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Crash risk evaluation of aggressive driving on motorways: Microscopic traffic simulation approach



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ABSTRACT

This paper provides quantitative evaluation of safety implications of aggressive driving (speeding, following closely and weaving through traffic) by using microscopic traffic simulation approach. Combination of VISSIM and Surrogate Safety Assessment Model (SSAM) were used to model motorway and assess safety of the simulated vehicle. The use of vehicle conflicts was validated by correlating it to historic crashes. Crash risk, severity levels and the magnitude of the perceived benefits of aggressive driving were quantified relative to normal drivers under two scenarios: (1) congested, and (2) non-congested traffic conditions. Involvement in vehicle conflicts is used to determine crash-risk while reductions in Post Encroachment Time (PET) and travel time were used to determine the severity levels of the expected crashes and the magnitude of the perceived benefits. The results indicated that the crash risk of aggressive drivers was found to be in the range 3.10–5.8 depending on traffic conditions and type of road aggression. PET of the conflicts involving aggressive drivers reduced by 7–61% indicating high severity levels of the expected crashes. Moreover, the magnitude of the perceived benefit in terms of reduction in travel time was found to be as little as 1–2%. The study concluded that aggressive driving is entailed with a massive risk while its benefits are actually very little.

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1. Introduction

Roadside crashes are the result of complex interactions among drivers, vehicles, traffic context as well as the environmental and situational conditions. However, driver error is believed to be the leading crash causation factor and the majority of road crashes (75–95%) are related to it in one form or the other (Stanton & Salmon, 2009; Sun, Benekohal, & Estrasa, 2008). The act of aggressive driving is one form of driving error with severe consequences (AAA, 2009; Tasca, 2000).

Aggressive driving is a deliberate action by drivers which is likely to increase the risk of crashes. It is usually motivated by impatience, annoyance, hostility and an attempt to save time compromising the safety of one's own self and other road users (Tasca, 2000). Its impact is immense that a few aggressive drivers are terrorizing many others. People admit of being its victims than its perpetrators and it is believed to be the biggest threat that road users are faced with (AAA, 1997a, 1997b; Dukes, Clayton, Jenkins, Miller, & Rodgers, 2001; Parker, Lajunen, & Summala, 2002).

According to Shinar (1998), aggressive behavior can be either instrumented or hostile. Instrumented aggression is exercised as a means to proceed in traffic and is usually manifested in terms of speeding, tailgating and weaving through traffic. Similarly, hostile aggression is practiced as a means to vent anger using offensive hand and facial gestures, verbal assault and horn honking. A study by Parker, Lajunen, and Stradling (1998) on highway violations found that instrumented

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road aggressions which includes speeding, close following and risky overtaking had respective mean scores of 1.84, 2.81 and 2.33 on a scale from 1 (never) to 6 (nearly all the time).

Though it is difficult to set a boundary for how safe is safe enough, driver safety is estimated in terms of an individual's level of risk acceptance as a driver and comparing this level of risk to a threshold value (Hakamies-Blomqvist, 2006). Similarly, Fuller (2005) stated that risk taking behavior of drivers increases their driving task difficulty which is the outcome of the dynamic interface between the demands of the driving task and the reserve of capability of a driver. In this paper, in conjunction with risk taking behavior of drivers, 'normal drivers' represent the family of drivers with an adequately safe driving behavior where risky driving is perceived negatively and traffic regulations are complied with. It is assumed that normal drivers are well calibrated in terms of adjusting their driving task difficulty (Fuller, 2005). On the other hand, aggressive drivers represent the segment of drivers whose level of risk acceptance is considerably high and thus unnecessarily increase their driving task demand by speeding, following closely or weaving through the traffic (Section 2.1. presents more discussion on the definition of aggressive driving).

This research focuses on instrumented road aggression and aims at determining the crash risk of aggressive drivers relative to normal drivers. It also provides an insight into the massive risk associated with aggressive driving behavior in contrast to its perceived advantages, i.e., reduction in travel time.

A motorway was modeled, calibrated and validated in VISSIM microscopic traffic simulator. A small proportion of the simulated vehicles were made to behave aggressively. This was done by modifying VISSIM's driver behavior parameters for car-following and lane-changing logics so that a predefined proportion of the simulated vehicles would demonstrate the behavior of aggressive drivers. Three forms of instrumented road aggressions were considered in this research and they are: (1) speeding above the legal speed limit and/or driving too fast for the prevailing traffic conditions, (2) following closely or tailgating, and (3) weaving through traffic by abrupt change of lanes. Quantifying the impact of instrumented road aggression was performed under two scenarios of traffic conditions, which include: (1) congested, and (2) non-congested. Surrogate Safety Assessment Model (SSAM) was used to analyze the trajectories of the simulated vehicles and detect conflicts among them. To reinforce the credibility of the methodology followed in this paper and validate the use of vehicle conflicts as a surrogate measure for crashes, simulated vehicle conflicts were correlated to real crashes. The results of this research provided quantitative evaluations on the crash risk of aggressive drivers relative to normal drivers, severity of the resulting crashes and the magnitude of the perceived benefit.

2. Review of literature

2.1. Aggressive driving and its impacts on road safety

A report by CTC & Associates (2009) provided a list of definitions for the term 'aggressive driving':

- "Operating a motor vehicle in a selfish, pushy, or impatient manner, often unsafely, that directly affects other drivers." (National Cooperative Highway Research Program, NCHRP)
- "Driving actions that markedly exceed the norms of safe driving behavior and that directly affect other road users by placing them in unnecessary danger." (National Highway Traffic Safety Administration, NHTSA)
- "Any unsafe driving behavior that is performed deliberately and with ill intention or disregard for safety." (American Automobile Association, AAA).

A study by AAA (2009) concluded that 56% of fatal crashes from 2003 through 2007 involved one or more driver actions typically associated with aggressive driving and this has been increasing each year by 7%. Moreover, 50% of these crashes were single-vehicle crashes while two-vehicle and multi-vehicle crashes accounted for 42.2% and 7.8% respectively.

According to Fuller (2005), the task of driving can be easy or difficult depending on the momentary task demand of driving and the driver's reserve of capability to control his/her vehicle accurately. The driving task demand of a driver is highly influenced by his/her behavior and especially by the choice of the following headway, speed and acceleration. Safety margin is the difference between a driver's level of capability and the task demand of the driving environment. Depending on the threshold of the safety margin that drivers allocate, aggressive drivers are identified as high risk group of drivers with small or no margin of safety at all (Fuller, 2005). In psychological terms, aggressive driving is classified as type-A personality which is characterized by risky and competitive driving behavior with underlying elements of hostility, aggression, impatience and urgency (Miles & Johnson, 2003).

An empirical study on aggressive behavior noted that there is spatial and temporal variations among reported violations (Sarkar, Martineau, Emami, Khatib, & Wallace, 2000). The frequency of these violations showed notable fluctuations based on location of the motorway segment, month of the year, day of the week and time of the day. A similar study implied that aggressive driving is positively correlated with the individual's social status and the type of vehicles they drive (Diekmann, Jungbauer-Gans, Krassnig, & Lorenz, 1996).

A study by Rong, Mao, and Ma (2011) indicated that about 34% of the sampled drivers fell into the category of 'aggressive drivers'. These individuals were found to be young in age, less driving experience, drove at higher speeds, accepted smaller gaps and obtained lower scores on the overall driving safety evaluations. Moreover, the study showed that the quality of the

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