Transportation Research Part F 58 (2018) 156–166

Contents lists available at ScienceDirect

Transportation Research Part F

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

Priority rule signalization under two visibility conditions: Driving simulator study on speed and lateral position

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ARTICLE INFO

Article history:
Received 29 January 2018
Received in revised form 21 April 2018
Accepted 8 June 2018

Keywords:
Driving simulator
Priority rule signalization
Intersection
Speed
Lateral position
Visibility

ABSTRACT

In literature, priority-controlled and right-hand priority intersections have rarely been compared on other elements than the number of right-of-way violations and collisions. This study investigates the effect on speed and lateral position of five priority rules under two visibility conditions at an intersection (without hierarchy between branches), which is, at this moment, a knowledge gap.

Fifty participants drove five different routes in a simulator and were exposed to the following manipulations: priority to the right rule applying and indicated (road sign and road sign with road marking), priority to the right rule applying but not indicated (no sign), priority to the right rule not applying and indicated (priority road and priority at next intersection), under good and bad visibility.

Results show a significant speed decrease for both situations where the priority to the right rule was indicated compared to situations with no priority to the right rule, especially when visibility was bad. Priority to the right signs with additional road marking resulted in lowest speed under both visibility conditions. For all priority rules, lateral position shifted more towards the middle of the road when visibility was bad.

Since speed was higher in case of priority roads or roads with priority at next intersection, it can be concluded that a higher level of control (priority-controlled intersections) does not necessarily result in a traffic safety improvement. Therefore, policy makers should take into account the results of this study and not generally change all the priority to the right intersections by priority-controlled intersections.

1. Introduction

The car is one of the most used transportation modes in our daily life (European Environment Agency, 2015). Since the car occupies such prominent role in the movement patterns of almost everyone in the 21st century, clearly understandable rules are a necessary precondition for safe and fluent traffic. Intersections geometrically align and shape the road environment.

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https://doi.org/10.1016/j.trf.2018.06.011
1369-8478/

Approaching an intersection is considered a complex task, requiring multitasking as an essential skill (Lemonnier, Brémond, & Baccino, 2015). According to Simon, Hermitte, & Page (2009), 43% of all road injury crashes in EU27 occur at intersections. Research also shows that the number of priority violations is higher at priority to the right intersections compared to priority-controlled intersections (De Ceunynck et al., 2013). Therefore, traffic safety at intersections has become a critical issue in the transportation system (Liu, Lu, Wang, Wang, & Zhang, 2014).

Still frequently, unsignalized intersections shape the landscape in most urban and rural areas. The general conclusion in literature is that motor vehicle injury fatality rates are consistently higher in rural areas than in urban areas (Zwerling et al., 2005). Zwerling et al. (2005) concluded that fatal crash incidence (i.e. number of fatal crashes per 100 million miles driven), injury fatality rate (i.e. number of fatal crashes per 1000 crashes with injuries) and crash injury rate (i.e. number of crashes with injury per 1000 crashes) was respectively 2.2, 3.0 and 1.1 times higher at rural roads compared to urban roads. Only the crash incidence density (i.e. number of all crashes per million miles driven) was 0.6 times lower. According to NHTSA (2015) traffic safety statistics the fatality rate per 100 million vehicle miles travelled was 2.5 times higher in rural areas than in urban areas (data of 2010). Geurts, Thomas, & Wets (2005) analyzed different characteristics of accident spots and identified 50 kph speed limit areas with intersections with traffic signs where no priority was given to be frequent crash locations (a set of items was categorized as frequent when the combination of items or accident characteristics was above 5% (here 5.6%)). Compared to inside urban areas, higher speed limits or delayed time for medical response in rural areas lead to higher mortality in rural crashes (Clark & Cushing, 1999; Eiksund, 2009; Jones & Bentham, 1995; Muelleman, Wadman, Tran, Ullrich, & Anderson, 2007). Zwerling et al. (2005) suggested that interventions to reduce speed (and increase seat belt usage) on rural roads may help to reduce disparity in fatal crash involvement rates. Due to the difference in characteristics of rural and urban intersections, there is no single preferred solution to reduce the number of crashes at intersections. Mobility experts have to take into account these surrounding factors when designing the road environment (Tay, 2015).

Most countries implement the priority to the right rule when yield road signs (e.g., stop signs) are absent (Elvik, Vaa, Erke, & Sorensen, 2009; European Commission, 2003; Liu et al., 2014). The Vienna Convention on Road Signs and Signals has, worldwide, 65 parties/countries involved and 35 countries have ratified it (UNECE, 2017). This convention recognizes that international uniformity of road signs, signals, symbols and road markings is necessary in order to facilitate international road traffic and to increase road safety (United Nations, 1968). The Vienna Convention also describes the priority signs and these are used in this paper.

Other factors besides the type of priority rule, such as the visibility at intersections, influence driving behavior. Roads with limited visual complexity induce longer eye fixations compared to visually complex urban roads (Chapman & Underwood, 1998). Shinar (2007) refers to several studies arguing that up to 90% of the information used for conducting the driving task consists of visual input. Furthermore, Vollrath, Briest, Schießl, Drewes, & Becker (2006) concludes that the lack of visual information is a direct accident cause in over 90% of all crashes at intersections. Graab, Donner, Chiellino, & Hoppe (2008) did an error analysis on 278 accidents and in slightly less than 20% of all accidents there was a visual impairment before the accident. In 52% of these accidents there were objects such as buildings, vegetation and parked or stationary vehicles. Thus, we can conclude that poor visibility (at intersections) correlates with the occurrence of crashes.

Speed is defined as an important risk factor in traffic safety. Higher speeds have been proven to increase the likelihood of getting involved in a crash (De Pauw, Daniëls, Brijs, Hermans, & Wets, 2014; Elvik et al., 2009). Furthermore, as kinetic energy in case of a crash at higher speed is more intense, severity will increase. Therefore, lower speeds at intersections are better for traffic safety. Observation of speed behavior has been widely studied but not that much attention has been paid to intersection-related settings (Montella et al., 2011). Some researchers have found speed-reducing effects of infrastructural (e.g. channelizing separator islands, gates, etc.) and perceptual (e.g. rumble strips, dragon teeth markings, colored intersection area, etc.) measures at intersections (Ariën et al., 2013; Godley, Fildes, & Brian, 2002; Gross, Jagannathan, & Hughes, 2009; Jamson, Lai, & Jamson, 2010; Katz, Molino, & Rakha, 2008; Macaulay et al., 2004; Montella et al., 2011; Thompson, Burris, & Carlson, 2006).

A review of fourteen studies conducted by Elvik et al. (2009) (described in De Ceunynck et al., 2013) concludes that when priority to the right intersections are replaced by priority-controlled intersections, in general, the number of injury crashes drops by 3% only [95% confidence interval (CI) (−9, +3)]. However, the results are not unanimous. Some studies even indicate an increase in the number of crashes, and the crash severity is generally higher at priority-controlled intersections (De Ceunynck et al., 2013). De Ceunynck et al. (2013) referred to Casteels & Nuyttens (2009) and concluded that the crash severity is generally higher at priority-controlled intersections because of no yielding behavior and consequently higher approaching speeds. However, based on both references (Casteels & Nuyttens, 2009; De Ceunynck et al., 2013), it is not possible to conclude if this refers to intersections with the same speed limit.

According to De Ceunynck et al. (2013), priority-controlled and right-hand priority intersections have rarely been compared on other elements than the number of right-of-way violations. This study further extends previous work because it compares different types of priority regulation at intersections (described in the Vienna Convention) on speed behavior and lateral position which has not yet been done before. Thus, the main purpose of this study is not to investigate effects on yielding behavior but on speed and lateral position in function of five priority rules and under two intersection visibility conditions in a fully controlled environment. Which is, at this moment, an identified knowledge gap.