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The impact of high-risk drivers and benefits of limiting their driving degree of freedom

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ABSTRACT

The perception of drivers regarding risk-taking behaviour is widely varied. High-risk drivers are the segment of drivers who are disproportionately represented in the majority of crashes. This study examines the typologies of drivers in risk-taking behaviour, the common high-risk driving errors (speeding, close following, abrupt lane-changing and impaired driving), their safety consequences and the technological (ITS) devices for their detection and correction. Limiting the driving degree of freedom of high-risk drivers is proposed and its benefits on safety as well as traffic operations are quantified using VISSIM microscopic traffic simulation at various proportions of high-risk drivers; namely, 4%, 8% and 12%. Assessment of the safety benefits was carried out by using the technique of simulated vehicle conflicts which was validated against historic crashes, and reduction in travel time was used to quantify the operational benefits. The findings imply that limiting the freedom of high-risk drivers resulted in a reduction of crashes by 12%, 21% and 27% in congested traffic conditions; 9%, 13% and 18% in lightly congested traffic conditions as well as 9%, 10% and 17% in non-congested traffic conditions for high-risk drivers in proportions of 4%, 8% and 12% respectively. Moreover, the surrogate safety measures indicated that there was a reduction in crash severity levels. The operational benefits amounted to savings of nearly 1% in travel time for all the proportions of high-risk drivers considered. The study concluded that limiting the freedom of high-risk drivers has safety and operational benefits; though there could be social, legal and institutional concerns for its practical implementation.

1. Introduction

In past years, advances in vehicle technology, infrastructure engineering and traffic management contributed to decreasing roadside crashes and fatalities. The reward for these advances was a steady decline in the number of fatalities until the late 1990s. However, over the past 10–15 years, the numbers of fatalities in the developed countries has maintained a more or less constant trend with a very slight reduction (e.g., see WHO, 2009 report on the trends in road traffic fatality rates for high-income countries). This suggests that the aforementioned advancements might have reached their potential limit for decreasing crashes and fatalities. As a result, road safety research has been focused on minimising the occurrences and mitigating the consequences of driver errors and particularly the impact of high-risk driving errors.

Studies by Stanton and Salmon (2009) and Sun et al. (2008) mentioned that about 75–95% of crashes are related to one or more driver errors. Archer and Kosonen (2000) observed that drivers make one driving error every 2 min or every 2 km of driving distance while travelling at 60 km/hr. Harvey et al. (1975) defined driver error as '. . . any action or lack of action by drivers that would require them to implement a correction in order to make the situation safe again'.

According to Reason (1990) human errors are classified into slips, mistakes and violations. Slips and mistakes refer to attentional and memory failures while violations are wilful and deliberate actions that compromise safety. Hutabarat et al. (2004) mentioned that driver errors could be due to inadequate experience and skills (i.e., slips and mistakes) or wilful inappropriate actions (i.e., violations). However, the majority of the driving errors by high-risk drivers are intentional violations rather than errors of slips and mistakes which suggest that such behaviour does not directly result from lack of driving skill but from inappropriate driving behaviour (Rolls and Ingham, 1992). The most common high-risk driving errors include: speeding, close following, abrupt lane-changing and impaired driving. Other high-risk driving errors include internal and external distractions, carelessness and recklessness, violating traffic signs, driving under the influence of drugs or alcohol, aggressive driving and the like.

With advances in technology and telematics, it is now technically possible to detect some sort of driving errors and assist drivers

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in taking the appropriate counteractions. For example, Stanton and Salmon (2009) suggested the use of intelligent transportation systems (ITS) as a potential solution for driver errors either to prevent them or mitigate the resulting consequences. Therefore, making use of the technologies that assist drivers is a potential solution to counteracting crashes and fatalities arising from high-risk driving behaviour.

High-risk drivers constitute only a small segment of the total drivers; however, they disproportionately represent the majority of crashes. For example, Guo and Fang (2012) found that high-risk drivers make up only 6% of the driving population but accounted for 65% of total crashes and near crashes. Thus, this paper suggests limiting the driving degree of freedom of high-risk drivers to counteract the common driving errors they usually demonstrate. In other words, driver competence and level of performance is used as an additional traffic management criterion to reduce the common driving errors. Unlike the macroscopic (aggregated) traffic management strategies which correspond to network wide schemes (e.g., setting maximum speed limits and implementation of measures like tolls and congestion pricing), a disaggregated and driver-performance-responsive management strategy directed to individual high-risk drivers is proposed and its potential benefits on traffic safety and operations are quantified. VISSIM microscopic traffic simulation model and Surrogate Safety Assessment Model (SSAM) are employed in this research work. The potential use of ITS for detecting and correcting high-risk driving errors of speeding, close following, abrupt lane-changing and impaired driving is explored.

The structure of this paper is as follows: firstly, there is a general overview of the theme of the research; secondly, there is a review of the literature on the task of driving, high-risk driving behaviour, its safety consequences and the technological devices for its detection and correction. Then the credibility of the adopted methodology of the research is demonstrated and this is followed by a discussion of the results of limiting the freedom of high-risk drivers in terms of improvements in the safety and operations of motorway traffic. Finally, some conclusions are presented which indicate the benefits to traffic and the possible direction of future work.

2. Literature review

2.1. The driving task

Driving is a complex task which involves a hierarchical process at three distinct levels, namely: navigation, guidance and control. Navigation refers to the strategic planning and scheduling of a trip as well as choosing a convenient route to the destination. Guidance denotes the tactical decisions a driver makes to maintain a safe trajectory and keep the vehicle in the proper lane. Control refers to the operational part of driving which includes driver interaction with the vehicle in terms of accelerating, braking and steering (Summala, 1996; Koppa, 2005). The three levels of the task of driving are influential to the crash risk in one way or the other.

Fuller (2005) developed the Task–Capability Interface model which describes the task of driving. The model formulates the concept of driving task difficulty as the determinant factor for crash involvement. Driving task difficulty is the outcome of the dynamic interface between the demand of the driving task and the available capability of the driver, i.e., the task of driving can be easy or difficult depending on the current demand of the driving task and the driver's reserve of capability to control the vehicle.

The driving task demand is dictated by the driver's choice of speed, headway, magnitude of gap accepted, nature of traffic, behaviour of other road users and environmental factors such as visibility and road alignment. In the same way, the capability of driver is limited by acquired characteristics and biological factors which include knowledge of road rules, driving skills, training and experience, human limitations in information processing, reaction time as well as physical strength and flexibility (see Fuller, 2005; Fuller and Santos, 2002). Combining the concepts of *driver capability* and the *driving task demand* gives rise to the Task–Capability Interface model which states that: 'If capability exceeds the driving task demand, then the driver is able to progress safely. However, if capability falls short of task demand, then collision or loss of control is implied' (Fuller and Santos, 2002). Nevertheless, since driving is a self-paced task, drivers can adjust their driving task demand by modifying their speed, following headway, making a strategic selection of route to destination or adjusting the timing of journey to avoid congested roads or rush-hours that increase their driving task demand (Fuller, 2005).

According to Hutabarat et al. (2004), the task of driving involves a complex interaction between human factors and system response with the sequence of problem recognition, decision making and execution of a manoeuvre, although it is difficult to pinpoint the boundaries. An error in one or more of these steps results into a situation of a crash or a near crash. Problem recognition errors involve failure to yield to a stop sign, delay in problem recognition, inattention and distractions. Decision errors are those such as excessive speed, improper manoeuvring, tailgating, misjudgement of distance or closure and excessive acceleration. Execution errors include evasive actions, inadequate directional control, panic or freezing.

2.2. Risk-taking behaviour of drivers and high-risk driving

Before dealing with drivers' risk-taking behaviour, it would be more appropriate to determine what *risk* is. Haight (1986) defined risk '. . . as the probability of each event multiplied by the cost of the event, if it does in fact occur'. Therefore, risk-taking behaviour of drivers is any activity that increases the probability of involvement in crashes which is costly in terms of material damage, human trauma and death. Several authors attempted to define what high-risk driving is. Evans (1991) defined risky driving as any behaviour that increases the driving task difficulty and compromises the road safety. Similarly, Boyce (1999) outlined risk-taking behaviour as any action that '. . . increases driving task difficulty by: a) decreasing the reaction time necessary for successful evasive manoeuvring, b) diverting attention away from the driving task, or c) increasing response time to perform typical driving behaviours'. High-risk driving has also been identified as a driving style with no margin of safety which does not conform to traffic regulations (Risser, 1985). NHTSA (2011) defined it as an inappropriate driving action which '. . . markedly exceed the norms of safe driving behaviour and that directly affects other road users by placing them in unnecessary danger'.

The important aspect of safe driving is the ability of the driver to keep a suitable margin of safety by constantly examining his or her driving capability and the driving task demand. Fuller (2005) and Fuller et al. (2008) called this 'calibration' of drivers and it allows them to precisely estimate the driving task difficulty. Safer drivers are well calibrated and supposedly have a wider margin of safety. On the other hand, high-risk drivers are poorly calibrated in terms of underestimating the driving task demand and are likely to overestimate their driving capability and thus remain with little or no safety margin. Therefore, high-risk drivers unnecessarily increase their driving task demand by speeding, following closely, changing lanes abruptly or choosing to drive while their capability is very low, e.g., impaired driving due to sleep.

In the same way, Evans (1991, 2004) distinguished between driver performance and driver behaviour. Driver performance is what the driver CAN do (driving skill) while driver behaviour is