



## POSSIBILITY TO APPLY CAPACITY ANALYSIS OF TWO-LANE ROADS WITH PASSING LANE IN HCM 7<sup>TH</sup> EDITION IN SOUTHEAST EUROPE COUNTRIES

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### Abstract

In the analysis of two-lane roads, the passing lane plays a very important role not only in improving the level of service but also in improving safety. This is best shown by a new design of self-explaining roads, or a European implementation of 2+1 roads. The positive effect of improving two-lane roads by passing lanes essentially extends beyond their end. The HCM methodology is mostly used in the region when analysing two-lane roads. The approach has been significantly changed in the seventh edition of the HCM and it cannot be applied in its original form. This article will show how this methodology can be applied under the prevailing road and traffic conditions outside the U.S. environment, especially in countries that do not have a developed capacity analysis methodology. This new methodology again uses density/follower density to determine LOS. The differences in the results of the final improvement will be shown in a particular example by comparison with previous methodologies of HCM and HBS 2015. On the basis of the results obtained, the conclusion will be made on the performance measures that can be applied in our prevailing conditions.

*Keywords: two-lane road, passing lane, HCM 7<sup>th</sup> Edition, improvement, application*

### 1 Introduction

On a two-lane road, passing lanes play a very important role not only in improving the level of service but also in improving safety. This is best shown by a new design of self-explaining roads, or a European approach to 2+1 roads. Regarding the improvement of two-lane roads by passing lanes, the positive effect essentially extends beyond their end.

Safety improvement of passing lanes is not the topic of this article. Many studies can be found in the literature with different results. European countries (Germany, Sweden...) consider 2+1 roads as a good and safe intermediate solution between freeways and two-lane roads. This could be a general response to the aspect of safety.

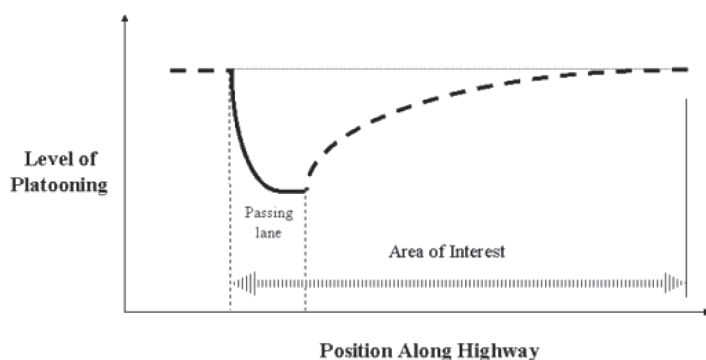
The HCM methodology is mostly used in the region for two-lane road analysis. It is important to emphasize the fact that HBS 2015 can be applied for new roads, while it cannot be applied for existing two-lane roads, primarily because the prevailing road conditions are significantly different and so is the passenger car speed. The difficulty in applying previous versions of HCM was the parameter percent no-passing zone (PNPZ) because the best two-lane roads have a PNPZ equal to or greater than 70% [1]. In the HCM 7<sup>th</sup> Edition, this difficulty is solved. The new version of HCM introduces percent followers (PF) as a performance measure instead of the earlier PTSF. Percent followers is the percentage of vehicles passing a given point on the roadway that are considered to be in a follower state.

Being in a follower state is used as a surrogate to indicate a driver's perception that they are being delayed by a slower driver. A critical headway threshold value of 2.5 s is used to determine whether a vehicle is in a follower state [2]. Generally, in terms of application in our prevailing conditions, the new approach is more realistic. The problem occurs with facility analysis with passing lane segments, which is the topic of this article.

The second and third chapters describe how passing lanes improve the operating conditions of two-lane roads by analysing the results of research in American (U.S.) and European (Germany) prevailing conditions. A simple example of the application of several passing lanes of different lengths within one section will show the observed deficiency in the application of HCM when it comes to facility analysis. With the awareness that road authorities in BiH and the region are not interested in the development of our methodologies, this article offers guidelines on how to make the HCM methodology applicable by conducting a relatively simple research. This is especially important as the HBS methodology is not applicable when it comes to improving existing roads by introducing passing lanes.

## 2 Operational improvement of a passing lane on a two-lane road

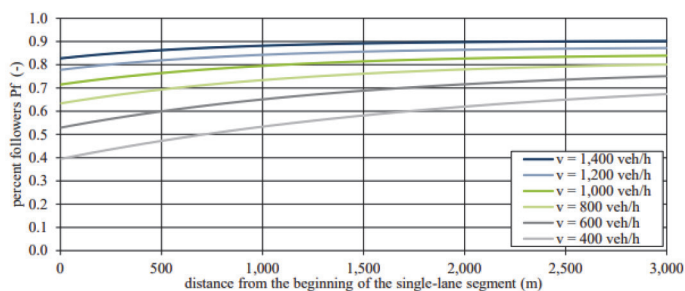
It is a well-known and generally accepted fact that the passing lane has a significant impact on platooning, while traffic speed is slightly affected by the presence of the passing lane. American literature describes the situation with the passing lane so that slower vehicles move to the right lane and that the left lane is for other vehicles [2, 3]. The European understanding is that the passing lane has the function of overtaking, unlike the climbing lane. In addition to this, there is a significant difference in the optimal lengths of the passing lanes. A clear distinction between Super 2 and 2+1 roads is described in detail in chapter F.5.1 Literature Review [3] and will not be repeated in this article. Figure 1 shows a theoretical graph of platooning level within and downstream of a passing lane on a two-lane highway.



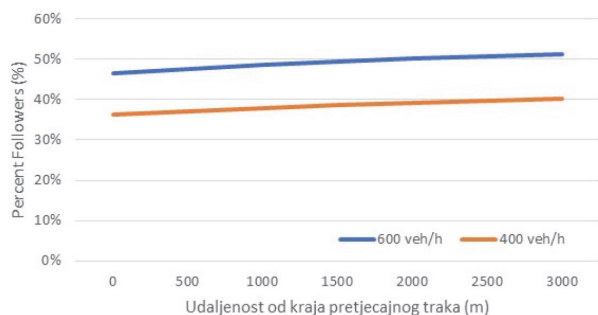
**Figure 1** Theoretical graph showing platooning level within and downstream of a typical passing lane on a two-lane highway [4]

Looking at the change of platooning level within the passing lane, it is evident that the maximum effect is reached before the end. The logical question is whether it is necessary to continue with the passing lane after the maximum effect has been reached when there is already a positive impact even after its end, i.e. whether two shorter passing lanes have a greater positive influence than one longer one. Most of the available studies show that the measurements are usually made before and after/downstream of the passing lane. This points to the need to measure parameters on multiple cross sections within the passing lane.

The only research in Germany found by the authors related to the change of percent followers downstream of the passing lane is shown in Figure 2. Empirical data from three-lane rural highways were analysed regarding the bunching of vehicles on the single-lane segment. For the classification of followers, a threshold headway of 3 s was defined. The functional relationship between the distance from the beginning of the single-lane segment and the proportion of bunched vehicles can best be described with a negative exponential function [5]. Results for directional flow rate 400 to 800 veh/h can be interesting for analysis of two-lane roads with passing lanes. For 800 veh/h the diagram shows that percent followers take on a constant value after 3 km. With the aim of comparing the results, the following was done. Facility analysis was conducted for six passing constrained segments  $L = 500$  m after passing lane segment (HCS 2023) to determine the change in PF. The same results could be obtained using the equation for percent improvement in PF (equation 15-36 in [2]). The results for directional flow rates of 400 and 600 veh/h are shown in Figure 3. The difference between the change in PF is evident in Figures 2 and 3. PF increases significantly more and faster in the case of German results.



**Figure 2** Percent followers on one-lane directional segments of three-lane rural highways depending on the distance from the beginning of the single-lane segment for different traffic [5]



**Figure 3** Percent followers downstream up to 3 km of passing lane calculated using HCM 7<sup>th</sup> Edition

### 3 Two-lane facility analysis with passing lanes

The limitation of the application that is stated in HCM 7<sup>th</sup> Edition is multiple passing lanes with overlapping effective lengths. The use of simulations is recommended. It has already been stated that HBS 2015 is inapplicable for the analysis of existing roads. Countries in the region do not have their own methodologies, so HCM is stated as a recommendation for application. In the absence of existing research related to the passing lane, the applicability of HCM will be demonstrated through some examples, on the condition that it is necessary to finally conduct field research in combination with simulation to confirm the values of some parameters.

A 15 km long facility was taken with a total length of passing lanes of 3 km. Horizontal class 2 and vertical class 1 are assumed for all segments. This is because the HBS 2015 methodology could also be applied (Design Class EKL 2, the requirement is min 20% passing lane segments).

The idea is to determine the facility improvement for 1 passing lane with a length of 3.0 km and 2 passing lanes with a length of 1.5 km. Given that HCM 7<sup>th</sup> Edition does not allow multiple passing lanes with overlapping effective lengths, the concept of the earlier HCM 2016 methodology will be applied in the case when the facility is shorter than the effective length. This concept is explained in Figure 4 and equations (1), (2).

$$PF_{pl} = \frac{PF_d \left[ L_u + f_{pl,PF} \cdot L_{pl} + f_{pl,PF} \cdot L'_{de} + \frac{1 - f_{pl,PF}}{2} \cdot \frac{L'_{de}{}^2}{L_{de,PF}} \right]}{L_t} \quad (1)$$

$$S_{pl} = \frac{S_d \cdot L_t}{L_u + L_d + \frac{L_{pl}}{f_{pl,S}} + \frac{2L_{de,S}}{1 + f_{pl,S}}} \quad (2)$$

Where  $PF_d$  and  $S_d$  are percent followers and speed of facility without passing lane determined as weighted average value of all segments calculated with HCM 7<sup>th</sup> Edition. Facility follower density is:

$$FD_{pl} = \frac{PF_{pl} \cdot v_d}{100 \cdot S_{pl}} \quad (3)$$

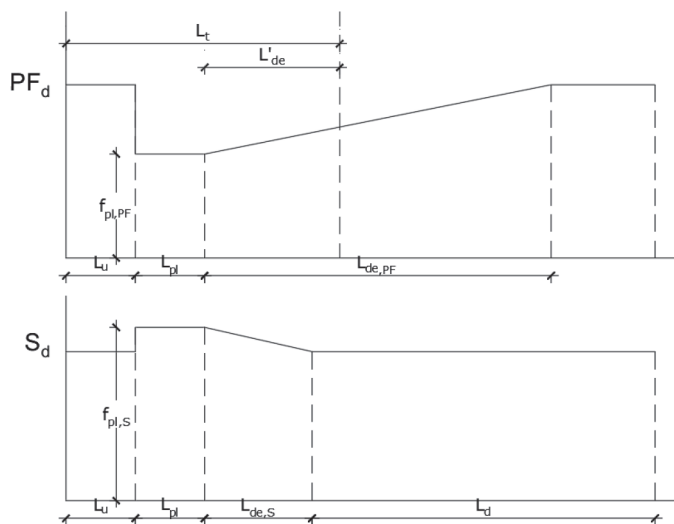
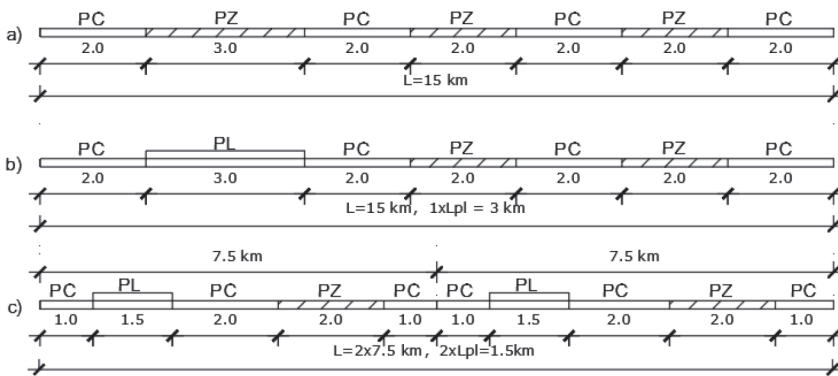


Figure 4 The concept of HCM 2016 for improvement of a passing lane on a two-lane road

Figure 5 shows the analysed scenarios. Facility is divided into segments in accordance with HCM 7<sup>th</sup> Edition [2]: PC - passing constrained segment, PZ – passing zone segment and PL – passing lane segment. This is a great progress to apply in our prevailing conditions. Other input data: directional/opposing flow rates are 200/130, 400/260, 600/400 and 800/530 veh/h (directional split approximately 60/40); 10 %HV; PHF = 1.0.



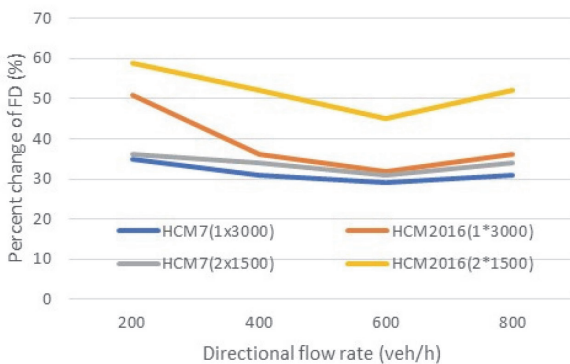
**Figure 5** Facility division into segments according to HCM 7<sup>th</sup> Edition

There are five scenarios:

- Facility  $L = 15$  km without passing lane using HCM 7<sup>th</sup> Edition - a)
- Facility  $L = 15$  km with passing lane  $L_{pl} = 3$  km using HCM 7<sup>th</sup> Edition - b)
- Facility  $L = 15$  km with passing lane  $L_{pl} = 3$  km using (i) + equations (1), (2) and (3)
- Facility divided into 2 subfacilities  $L = 7.5$  km with  $L_{pl} = 1.5$  km using HCM 7<sup>th</sup> Edition - c)
- Facility divided into 2 subfacilities  $L = 7.5$  km with  $L_{pl} = 1.5$  km using (iv) + equations (1), (2) and (3)

Follower density (FD) of facility is calculated for each scenario. The results of improvement expressed as percentage change of FD are shown in Figure 6. The following can be stated:

- There is no significant difference between cases (ii) and (iv), which corresponds to the previously stated limitation of the application of multiple passing lanes when the facility is divided into two subfacilities.
- Cases (iii) and (v) show the expected result that two lanes of 1.5 km give a significantly greater improvement than one lane of 3.0 km.
- For directional flow rates less than 400 veh/h, there is a significant difference between cases (ii) and (iii) ( $1 \times L_{pl} = 3$  km), while for values greater than 400 veh/h the differences are almost insignificant.



**Figure 6** Percent change of follower density for defined scenarios

As there is no relevant research in the Southeast Europe region, analysis will be carried out in the same example using HBS 2015 (Design Class EKL 2).

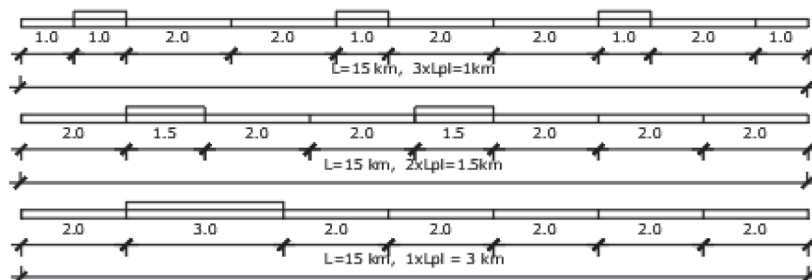


Figure 7 Facility division into segments according to HBS 2015

Due to the simplicity of HBS methodology, three cases of improvement, shown in Figure 7, were made ( $1 \times L_{pl} = 3.0 \text{ km}$ ,  $2 \times L_{pl} = 1.5 \text{ km}$ ,  $3 \times L_{pl} = 1.0 \text{ km}$ ). The facility is divided into segments in such a way as to include a 2 km positive impact of the passing lane on the speed as required by this methodology. The level of service is determined based on the density  $D$  [8]. The results of improvement expressed as percentage change of  $D$  are shown in Figure 8. Although the PF on which passing lanes have the greatest influence is not used, the results show an essential difference in the American and European approaches to the passing lanes. Thus, the assumption that a larger number of shorter passing lanes has a significantly greater positive impact compared to a smaller number of longer passing lanes is confirmed by this methodology.

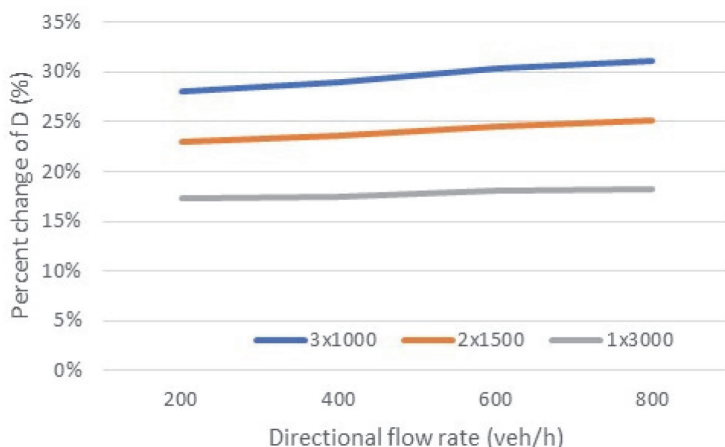


Figure 8 Percent change of density by HBS 2015

## 4 Conclusion

A two-lane road analysis of the operational performance in the new version of HCM has made a significant change. From the point of view of its application in our region, the most important progress is in defining the segments and passing zone lengths compared to the earlier percent no-passing zone. Previous research in the region also shows that PF is one of the performance measures that should be used in analyses.

Investigation of passing lanes in the region practically does not exist because the emphasis is on the construction of multilane highways. The article shows how the American approach to the impact of passing lanes on improvement differs from the European one. For this reason, a method that shows a more realistic description of the passing lane operational improvement is presented primarily to indicate the direction of future research. Measurements should be carried out in several sections within the passing lane as well as a series of usual downstream ones. The estimation of certain parameters (in this case  $f_{pt}$  and  $L_{de}$  with linear or other shape) would give the possibility of applying HCM in our prevailing conditions until the development of our own methodology.

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