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Development of a new microscopic passing maneuver model for two-lane rural roads

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ABSTRACT

Microsimulation is a useful tool to analyze traffic operation. On two-lane highways, the complexity of passing and the interaction with oncoming traffic requires specific models. This study focused on the development of a passing desire, decision and execution model. Results of the observation of 1752 maneuvers on 10 rural roads in Spain were used for this development. The model incorporated the effect of new factors such as available sight distance, delay and remaining travel time until the end of the highway segment. Outputs of the model were compared to observed data: firstly, individual passing maneuvers; secondly, traffic flow, percent followers and number of passing maneuvers in four single passing zones with two different traffic levels. The model was validated in four alternative passing zones.

1. Introduction and background

Microsimulation of traffic requires the description of the movement of each individual vehicle in the traffic stream. Therefore, microscopic models include several components to represent the maneuvers performed by individuals, such as acceleration, deceleration, car following or lane changing (Barceló, 2010).

Common applications of microscopic modeling of traffic are, among others, the study of signalized and unsignalized intersections (Stevanovic et al., 2013), roundabouts (Ištoka Otković et al., 2013), emission estimations (Jie et al., 2013), passing and climbing lanes (Valencia Alaix and García, 2010), or evaluation of intelligent transportation systems (ITS) and cooperative systems (Hegeman et al., 2009).

The application of microsimulation to analyze two-way two-lane rural roads is also possible. However, the interaction with opposing traffic flow implies the development of specific passing models. On two-lane rural roads, passing maneuver allows faster drivers to pass slower vehicles and drive at their own desired speeds. This maneuver has an important effect on the level of service and contributes increasing the capacity of these roads (Transportation Research Board, 2010).

Passing is only possible on certain sections where available sight distance exceeds a minimum passing sight distance (*PSD*) requirement determined by standards. Therefore, there is an effect of geometric design on the frequency and characteristics of passing maneuver. However, this maneuver depends mainly on the human factor, since it involves several complex decisions. Traditionally, the following stages explain passing driver's behavior:

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- Passing desire: driver's desire to pass or to keep on following the slower vehicle.
- Passing decision (gap acceptance): for drivers who desired to pass, their decision to accept or reject a passing opportunity (named gap) in the opposing traffic.
- Passing execution: for drivers who accepted a gap, the passing performance and the decision to complete or abort the maneuver, before reaching the critical point (point of no return).

The complexity and higher dispersion of passing process is visible in many observational studies (Polus et al., 2000; Carlson et al., 2006; Harwood et al., 2010; Llorca et al., 2013a,b). Consequently, many researchers considered the use of alternative approaches to analyze two-lane roads, such as driving simulators (Jenkins and Rilett, 2004; Farah and Toledo, 2010; Farah, 2011) or microscopic modeling. The following section focuses on the existing microscopic passing models.

1.1. Existing models

There have been previous research focused on the development of passing models. However, their level of detail, their validation or their field of application are not homogeneous.

The Interactive Highway Safety Design Model (IHSDM) includes a passing model as part of the Traffic Analysis Module (TAM, previously named TWOPAS). This model has been used to analyze average travel speeds (*ATS*) and percent time spent following (*PTSF*) (Bessa and Setti, 2011), or the addition of climbing lanes to facilitate passing (Valencia Alaix and García, 2010). Harwood et al. (2010) used this model to demonstrate that short passing zones (under 240 m) did not contribute to improve the level of service of rural roads. Authors did not validate TAM with this study, assuming TAM initial calibration based on 1970's data (Harwood et al., 1999).

Several authors detected limitations in TAM. According to Li and Washburn (2011), this model does not provide the ability to include signalized intersection within the modeled highway. Kim and Elefteriadou (2010) stated that the program stalls when traffic volume exceeds 1700 vph.

Li and Washburn (2011) developed a passing model for CORSIM software. The CORSIM model includes the following steps: passing desire, depending on tolerable and desired speed, as well as impatience; and passing decision and execution: based on estimated *PSD* according to the Manual on Uniform Traffic Control Devices (FHWA, 2003) and Harwood et al. (2010), also included in AASHTO Green Book (2011). CORSIM can take into account no-passing zone marking and opposing traffic, although the effect of available sight distance is not considered. Although this model increased the level of detail of TAM, there is still neither any validation nor calibration with field data.

Kim and Elefteriadou (2010) developed a microsimulation model to determine two-lane highways capacity. This model assumes a consistent and homogenous driver behavior. To consider passing, driver's desired speed should be 8 km/h higher than the leading vehicle. TWOSIM uses the Green Book (2004) *PSD* values. This model was verified comparing results of *ATS* and *PTSF* with TAM model. The authors also compared passing times with field data from other authors. Authors obtained a capacity up to 2100 vph for two-lane roads applying this model to generated road segments. Previously, Dey et al. (2008) described another passing microsimulation model. Those authors used also the model to evaluate capacity of two-lane rural roads. The results of capacity ranged between 2400 and 3000 passenger car units (*PCU*). However, the only validation process of this model was the comparison of arrival distributions and spot speeds with real data.

Hegeman et al. (2009) used the microsimulation model RutSim to test the effect of driver's assistant systems. This model was an evolution of the VTI model, developed by Tapani (2005). VTI was validated at a microscopic level, although the frequency and characteristics of passing maneuvers were not tested. Other models that have been used mainly in research studies were LASI (Brilon and Brannolte, 1977), TRARR (Hoban et al., 1991), and Ghods and Saccomanno (2013).

Other passing studies (such as Khoury and Hobeika, 2012; Farah and Toledo, 2010) modeled single passing maneuvers or binary choice processes, respectively, but they are not strictly microsimulation models. Lastly, Jenkins and Rilett (2004) combined a microscopic model (not able to represent passing maneuvers) with a driving simulator, while the microsimulator generated the rest of traffic. A sample of drivers performed passing maneuvers in a controlled driving simulator experiment. However, those studies cannot be applied to evaluate the traffic performance on different real rural road scenarios.

As seen in the literature review, there are different approaches to microscopic passing maneuver models. They include different parameters and assumptions, which are rarely justified by the observation of the phenomenon. Besides, most of them are still not validated with detailed observations of passing maneuvers, and may provide unrealistic results under conditions other than the tested. The complexity of modeling two-lane rural roads, compared to other facilities, such as freeways, and their lower traffic volume may explain why those models are generally only applied in research studies.

The conclusion of the literature review is the necessity of calibrating and validating a passing maneuver model, as part of a microsimulation software. With this contribution, microsimulation tools might be also applied in operational analyses involving two-way two-lane rural road segments.

2. Objectives

The aim of this paper is the development and calibration of a passing maneuver model in Aimsun microsimulation software (Transport Simulation Systems, 2013). This main goal is divided into the following objectives: