curb extensions. Very few studies have discussed the safety benefits and limitations of having wider lanes in general; studies that focus on those parameters specifically in urban areas are fewer still. Further, there seems to be a general belief that wider lanes are safer. Despite that widely accepted engineering notion, research has shown that narrower lane widths are associated with fewer traffic injuries and fatalities (Milton and Mannering, 1998; Noland, 2003).

An important issue that has been gaining attention in the literature is the relationship between the total lane width of specific roadway types (for example, arterial, collector, etc.) and their safety risk. For urban metropolitan areas, the safety of collectors is hardly investigated in the literature. Collectors are designed to provide a balance between traffic mobility (potential for movement) and land access (potential for interaction). Providing connectivity between arterials and other collectors allows collector roads to access neighboring activity centers, such as commercial areas, town centers, schools, parks, and residential neighborhoods. In addition to emphasizing mobility and accessibility, collectors need to provide an adequate level of safety.

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http://dx.doi.org/10.1016/j.ssci.2013.09.005

This research paper will attempt to investigate the safety effects of oversized urban collector roads. The paper will determine the safety implications of oversized collectors by studying collision statistics, traffic-survey data, and roadway-inventory data. The paper's main objectives are to assess the effect of road width on collisions for urban collectors, and to provide guidance and recommendations for remedial actions (if required). The findings from this paper are timely given the apparent lack of documentation on the safety effects of urban collectors, and the contradicting evidence that exists in the literature regarding the relationship between safety and oversized collector roads.

2. Previous work

In the current road-safety literature, the importance and significance of lane width, shoulder width, and road width on collision rates and frequencies has been well documented. Because of the differences between urban and rural environments, it is expected that the effects of these factors might not be the same in the two different settings. Thus, the literature review in this section grouped together the previous findings in each context.

In a rural two-lane or multilane setting, aspects of road geometry related to road width, such as the number of lanes, lane width, shoulder width, and median width, were significant and correlated with collision risk (Ahmed et al., 2011; Zhu et al., 2010; Pande and Abdel-Aty, 2009). Where the absolute lane width was not a significant factor, or was not included as a risk factor, the effect was assumed, or taken to be captured, in another variable of related road geometry. For instance, one recent study found that lane width and shoulder width were not significant factors, but hypothesized that the significant effect of shoulder type influenced their insignificance (Nowakowska, 2010). In this case, a paved shoulder was found to decrease collisions by 30–70% compared to unpaved shoulders. In contrast, one earlier study found that rural two-lane highways with narrow shoulders, or no shoulder, have lower rates of injury and fatal collisions than their wider counterparts (Garder, 2006).

Similar to the findings from studies on rural settings, studies on urban areas were also found to have inconsistencies in terms of the effect of road geometry. For instance, while several studies on urban roadways reported that wider facilities had higher collision frequencies than narrower facilities (Strathman et al., 2001; Hauer et al., 2004; Potts et al., 2007), another study on urban arterials found that increases in lane width and decreases in shoulder width reduce both roadside and midblock collisions (Dumbaugh, 2006).

In the case of mixed urban–rural, multilane, and two-lane studies, so too are the results mixed. Several studies found that narrower lane widths increase road safety, while wider lane widths either decrease road safety, or have an insignificant effect (Milton and Mannering, 1998; Noland, 2003). However, others found that wider lanes corresponded to a decreased collision risk (Hadi et al., 1995; Yanmaz-Tuzel and Ozbay, 2010).

Few studies have exclusively explored the specific safety implications of lane width. For instance, Gross and Jovanis (2007) found that Collision Modification Factors (CMFs) generally decreased and were consistent with the Highway Safety Manual (HSM), except at the extreme ends of lane width, where widths less than 3.05 m resulted in odds ratios below 1, and widths greater than 3.81 m increased the odds ratio in an apparent "U-shaped trend", where the minimum exists at 3.81 m. Similar trends regarding the effect of lane width were found in other studies as well (Hedman, 1989; Hauer, 2000; Gross and Donnell, 2011). Gross et al. (2009) studied the safety trade-off of lane and shoulder width at a constant total width. They found that there was no clear trend in trade-off after an analysis of their research dataset, but that there was a clearer trend of slightly greater benefit to increasing the lane width over the shoulder width when comparisons and selection of CMFs in literature were made in addition to their results.

It is important to note here that due to road design standards and good practice recommendations, several characteristics such as lane width, shoulder type and width, horizontal curvature, are not freely selected; instead, there is a limited number of available combinations, depending on each road type and its traffic volumes.

In terms of the research methodology, previous studies on road geometry have adopted both longitudinal and cross-sectional approaches. For instance, Huang et al. (2002) used a before–after study to investigate of the effect of road dieting in California and Washington cities. Similarly, Yanmaz-Tuzel and Ozbay (2010) applied a before–after analysis to measure the effect of lane widening on a New Jersey urban arterial. Gross and Donnell (2011) used a cross-sectional analysis to develop CMF for fixed roadway lighting and the allocation of lane and shoulder widths.

Though a before–after study is susceptible to fewer biases, it is not always possible to use this method, because it requires implementing a safety treatment. Thus, a cross-sectional study is often used to evaluate the safety effect of particular road features. In a cross-sectional study, the safety-performance of one group of entities with a particular feature is compared to another group of entities without that same particular feature, to understand that feature's effect. As the safety-performance of these two different groups of entities could be influenced by factors other than the particular feature under consideration, a cross-sectional study is subject to potential issues and biases, if precautions are not taken (Carter et al., 2012). Some of these biases arise from the failure of controlling confounding factors, improper selection of appropriate functional form of the model, correlation or collinearity among the independent variables, overfitting of prediction model, low sample mean and small sample size, and the unobserved-heterogeneity and omitted-variable bias (Carter et al., 2012).

In summary, the literature review of the effect of lane width on speed revealed that inconsistencies exist within rural and urban studies. While increases in lane width usually correspond to higher speeds, the correlation was sometimes not statistically significant. In addition, the effect of lane width on road safety in the relevant literature as a whole is inconsistent. Overall, the effect of road geometries related to width is well captured in the rural context, while the significantly fewer number of studies performed in the urban context are either inconsistent, or showed that the effect of width to road safety was contrary to the rural perspective. In terms of methodology, a cross-sectional study is an effective approach of evaluating the safety effect of lane width, if the potential biases are taken into account.

3. Methodology

3.1. Negative Binomial (NB) Safety Performance Functions (SPFs)

The development of SPFs to predict traffic collisions has been the subject of numerous studies. Most SPFs were developed using NB regression (Hauer, 1997; Kulmala, 1995; Maher and Summersgill, 1996; Sawalha and Sayed, 2001, 2006).

Let Y denote the random variable representing collision frequency at a given road segment. It is assumed that Y is Poisson distributed with parameter λ

$$Y|\lambda \sim \text{Poisson}(\lambda) \tag{1a}$$

To address the problem of over-dispersion that usually exists in traffic collision datasets, it is typically assumed that

$$\lambda = \mu \exp(u) \tag{1b}$$