



Modeling drivers' speed selection as a trade-off behavior

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ABSTRACT

This paper proposes a new model of driver-preferred speeds derived from the assumption that drivers trade-off a portion of their safety for a time gain. The risk of receiving a ticket for speeding is also considered. A trip disutility concept is selected to combine the three components of speed choice (safety, time, and enforcement). The perceived crash risk and speed enforcement are considered as speed deterrents while the perceived value of a time gain is considered as a speed enticement. According to this concept, speeds that minimize the perceived trip disutility are preferred by drivers. The modeled trade-off behavior does not have to be fully rational since it is affected by drivers' preferences and their ability to perceive the risk. As such, the proposed framework follows the concept of bound rationality.

The attractiveness of the model lies in its parameters being estimable with the observed preferred speeds and then interpretable as the factors of risk perception, the subjective value of time, and the perceived risk of speed enforcement. The proposed method may successfully supplement behavioral studies based on a driver survey.

The study focuses on four-lane rural and suburban roads in Indiana, USA. The behavior of two types of drivers (trucks and cars) is modeled. The selection of test sites was such that the roads and other local characteristics varied across the studied sites while the population of drivers could be assumed as the same. The density of intersections, land development along the road, and the presence of sidewalks were the identified prominent risk perception factors. Another interesting finding is that the speed limit seems to encourage slow drivers to drive faster and fast drivers to drive slower.

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1. Background

This study proposes modeling speed choice as a trade-off between the perceived risk of crash, the subjective cost of time, and the perceived risk of speed enforcement. Unlike other ad hoc speed models, the structure of the proposed model was derived beforehand from assumptions supported by past research. The following section first overviews the existing state of the art in statistical speed modeling. Then, various past studies on risk perception are presented to support two key assumptions of the proposed model structure: (1) drivers feel risk and (2) this feeling, called also risk perception, affects their behavior. We cite selected authors and emphasize selected findings relevant to the purpose of this overview. This literature review is not meant to be complete or rigorous from the aspect of any in-depth psychological theory or hypothesis.

A large body of research work has been aimed at identifying speed factors, using large samples of speeds measured under various conditions and applying cross-sectional analysis to link the road and driver characteristics with preferred speeds. We will dis-

cuss here only representative work to characterize the current state of the art. Polus et al. (2000) concluded that vehicle speeds on tangents were dependent on the length of the tangent section, the radius of the horizontal curve before and after the section, the cross-sectional elements, the vertical alignment, the general terrain, and the available sight distance. Numerous studies have dealt with roadway characteristics as speed factors on two-lane rural highways. Yagar and Van Aerde (1983) studied the effects of the geometric and environmental conditions on mean speeds. Mean speeds were found to be related to the roadway grade, the lane width, the land use, the highway access, and the speed limit. Several studies (Polus et al., 2000; Yagar, 1984; Schurr et al., 2002) identified a number of roadway characteristics as speed factors on two-lane rural highways. The operating speeds were found in these studies to be related to the speed limit, highway grade, traffic volume, and specific elements of the horizontal and vertical curvature, such as the radius, the super-elevation rate, and the sight distance. However, the impact of the cross-section dimensions on speeds has not been easy to identify. The research on speed factors for other highway types has not been as extensive as for two-lane rural highways. Fitzpatrick et al. (1997) evaluated operating speeds on suburban highways. The access density, the curvature, and an inferred design speed based on the sight distance were identified as good predictors of operating speed on tangents, horizontal curves, and vertical

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curves, respectively. Poe and Mason (2000) evaluated speeds on tangents and horizontal curves on urban and suburban collectors. The curvature, the highway grade, the lane width, and the presence of a roadside hazard rating were found to be significant mean speed factors at the curve midpoint. When the observed speeds on tangents and curves were combined as one sample, only the curvature and the absolute value of the highway grade were found to be significant mean speed factors.

A number of investigations of driver speed selection clearly indicate that driver-preferred speeds are affected by the socioeconomic characteristics of the driver, as well as by the road geometry, speed limit, and weather conditions. These models do not employ any of the existing theories or hypotheses that attempt to explain the mechanism governing the speed selection. Doing so could help interpret the obtained models and undertake more effective countermeasures against excessive speeds and better design of the roads to make them more “self-explanatory” to drivers.

Before we propose a modeling context in which a model structure is derived, a number of past studies should be mentioned. There is a consensus among a large group of researchers that drivers perceive crash risk. Farrow and Brissing (1990) found that males reported a significantly lower score in their perception of risk compared to women. Also, DeJoy (1992) found that males perceived lower risks for specific hazardous driving behaviors (not using a safety belt, drinking and driving, etc.) than female drivers. Males tended to show more “optimism bias” toward their driving skills and they consider themselves less likely to be involved in a crash and more likely to be better drivers than others in their peer group. DeJoy (1992) concluded that low perceived risk is correlated with risky driving and high driving speeds. Renge (1998) used videotaped traffic scenes and drivers with diverse experience to measure their hazard perception skills, their rating of risks, their safe driving level of confidence, and their speed selection. He argued that driving experience is a significant factor in the development of a driver’s risk perception. The results of this study showed that, with increasing experience, drivers more appropriately perceived hazardous situations on the road, evaluated the risks as higher, and selected lower driving speeds. If one agrees that experience grows with age, then several studies which found that young drivers tend to perceive less risk in specific crash scenarios and during general driving than older drivers are consistent with Renge’s conclusions (Jonah, 1986; Finn and Bragg, 1986; Brown and Groeger, 1998). Young drivers both drive at higher speeds than older drivers (Quimby and Watts, 1981), and perceive themselves as less likely to be involved in a crash than other drivers (Mathews and Moran, 1986).

An interesting study was reported by Streff and Geller (1988) who investigated the response of go-kart drivers to seatbelt use. Unlike other authors, they could compare the behavior of the same drivers in two distinct situations, namely, wearing and not wearing seatbelts. The drivers’ responses were measured by their driving speeds and a survey of their opinions. The results of this unique study confirmed that drivers reduce their speed when they feel less safe.

If one agrees that drivers arrive in some way at a specific level of perceived risk or feeling of safety, regardless if it is adequate or inadequate, the next question pertains to the mechanism that converts that perception into specific behavior as suggested by Streff and Geller (1988). The most popular is a group of hypotheses that have a common component: a certain fixed or varying target risk that drivers try to maintain. Naatanen and Summala (1976) postulated that drivers predominantly select behaviors that eliminate any perceived risk of accident (zero target risk). Wilde (1982, 1994) and Adams (1985), on the other hand, put forward the idea that drivers attempt to maintain a risk level close to their fixed target risk. Wilde introduced this hypothesis in 1982 under the term of risk home-

ostasis. One of his key arguments was a steady number of crashes after efforts to improve road safety, including the British Columbia drunken-driving campaign and the Munich cabs experiment. They were interpreted as the result of driver risk-compensating behavior in an attempt to regain the target risk. Wilde’s proposition was rebutted by O’Neil and Williams (1998) as unsupported and conflicting with other successful cases not mentioned in Wilde’s publications. Other authors proposed a less restrictive hypothesis that the target risk changes with the circumstances. According to some authors, it is selected at the optimal level at which the perceived trip utility is maximized or disutility minimized (O’Neil, 1977; Janssen and Tenkink, 1988). These propositions are consistent with the theory of rational choice commonly used to explain economic and consumer behavior (Arrow, 1987; Allingham, 2002).

To make this brief overview representative, we should mention another opinion shared by some and recently clearly expressed by Fuller (2005), who questioned if drivers can perceive risk and use it consistently when driving. He proposed a more basic mechanism based on work load. According to his hypothesis, drivers adjust their behavior to maintain the current work load below their capacity. He introduced a new hypothesis that he named “task difficulty homeostasis.” The proposed theory of task difficulty homeostasis defines task difficulty as the difference between the current task demand and the current driver capability. Fuller postulates that the measure of driver arousal through galvanic skin response (GSR) interpreted by Taylor (1964) as an indicator of risk perception is actually reflective of the task difficulty the drivers experienced.

Is it risk homeostasis, rational choice, task difficulty homeostasis, or a combination thereof? A specific answer to this question is not needed to propose a useful speed modeling framework. It seems plausible that drivers, in general, attempt to drive as fast as they feel comfortable. The speed, on the other hand, seems to be curbed by a feeling of uneasiness which has two sources: the possibility of crashing and the possibility of the discomfort caused by receiving a speeding ticket. This feeling of uneasiness is reduced to a comfortable level (if not eliminated completely) after a driver adequately reduces the speed and before the dissatisfaction caused by a lower than acceptable speed occurs. The selected speed is optimal in the sense of driver preferences and subjective judgment of safety and speed enforcement. The next section proposes a modeling framework which encompasses this mechanism.

2. Concept

Excessive speed induces uneasiness in drivers. We do not attempt to explain how this induction comes into existence. Instead, we will try to link the growing feeling of uneasiness with a speed deterrent curve that represents the level of driver concern about safety and a speeding ticket. There is also a contradicting feeling of frustration when speed is perceived as unduly low. As in the previous case, we will simply contend that fact and introduce another curve called a speed enticement curve that takes high values at low speeds and declines with speed increases. The two curves are shown in Fig. 1. This concept follows the utility-based theory of choice commonly used to explain economic and consumer behavior (Arrow, 1987; Allingham, 2002). In our case though, the perceived disutility is a non-linear function of speed.

The total trip disutility is a sum of three components: subjective cost of the travel time, perceived risk of crash and its potential consequences, and perceived enforcement of the speed limit:

$$\begin{aligned} \text{trip disutility} = & \text{subjective time value} + \text{perceived risk} \\ & + \text{perceived enforcement.} \end{aligned} \quad (1)$$

There is no doubt that drivers feel a loss of time and become frustrated when the speed is too low. The majority of accepted network

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