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Analyzing drivers' crossing decisions at unsignalized intersections in China

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ABSTRACT

In China, when two vehicle drivers encounter at an unsignalized intersection, almost neither of them completely stops the vehicle. Instead, one gradually approaches and dynamically makes a decision to either yield or preempt by gaming with the other vehicle. This process generates traffic conflicts and increases the probability of accidents. In this study, we aimed to study how straight-moving drivers made preemptive/yielding decisions when they encountered other drivers straight-moving across at unsignalized intersections. A total of 150 crossing cases were collected at an unsignalized intersection in Kunming City, China. By using detection program we made, motion parameters of the vehicles were extracted. Classification tree analysis was used to identify the decision moment of drivers and the major motion parameters that affected their decisions. Results showed that for crossing processes at unsignalized intersections in China, straight-moving drivers from the right side made preemptive/yielding decisions from 0.9 s to 1.3 s before reaching the crossing point. However, straight-moving drivers from the left side made decisions from 0.9 s to 1.2 s before reaching the crossing point. The speed difference between the two vehicles was the most important factor that affected a driver's decision-making. If the vehicle driver from the right side drove significantly slower than that from the left, then most drivers from the right side would yield to those from the left. On the contrary, if the vehicle driver from the right side drove significantly faster than that from the left, then most drivers from the right side would preempt those from the left. The findings of this study will help understand the decision-making patterns of drivers under crossing conditions, and thus provide suggestions to improve drivers' behavior at unsignalized intersections in China.

1. Introduction

Intersections are important hinge points, which join two or more roads. Traffic conflicts are easily generated in intersections. This makes many intersections to be accident black points, where traffic accidents are more likely to occur than anywhere else on the road. Traffic safety in intersections has attracted considerable research attention. National Highway Traffic Safety Administration (2009) statistical data showed that approximately 40% of the total 5,811,000 vehicle crashes in the US in 2008 occurred at intersections. The American Institute of Transportation Engineers asserted that road intersection safety was an important subject which should be studied closely (Elmitiny, Yan, Radwan, Russo, & Nashar, 2010).

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Although signalized intersections have been constructed widely, many unsignalized intersections are prevalent in both urban and rural areas. A popular tool used to control traffic at unsignalized intersections is the stop sign (Prasetijo & Ahmad, 2012). When there has no stop sign, the right-hand priority rule is used in most countries and regions (Bjorklund & Aberg, 2005; Elvik, Hoye, Vaa, & Sorensen, 2009). In China, road traffic rules indicate that when two straight-moving vehicles from different directions encounter at unsignalized intersections where no other traffic control is present, the straight-moving vehicle from the right side should have priority. Furthermore, between a straight-moving vehicle and a turning vehicle, the former holds the right of way. In China, however, neither of two vehicles that encounter at unsignalized intersections completely stops on the basis of priority rules. Rather, vehicle drivers gradually approach and dynamically make a decision to either yield or preempt. This uncertain process can bring in more traffic conflicts and increase the probability of accidents. Data show that the crash rate at unsignalized intersections in China is higher than those of other countries (Wang & Yang, 2008). NHTSA (2009) statistical data indicated that the number of crashes occurred at intersections with no traffic control device, with traffic signal, with stop sign, and unknown conditions were 3,474,000; 1,244,000; 571,000; and 522,000, respectively. In other words, approximately 70% of the total intersection crashes in the US occured at unsignalized intersections, compared to approximately 80% in China. Fatalities and injuries at unsignalized intersections in China accounted for approximately 13% of the total accident fatalities and 18% of the total accident injuries, whereas those at signalized intersections accounted for 5% and 7%, respectively (National Bureau of Statistics of China, 2009). In other words, the safety problem at unsignalized intersections is more serious than that at signalized intersections. In this regard, an analysis of drivers' crossing behavior is necessary to identify the main factors that affect drivers' decisions and thus correspondingly propose safety improvement measures for unsignalized intersections in China.

A field observation was conducted for eight hours daily to observe two vehicles' crossing condition at an unsignalized intersection (located at 25.05° north latitude, 102.74° east longitude) in Kunming City, China. Each direction of the intersection was a two-lane, two-way road. At this intersection, pedestrians, non-motor vehicles, and motor vehicles traveled together on the road. The results showed that 131 crossing decisions failed to follow priority rules to preempt or yield. This number accounted for 46.2% of the total crossing cases. Among all cases, the crossing behavior between one left-turning vehicle and one straight-moving vehicle accounted for 19.7%, whereas the crossing behavior between two straight-moving vehicles accounted for approximately 81.3%.

Thus, we aimed to study how straight-moving drivers make preemptive/yielding decisions when they encounter another straight-moving vehicle at unsignalized intersections. Most studies on crossing decisions (Becic, Manser, Creaser, & Donath, 2012; Guo & Lin, 2011; Hamed, Easa, & Batayneh, 1997; Hossain, 1999; Madanat, Cassidy, & Wang, 1994; Pollatschek, Polus, & Livneh, 2002; Spek, Wieringa, & Janssen, 2006) focused on drivers' gap acceptance. However, relatively few studies have been conducted on crossing decision moment and the main factors that affected drivers' decisions.

Therefore, in this study, we focused on when the straight-moving drivers completed their crossing decisions and what factors affected the drivers' decision-making.

The rest of the paper was structured as follows. The next section provided the background of the study. Then, the research method, including the observation site, data collection, and processing method, and the approach to analyze decision-making behavior were introduced. Section 4 discussed the decision moment and factors that affected drivers' decisions. Finally, data analysis results were discussed, and conclusions were made.

2. Literature review

Unsignalized intersections notably fail to provide an indication to drivers about when entry to intersections is appropriate. The crossing decision process of a driver at unsignalized intersections is more difficult than that at signalized intersections and can be considered "a complex and highly interactive process, whereby the driver makes individual decisions about when, where, and how to complete the required maneuver, subject to his/her perceptions of distances, velocities, and own car's performance" (TRB., 1997). Many studies have been conducted on the crossing decisions of drivers at unsignalized intersections. Most researchers have focused on the modeling of gap acceptance to describe crossing decisions (Becic et al., 2012; Guo & Lin, 2011; Hamed et al., 1997; Hossain, 1999; Madanat et al., 1994; Pollatschek et al., 2002; Spek et al., 2006). Besides, traffic conflict method has also been conducted on analyzing crossing decisions of drivers.

Furthermore, various mathematical methods, including fuzzy theory method, expert system, petri-network, and artificial neural network, have been applied to analyze decision behavior (Russell & Stuber, 1995; Tsguhide & Magnus, 2006; Wang & Yang, 2008; Yinghi & Hlaing, 2007). In this study, classification tree method was used to analyze drivers' crossing behavior decisions at unsignalized intersections.

2.1. Gap acceptance model

Gap acceptance studies mainly focused on two issues: determining the critical gap and analyzing the significant factors of gap acceptance behavior.

For instance, Drew (1968) assumed that the basis of a driver's crossing decision and behavior was the gap that he/she faced. The driver accepted the gap and moved across when the gap was larger than his/her critical gap. Otherwise, the driver would wait for an acceptable gap. In this study, the critical gap was assumed to be the same for all drivers. However, because