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Safety assessment of passing relief lanes using microsimulation-based conflicts analysis

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ABSTRACT

The paper target is to analyze the influence of passing lane section and merging area lengths, which represent a critical part in the geometric design of passing lanes. The lack of observed data and the still limited implementation of short passing 2 + 1 lane in Poland do not allow to perform a reliable performance-based design of their length to balance context and economical restrains with operational and safety performances. Besides, defining the optimum geometric design from observed data is a reactive approach which require detailed observations and evaluations of the safety and operational performances for different geometric configurations. The present research work aims to fill the gap by performing an evaluation of optimal length, based on microsimulation analysis. Particular attention was paid to the calibration and validation of microsimulation models using real data of traffic characteristics and crash history. The assessment was conducted using simulation models in VISSIM and Surrogate Safety Assessment Model (SSAM) software and comparison based on simulated results at different lengths of passing lane, merging area in a wide range of AADT values. The results suggested not only that conflicts can be a surrogate measure of safety but also that the influence of geometric parameter, such as the length of the additional lane, plays a fundamental role in the safety performance of the 2 + 1 short passing lane.

1. Introduction

Defining the optimum geometric design from observational data is a reactive approach that requires a suitable sample of sites and a historical evaluation of the safety and operational performance. As far as the safety performance is concerned, SPFs and CMFs are statistically-based prediction methods which require significant efforts in crash data collection and long periods to observe crash occurrence. Traffic conflict studies can mitigate this issue using a short time survey to count the number and severity of traffic conflicts which are assumed as surrogate measures of safety. Unfortunately, they are again field-based studies which can be carried out only after the implementation of the treatment. Moreover, international transferability of existing studies is another issue which limits the predictability of future performances basing on literature case studies (Cafiso and D'Agostino, 2016, 2015; D'Agostino, 2014). That is the case of the evaluation of safety performance of new design schemes or treatment typologies such as the design of 2 + 1 lanes, objective of the present research work.

Nowadays, micro-simulation is well established tool for analyzing the operational effects of new or complex geometric schemes (Anon, 2006; Dowling et al., 2006). Recently, several studies (Huang et al., 2013) are attempting to use micro-simulation vehicle trajectories to classify traffic conflicts, as well. Specifically, traffic conflicts can be detected through the Surrogate Safety Assessment Model software (SSAM) (Pu and Rahul, 2008) where vehicle trajectories obtained from micro-simulation software (e.g. VISSIM) are post-processed. Despite the well-known potentialities of these software tools, care has to be taken regarding the appropriateness of the microsimulation in reproducing the real word number and severity of traffic conflicts. Therefore, calibration of models and validation of results should be carefully considered.

In this framework the present research work deals with short passing 2 + 1 lanes. According to technical standards of different countries the minimum length varies from 0.5 km (in Poland) to 1.2 km (in Austria), while the commonly suggested length is equal to 1 km (Koorey et al., 1999). The reasons of the application of shorter lanes in Poland include: the high density of intersections and budget constraints for a comprehensive reconstruction of the entire road network. Short passing sections can limit the main functions of longer 2 + 1 sections, i.e. the ability to disperse traffic platoons and it may lead to hazardous

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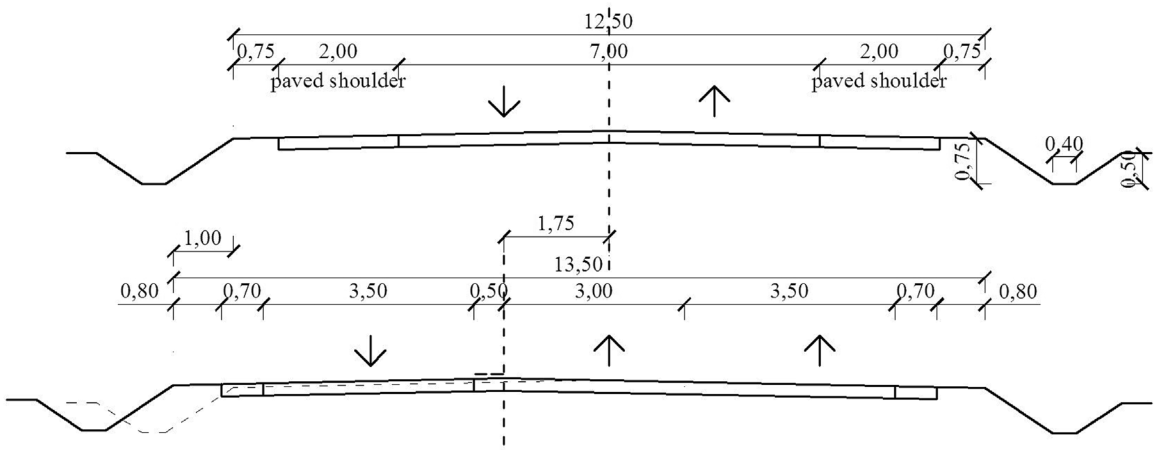

Fig. 1. Converting a two-lane road with wide paved shoulders into 2 + 1 cross-section.

maneuvers, for instance aggressive lane changing and increase in number of conflicts in the merging area. Moreover, the presence of small urbanized areas breaks the continuity of the alignment thus limiting the possibility of repetition of alternate passing lanes (Fig. 1).

All these local factors are cause of concerns regarding traffic and safety effectiveness of the new passing relief lanes related more on the optimal length at varying traffic flows. Facing the difficulties, due to the long period of data collection and limitation of data sources, the analysis using surrogate measures of traffic safety is introduced more and more frequently (Wang and Stamatiadis, 2013). The application of micro-simulated conflicts is considered as one of the methods based on surrogate measures which allows to estimate the number of conflicts for different road and traffic configurations (Fan et al., 2013; Shahdah et al., 2013; Cafiso et al., 2016; Gettman et al., 2008). Such an approach is much more popular in the analysis of intersections and, although simulation modeling for road sections with additional lanes and their lengths is described in literature, these limited studies mainly discuss the modeling in the context of the evaluation of traffic performance (Brewer et al., 2012; Kirby et al., 2014) and they do not assess performance based design of length of passing relief lanes. The paper presents a micro-simulation study of operational and safety performance of 2 + 1 additional passing lanes considering the length of the passing and merging sections as geometric variables and traffic volume as main operational variable, in the case of not physical separation of the two traffic flow direction (Cafiso et al., 2017). Real world traffic and crash data were also collected in the field to calibrate and validate the models.

2. Safety and operational performance of 2 + 1 sections

Gattis et al. (2006) studied passing lanes' operations focusing on continuously alternating passing lane sections in Arkansas. Their findings indicated that passing lanes reduced the percentage of vehicles in platoons by about 14%, with much of that reduction in the first 0.9 mi (1.4 km) of the passing lane. They also found out that passing maneuvers increased along with volume, which may indicate that higher-volume roads could use longer passing lanes. In the European operational analyses of 2 + 1 road sections, Weber and Löhe (2003) recommended a minimum length of 1.0 km for passing lanes within 2 + 1 roads with mixed traffic. Irzik (2010) indicated the optimum length of passing lanes in terms of platoon discharge, related to traffic volume, longitudinal grade and share of heavy vehicles starting from a minimum length of 0.9 km. According to the studies of 2 + 1 sections carried out in Korea (Lee et al., 2010), a decrease in the share of traffic in platoon of about 8% was confirmed at a distance of 1.0 up to 1.2 km. From the safety point of view, the results of the impact of additional lanes on traffic safety have been developed on the basis of reported accidents (Highway Safety Manual, 2010; Weber and Jährig, 2010). They indicate a decrease up to 50% in crashes after the implementation of passing lanes. Weber and Jährig (2010) analyzed also passing lanes with a speed camera for lane lengths from 600 m to 1200 m, which is shorter than recommended in Germany. Also in Sweden 2 + 1 design has been positively evaluated which resulted in very massive reconstruction of the rural roads to such design (Carlson, 2009). The implementation of additional passing lanes was effective in the avoidance of head-on crashes and there was no negative influence on traffic flow. Apart of the overall benefits of passing lanes, from the literature analysis, there are not studies focusing on safety effects of length of the additional lane and of the merging area which represent on the main variables of their geometric design.

3. Micro-simulation modeling

Micro-simulations were carried out with the PTV VISSIM and SSAM software. In-field collected data were used for calibration and validation of the model.

3.1. Empirical data

The empirical data was collected during field observations at 5 test sites on the same 2 + 1 road in Poland. The field observations were conducted during the day, in good weather conditions for a minimum of 4–5 h including peak hour periods. The lengths of the section with the additional lane ranged from 550 m to 1000 m while the traffic volume (calculated within 5-min intervals) falls within the range of 240–1,116 veh/hour/dir (Table 1). All sections were located on level terrain with vertical grade alignment lower than 3%. The data was collected with the help of pneumatic sensor traffic recorders and ANPR cameras (Automatic Number Plate Recognition). The field study documented driver behavior and traffic operation at the beginning and at the end of the sections. Observed data are presented in Table 1. Share of platoon, speed and number of passes were selected as parameters for calibration and validation of microsimulation model.

Share of platoon is defined as the share of vehicles travelling at a distance of less than 3 s between each other. Share of the platoon in the 5-min interval was observed at the beginning and at the end of the 2 + 1 section based on data from 5 test sites (distinguishing 312 measurement intervals).

Because the platoon share is characterized by time variability in function of traffic volume and speed, a regression model was developed by using traffic volume and average speed as covariates and the Share of Platooning Vehicles (SPV) as dependent variable in the sample of real data. Such a model with all the variables significant over the 95th percentile is reported in Eq. (1):