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Operational Impact of Horizontal and Vertical Alignment of Two-Lane Highways

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Abstract

The effect of highway bendiness on traffic performance is not addressed on the current HCM analysis procedure for two-lane highways. Given the relationship between operating speed and horizontal alignment, highway bendiness could potentially affect speeds and platooning; and therefore the ideal performance measure should be sensitive to highway geometry variations. The influence of horizontal and vertical alignment on their traffic operation was studied on 19 uniform segments from Spanish two-lane highways using TWOPAS. Alignment was classified following the German procedure: curvature change rate (*CCR*) and class of gradient. Among the performance measures, follower density was correlated to both traffic and roadway conditions in a more meaningful way.

Keywords: Two-lane highways, Traffic operation, Microsimulation, Geometric Design, Horizontal alignment, Vertical alignment, *ATS*, *PTSF*, Follower density

1 Introduction

Spanish standards (Ministerio de Fomento 1999) rely on the U.S. Highway Capacity Manual (Transportation Research Board 2010) to analyze the level of service (LOS). For two-lane highways, LOS is based on one or more of three performance measures, depending on highway classification: average travel speed (*ATS*); percent time spent following (*PTSF*); and, percent of free-flow speed (*PFFS*). The three measures depend on some geometric and demand data, such as percent of no-passing zone, base design speed, directional traffic volume or directional split. Significant variations on the horizontal alignment are not included, neither on the analysis procedure nor the uniform segment identification. Given the relationship between operating speed and design elements, the average travel speed of a segment and platooning would be likely affected by a higher presence of curves (higher bendiness). [*]

In Germany, traffic performance is evaluated in terms of density, defined as the ratio between directional traffic volume and average travel speed of passenger cars. The performance measure is affected by both horizontal and vertical alignment (Forschungsgesellschaft für Strassen und

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Verkehrswesen 2015). Horizontal alignment is characterized through the curvature change rate (*CCR*); defined as the absolute angular change in horizontal direction per unit of distance. Boundaries for uniform segments consider significant variations of cumulative *CCR*. Vertical alignment considers the minimum speed that a heavy vehicle could obtain on the section and it depends on the length and grade of the most restrictive ramp along the segment. The heavy vehicle used in the analysis has a weight/power ratio of 0.138 kg/W (228 lb/HP). For each class of horizontal alignment, vertical alignment and percentage of trucks, speed-flow diagrams were developed using simulation results from the traffic microsimulation program Landstraßensimulation (LASI) (Weiser et al. 2011). Ideal segments were composed of a fictitious sequence of curves and tangents. The radii of the fictitious curves were constant and equal to the minimum radius defined on the German Geometric Design guideline (Forschungsgesellschaft für Strassen und Verkehrswesen 2013). Therefore, it might not be representative of actual two-lane highways alignment, as a sequence of curves with different radii and different tangent lengths. Directional analysis was used with balanced flows (directional split 50/50). Contrary to the US HCM, directional split and passing restrictions were not considered. Passing restrictions were removed from the analysis procedure because the influence of passes on speeds had been significantly overestimated (Weiser et al. 2011); and passing restrictions are usually a result of the horizontal alignment, which is already considered on the German HCM.

Moreno et al. (2015) analyzed the relationship between horizontal alignment and traffic performance for the Spanish conditions. The horizontal alignment of 8 Spanish uniform segments was introduced in the TWOPAS microsimulation program, which was previously calibrated and validated with Spanish field data. *ATS* was highly affected by *CCR* and the HCM analysis procedure overestimated *ATS* up to 20 km/h in sinuous highways (*CCR* higher than 75 gon/km). *PTSF* did not depend significantly on *CCR*. The research did not include the influence of vertical alignment or directional splits. In another research, passing restrictions did not influence much *ATS* in straight segments (Moreno et al., 2016). However, directional split had a great effect on both *ATS* and *PTSF*.

On the other hand, the most appropriate performance measure for two-lane highways is still open for discussion. Luttinen et al. (2003) proposed some conditions that ideal performance measures should present. Ideally, they should reflect the perception of road users on the quality of traffic flow; be easy to measure and estimate; and correlate to traffic and roadway conditions in a meaningful way, among others. Given the difficulties to measure *PTSF* in the field, some authors developed alternative performance measures, such as follower density (van As 2006); percent impeded (Al-Kaisy and Durbin 2008); freedom of flow (Polus and Cohen 2009); or number of followers as proportion to capacity (Penmetsa et al., 2015). Speed limit is usually included in the analysis procedure to determine the previous performance measures, but is not considered as a performance measure itself because it remains constant with all traffic flows. Field studies indicated that follower density was the most promising performance measure, as it presented the highest correlation to traffic variables (Al-Kaisy and Karjala 2008; Oregon Department of Transportation 2010; Hashim and Abdel-Wahed 2011; Moreno et al. 2014).

Even though follower density is indicated as the most promising performance measure for two-lane highways, it has not been verified its correlation to roadway conditions. Moreover, given the relationship between operating speed and horizontal alignment, highway bendiness could potentially affect speeds and platooning.

Therefore, there is a need to evaluate in actual (in operation) highways the influence of horizontal and vertical alignment on traffic operations. The study should not be limited to the HCM performance measures (*ATS*, *PTSF*), but also include alternative performance measures. Moreover, traffic demand should consider unbalanced flows and percentages of trucks. The results could provide guidance on which performance measure is correlated to traffic and roadway conditions in a more meaningful way.