Two-Lane Highway Analysis in HCM2000

Draft white paper by

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Introduction

The fourth edition of *Highway Capacity Manual* (HCM2000) was published in year 2000. Chapter 20 of the manual presents an analysis methodology for two-lane highways. Two classes of highways were defined. On Class I highways the level of service (LOS) is defined in terms of both percent-time-spent-following (PTSF) and average travel speed (ATS). On Class II highways LOS is defined in terms of PTSF only. A highway segment can be analyzed either as one two-way segment or two directional segments.

The methodology raised two major concerns:

1. The PTSF estimates obtained by the directional method are higher than the estimates given by the two-way procedure.
2. The procedures cannot be used to analyze two-lane highways in developed areas.

Suggestions to address these issues were presented in the Final Report of NCHRP Project 20-7 (160) in September 2003. For the directional PTSF estimation new coefficients and adjustment factors were proposed. Adaptations of existing methodologies were suggested for the analysis of developed areas. The Highway Capacity and Quality of Service committee decided to explicitly inform HCM2000 users that the operational analysis methodologies in Chapter 20 are not intended to address capacity and traffic flow on two-lane highways in developed areas. More research is needed to develop a methodology for two-lane highways in developed areas. The directional PTSF estimation procedure was modified following the NCHRP 20-7 report.

The purpose of this paper is to evaluate the possible need to further enhancements of the directional procedure as well as the methodology as a whole. Two specific issues are discussed:

1. Is the current directional procedure (as amended) appropriate, or should it be modified?
2. Is there a need for a larger revision of the two-lane methodology in a long run?

This paper is not a research report, but a collection of expert opinions for the development of Chapter 20 in HCM. Each discussion item is concluded by a summary. The most important conclusions have been printed in **bold face**.

In Appendix A Christo van As describes some results of South African research.

Evaluation of the directional PTSF methodology

In the analysis of PTSF the mathematical models for directional and two-way analysis are different, and the methods produce very different results. As the figure below indicates, under base conditions the directional methods gives significantly higher PTSF estimates.

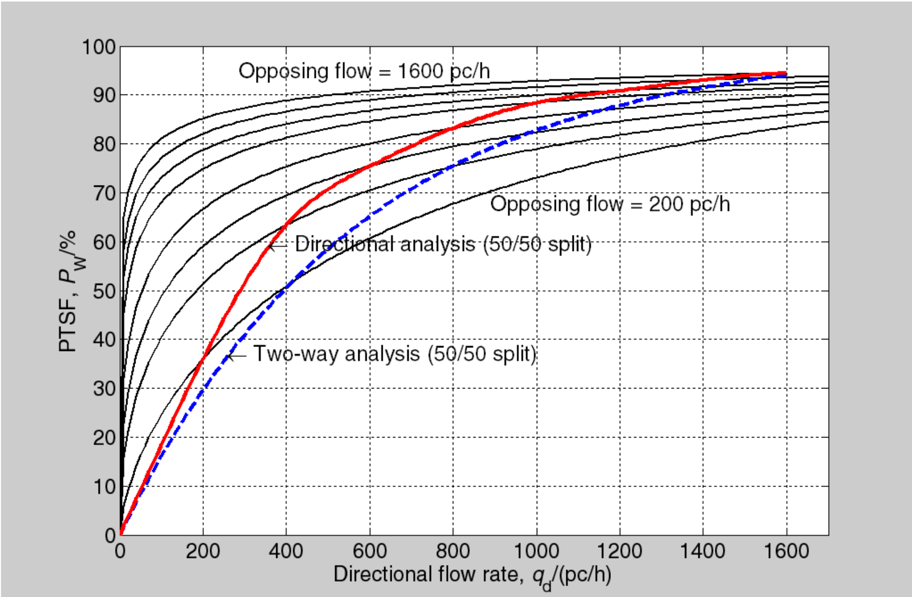

Figure 1 – *Base PTSF in HCM2000 according to directional and two-way methods.*

The shape of the directional base PTSF function is such that the effect of directional split is insignificant and even counterintuitive. Because the additive adjustment f_{np} does not depend on the flow rate in the subject direction, it is possible to have PTSF estimates greater than 100%, even as high as 130%.

The new method presented in the NCHRP 20-7 report revised the coefficients of the directional model and the adjustment factors. The revised adjustment for percent no-passing zones considers (indirectly) flow rate in subject direction. The PTSF > 100% problem appears to be eliminated.

The base PTSF estimates are, however, lower than the estimates obtained by the two-way analysis (see figure below). The adjustment factors are defined so that the differences between the two methods are minimized. Thus the BPTSF values are adjusted even under base conditions.

According to the calculations done at the University of Florida the new directional PTSF estimates are very similar to the two-way results. However, there are some significant differences for the 80/20 directional split condition and volumes of 1000 or higher. These differences are all related to the f_{np} value from the new Exhibit 20-20 for 100% no-passing zones. The difference between the results can be nearly ten per cent.

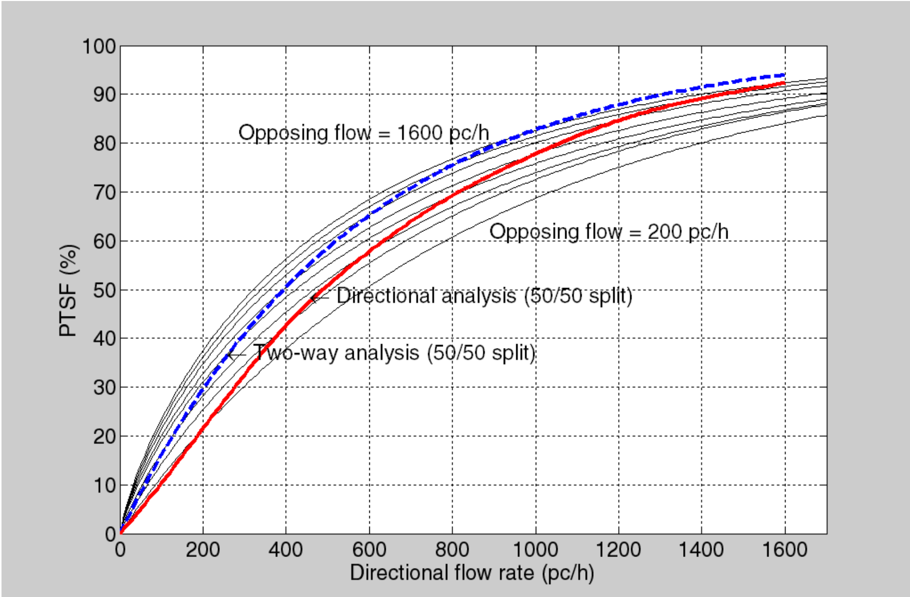

Figure 2 – *Base PTSF in HCM2000 according to the two-way method and the directional method in the NCHRP 20-7 report.*

Summary

The directional PTSF estimation method presented in the NCHRP 20-7 report is in better agreement with the two-way methodology than the original directional method in HCM2000. The method still has some problems:

- In a few cases the differences between the methods are too high.
- Equation (20-17) is assumed to give the base PTSF, but it does not. Adjustment factors are used even under base conditions.
- The directional method was amended so that it gives similar results as the two-way method. The method should be calibrated and validated with field measurements.

Recommendations

If directional traffic volumes are v_1 and v_2, the two-way PTSF is the weighted average of the directional percentages of time spent following:

$$\text{PTSF} = \frac{v_1 \text{PTSF}_1 + v_2 \text{PTSF}_2}{v_1 + v_2}.$$

Accordingly, the two-way method is redundant.

Both theoretical and empirical studies have indicated that for passing opportunities the opposing flow rate is a more significant factor than the directional split. Thus, from a theoretical point of view a directional analysis is conceptually simpler and has a more solid foundation than two-way analysis.

The analysis of other uninterrupted facilities is based on directional measures. Directional analysis of two-lane highways would be consistent with the methodologies for multilane highway and freeway segments.

It is suggested that

1. **In the next edition of HCM only directional methods should be presented**.
2. The directional method should have **better field validation**.

Other issues

1. The use of a service measure that cannot be reliably measured in the field—PTSF is difficult to measure, and it is difficult for practitioners to determine exactly where it should be measured along the length of a highway section. It should be possible (without an unreasonably difficult effort) to validate level of service results through field observation.
2. The procedure not being applicable to 2-lane highways in urban areas. We should have a procedure that can be applied to all types of 2-lane highway facilities.
3. Service measures that are quite likely not consistent with driver perceptions of what measures are important to them in evaluating service quality.
4. Complete lack of guidance for the selection or determination of a base free-flow speed.
5. Conflicting guidance on climbing lanes—the chapter indicates that adding a passing lane to a segment that is operating at LOS F will not improve LOS; thus there is no need to perform a passing lane analysis. However, if a passing lane is added on an upgrade segment (i.e., climbing lane), which is followed by a level segment, it is conceivable that the LOS could be improved.
6. Analysis volume iteration process is awkward and is likely commonly misunderstood and therefore miscalculated (although this might not be a problem for people that just use HCS, although they still may not understand how HCS arrived at its analysis volume).
7. Related to the above, having to calculate two different volumes—one for ATS and one for PTSF (if doing a Class I analysis), again likely can be confusing to users.

Two-lane highways in rural developed areas

However, if we are fortunate enough to get field data in rural developed areas and specific grades then it would be an excellent idea to consider modifying the existing procedures or augmenting them with additional ones. I specifically mention these two areas because our current procedures are based on very little data. I do remember hearing of some work done by Doug Harwood and others, collecting data on specific grades. Have anyone heard their results or seen any products of their research?

We do need to more closely study the effects of intersections on two-lane highway operations. At this time it seems that there is a large gap in the existing HCM procedures, with no procedure adequately addressing the situation of two-lane highways that exist in rural developed areas. Yes, report NCHRP 20-7 did propose some shortterm approaches to this problem, but they have not been validated with field or simulation data.

I am unsure as to the time that we have until the next HCM will come out. If we have time for another round of NCHRP proposals and projects then we may be able to get this additional data, with accompanying procedure modifications and additions. In this case, I would like to see some changes made to chapter 20 that would improve our ability to analyze rural developed two-lane highway sections and specific grades.

Average travel speed

The estimation methods for average travel speed have not received as much attention as the methods to estimate PTSF. There are, however, two concerns, which call for more field studies.

1. Directional distribution has no effect on ATS.
2. The slope of the speed-flow curves does not depend on the free-flow speed (FFS).

Figure 3 displays speed-flow curves when traffic is in one direction only and with a 50/50 split. HCM2000 curves are compared with Finnish curves, which do not have as steep slope. The optimum speed is much lower in the 50/50 case. For 50/50 split the optimum speed is 40 km/h lower than the FFS. For FFS 70 km/h this indicates that capacity is obtained at speed 30 km/h, which indicates optimum density as high as 53 veh/lane km. This result requires better field validation. Figure 4 displays a comparison of HCM2000 flow-density curves with Finnish curves.

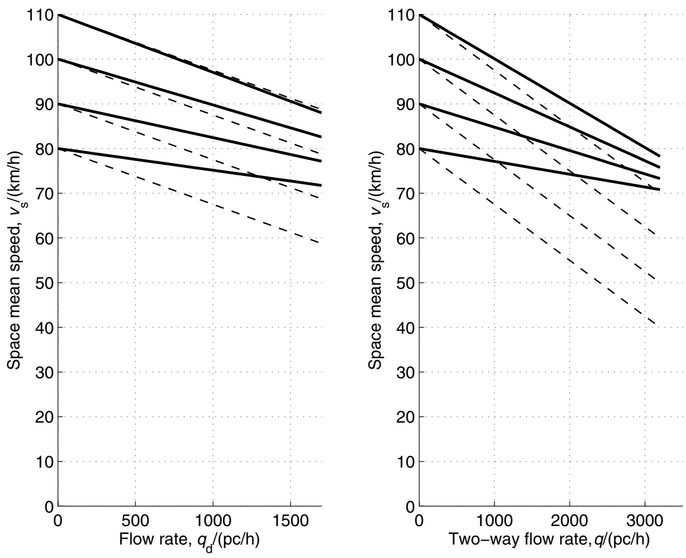

Figure 3 – *Speed-flow curves from Finland (solid) and HCM2000 (dashed) with traffic in one direction only (left) and 50/50 directional split.*

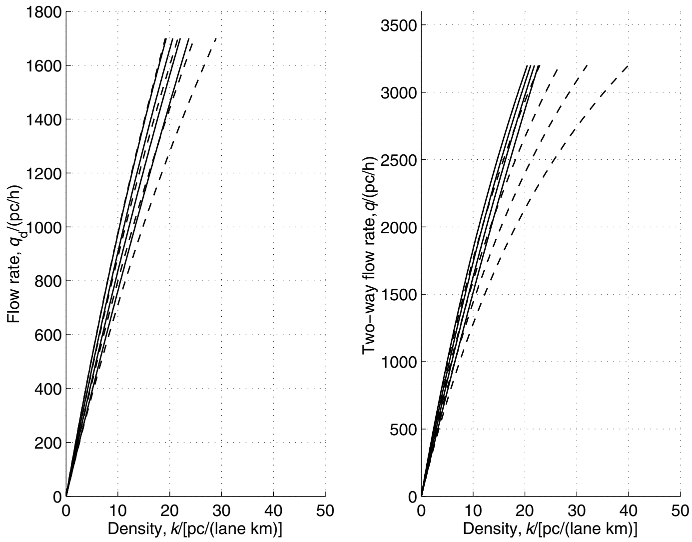

Figure 4 – *Flow-density curves from Finland (solid) and HCM2000 (dashed) with traffic in one direction only (left) and 50/50 directional split.*

The two-way ATS can be calculated as the weighted harmonic mean of directional average travel speeds:

$$\text{ATS} = \frac{v_1 + v_2}{\dfrac{v_1}{\text{ATS}_1} + \dfrac{v_2}{\text{ATS}_2}}.$$

Summary

This discussion indicates two conclusions:

1. **In the next edition of HCM only directional methods should be presented**.
2. In further research the shape of the speed-flow curve, the effect of opposing flow on ATS, and the shape of the FFS distribution (used in simulation studies) under different conditions should be verified.

Capacity

According to HCM2000 the capacity of one direction on a two-lane highway is 1700 pc/h. Two-way capacity is 3200 pc/h. This indicates that the capacity of the observed direction is reduced when the opposing flow rate exceeds 1500 pc/h. Theoretical studies have indicated that the influence of the opposing flow does not change significantly when the opposing flow rate has increased above 400–450 veh/h. Earlier studies do not give support to the assumption that the opposing flow has an effect on capacity only after the opposing flow rate has exceeded 1500 pc/h.

Finnish studies have indicated that there is a capacity drop under congested conditions. As traffic density exceeds optimum density (approximately 20–25 veh/km) the maximum flow rate is approximately 300–400 pc/h lower than capacity (see Fig. 5). This information is valuable in those rare cases when a two-lane highway is congested; e.g., during weekend peaks, work zone arrangements or incidents.

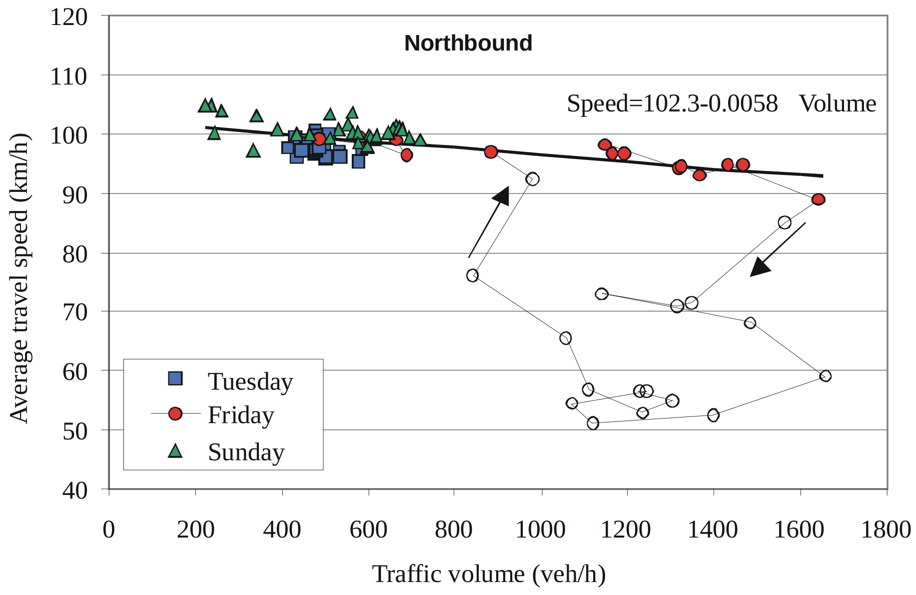

Figure 5 – Speed-flow values on Finnish arterial highway 4 (grade separated intersections and passing lanes) to the north of Lahti.

Summary

1. The effect of opposing flow on capacity deserves further study.
2. The capacity under congested conditions should be studied.

Performance measures

Ideally performance measures should

1. Reflect the perception of road users on the quality of traffic flow.
2. Be easy to measure and estimate.
3. Correlate to traffic and roadway conditions in a meaningful way.
4. Be compatible with the performance measures of other facilities.
5. Describe both uncongested and congested conditions.
6. Be useful in analyses concerning traffic safety, transport economics, and environmental impacts.

PTSF satisfies conditions 1 (maybe) and 3. However, it is difficult to measure, it is not compatible with the service measures of other facilities, it does not describe the extent of congestion and it is not very useful in other analyses.

The major problem with PTSF as a service measure is that it is difficult to measure directly. If the proportion of headways less than three seconds at a representative location can be used as a surrogate measure, could it also be used as the service measure? That would make the measurement of the service measure and the calibration of the model much easier. A measure based on a local platoon percentage is, however, a point measure.

Measures, similar to PTSF, are for example

- Platoon percentage (percentage of short headways)
- Platoon rate (measured percentage of short headways divided by the percentage of short headways in random flow)
- Follower density (see Appendix A).

ATS satisfies all conditions. Item 1 may, however, not be relevant on Class II highways. Measurement (Item 2) is easy, if point measurements are sufficient, otherwise register plate surveys are required. If the speed-flow curves of HCM2000 are correct, ATS has a good correlation with traffic conditions. (As Figure 5 demonstrates, this may not always be the case.)

The procedure should be such that it can be integrated with signalized and unsignalized intersection analyses to allow for a facility-based analysis (i.e., long stretch to two-lane highway with a number of segments with varying characteristics and the occasional intersection). For a corridor or area wide analysis it is necessary to integrate the two-way analysis also with the analysis of freeways and multi-lane highways.

There may be little justification for great complexity in a deterministic two-lane procedure, because the extent and quality of field data is so limited. This is likely true for both model development and model implementation. Given limited field data, the two-lane procedures should remain simple. Model improvements can be made commensurate with the ability of model developers and users to gain access to better field data. At this point in time, both parties only can access occasional traffic counts, very infrequent intersection counts, and rough heavy vehicle percentages.

Summary

The **service measure(s) of two-lane highways should be reconsidered** in the light of the criteria presented above; especially user perception, measurability and compatibility with other facilities.

Simulation

Before a completely new procedure can be developed that addresses the issues above, we likely need a **better two-lane highway simulation tool**, as it seems that TWOPAS and TRARR are limited in their potential to achieve some of these objectives in a new procedure. Additionally, whatever simulation tool is used, it needs to be **validated by a substantial amount of field data**, under a variety of conditions.

Related to this, careful thought needs to be given to the chosen performance measure(s) used to measure level of service such that this field data validation is feasible.

Only a limited degree of detail can be accomplished with a deterministic procedure. The **users should be informed as to when they should refer to micro-simulation** such as TWOPAS or TRARR.

Ease of use

The users need more guidance in the procedures concerning the base FFS, climbing lanes, which procedure to use, etc.

It would be an advantage, if the volume iteration process could be avoided. A separate volume calculation for each service measure may be confusing to some users. Confusion may also arise as to which adjustment factors to use in the estimation of capacity. A change in the structure of the model and/or clear advice to users could make the application of Chapter 20 easier.

Appendix A
An Overview of Research in South Africa

by Christo van As

Introduction

Various issues were identified in South Africa with the HCM (2000) methodology for the capacity analysis of two-lane highways. Some of these issues relate to differences in the use of two-lane highways in South Africa and the United States, but certain issues are somewhat fundamental in nature.

Some of the identified issues are relatively minor and can be addressed by minor adjustments to the methodology. Other issues, however, have major implications and require extensive research and development. These major issues were the motivation for the development of an alternative analysis procedure in South Africa (using macroscopic simulation techniques).

Limitations of the HCM methodology

The HCM states that the methodology for two-lane highways cannot be applied under the following circumstances:

- **Complex situations**. The HCM procedure cannot be used on two-lane highways where the interactions among several passing or climbing lanes are complex. The HCM recommends the use of simulation models under such circumstances. *This limitation is considered a serious issue in South Africa since passing and climbing lanes could be effective measures for improving the level of service on a highway*. This was one of the main motivations for the development of the macroscopic simulation model in the country.
- **Signalised intersections**. The methodology cannot be used for the analysis of highways with signalised intersections, but other chapters of the HCM can be used for the analysis of the intersections. This limitation is *not* considered a major issue in South Africa since traffic signals are not often found on rural highways. In urban areas, the two-lane highway is seldom the critical element, since flow would be restricted by the capacity of the signalised intersections. It would, however, be useful if the procedure could be extended to include the impact of intersection control on traffic operations (the macroscopic simulation model takes such impact into account but further development is required to improve the model).
- A further limitation of the HCM methodology is that it does not provide for the use of **wide shoulders** for passing purposes. In South Africa, this practice is allowed during daytime conditions and surveys have indicated that the practice significantly improves the level of service on a highway. This limitation of the HCM methodology is therefore considered a ***serious issue***.

Currently, there is a considerable debate in the country on how highways with a 13.4m paved width should be marked (many rural highways in the country were constructed to this width). The one alternative is to provide one lane per direction with wide shoulders. The second alternative is to reduce the shoulder width and to provide passing lanes at 2-kilometre intervals. An evaluation of the two alternatives has shown that, in level terrain, the levels of service are approximately the same on the two alternatives. In rolling and mountainous terrain, however, the second alternative does improve the level of service slightly, but only if the passing sections are located on uphill sections. It was not possible to undertake this type of evaluation by means of the HCM methodology and the macroscopic model was used for this purpose.

HCM Performance measures for two-lane highways

The HCM uses two performance measures to describe service quality for two-lane highways**: percent time spent following (PTSF)** and **average speed**. A number of issues have been identified with the use of these measures in South Africa.

- **Field measurements.** One issue that is of serious concern in South Africa is the difficulty of undertaking field measurements of PTSF. Field measurements not only provide an alternative method of establishing the level of service on a facility, but are also required to validate the applicability of the HCM methodology to conditions in other countries. The HCM does allow the use of percentage of vehicles travelling with headways of less than 3 seconds as a surrogate measure, but the question is whether this measure should not in the first place be adopted as the primary performance measure.
- **Warrant measure**. A second, more important issue with PTSF (or its surrogate measure) is that experience in South Africa with the use of the measure has indicated that it is not an adequate warrant for capacity upgrading. This problem was identified on two-lane highways with limited passing opportunities and which carry a high percentage of heavy vehicles, but on which traffic volumes are low. The PTSF may be high on such highways, indicating a poor level of service for individual users, but the traffic volumes are not sufficient to warrant capacity improvements.

  To address the above problem, consideration should be given to alternative performance aimed at addressing the level of service experienced by the total traffic stream rather than individual users. One such alternative is **"follower density"**, which is defined as the number of followers (vehicles in platoon) per lane-kilometre. This measure has several advantages. It accounts for the volume of traffic and therefore provides a better indication of when capacity upgrading is warranted. A further advantage is that it also accounts for the speed of traffic and it is therefore not necessary to use speed as a secondary measure. Another advantage is that some degree of correspondence is achieved with the analysis of freeways and multilane highways where density is used as the performance measure.

- **Average and worst performance measures**. The procedures provided by the HCM are mostly aimed at determining an average rather than the worst level of service for a facility. This approach is followed for most facilities, including two-lane highways. The HCM, however, is not always consistent in this approach. At signalised intersections, for example, the LOS is determined for the intersection as a whole but not at unsignalised intersections.

The approach of establishing an average LOS could result in a situation where operations on a facility can be defined as "acceptable" while the level of service may be unacceptable on certain elements of the facility. On a two-lane highway, for example, the LOS may be acceptable on average, but there could be sections (e.g. long steep upgrades with no passing opportunities) on which operations may not be acceptable. A worst-case analysis would allow for the identification of such sections and the implementation of local improvements such as passing or climbing lanes.

Two-way and directional segments

The HCM provides two procedures for the analysis of two-lane highways, namely for two-way and directional segments. The two-way segment analysis procedure is used to determine the average PTSF in both directions of travel, while the directional segment procedure is used to determine PTSF per direction of travel (which is then combined to determine an average for the two directions). Little guidance is provided on which procedure is most appropriate under which circumstances. It can probably be assumed that the procedure for directional segments would be more appropriate in circumstances where conditions in the two directions of travel differ significantly.

The problem with the two procedures is that they can produce results that differ somewhat from each other - something that is to be expected since no model is perfect. It does, however, result in questions regarding the accuracy of the procedures. The need for providing two procedures should therefore be questioned. The advantage of the directional procedure is that it can be used to analyse each direction separately but that the results can also be combined to provide an average for the two directions of travel. It is also likely that the directional procedure would be more accurate than the two-way procedure (or at least be improved to provide more accurate results). ***Consideration should therefore be given to only retain the procedure for directional segments.***

Average speed estimation

The following are a number of issues that have been identified with the procedures for estimating average speeds:

- **Free-flow speed estimation**. According to the HCM, no guidance can be given on the estimation of the "base" free-flow speed due to the broad range of speed conditions. The HCM does provide for adjustment factors for lane and shoulder widths and also access-point density. The approach followed by the HCM, however, creates a major problem since it requires the development of local free-flow speed models. Consideration should be given to expand the procedure to account for additional factors such as speed limits, curvature, gradients and percentage heavy vehicles. The South African macroscopic simulation model provides for these factors.

- **Free-flow speed and percentage heavy vehicles**. A problem in South Africa is that the free-flow speeds of light and heavy vehicles often differ significantly (probably as in the United States). This problem can be addressed if Equation 20-2 for establishing free-flow speed (FFS) is amended to include a factor that provides for percentage heavy vehicles. Consideration can be given to a formula such as the following:

  $FFS = (1-P_T).BFFS_{LV} + P_T.BFFS_{HV} + \ldots$

  in which P_T is the proportion of trucks, $BFFS_{LV}$ the base free-flow speed of light vehicles and $BFFS_{HV}$ the base free-flow speed of heavy vehicles.

  An adjustment is also required in the procedure for the field measurement of free-flow speeds. A problem in South Africa is that the percentage heavy vehicles can be significantly higher under periods of low flow conditions than during the typical analysis hour (which often occur during holidays when heavy vehicle volumes are low and light vehicle volumes high). The procedure for measuring free-flow speeds should therefore differentiate between light and heavy vehicles.

- **Free-flow and average travel speed**. Equations 20-5 and 20-15 for the estimation of average travel speed is based on a linear relationship that adjusts free-flow speed for traffic volume by an amount which is independent of the free-flow speed. However, when free-flow speeds are low (e.g. 70 km/h), it is unlikely that volume would have the same effect on speed as when free-flow speeds are high (e.g. 110 km/h). A possible method to address this issue is to multiply the free-flow speed with a factor that accounts for traffic flow (rather than to add the adjustment for traffic flow). Consideration can be given to use a formula such as the following:

  ATS = FFS x Factors that accounts for traffic flow, percentage no-passing, etc.

  in which ATS is the average speed and FFS the free-flow speed.

- **Average travel speed and traffic flow**. Equations 20-5 and 10.15 relates average travel speed with traffic flow without taking the degree of platooning directly into account. Traffic volumes may be high, but if few vehicles are following, then it is unlikely that speeds would be significantly affected. Consideration should therefore be given to relate average travel speed to PTSF (preferably percentage followers) rather than traffic volume. The following is a possible formula that can be considered for such purposes:

$$ATS = FFS \cdot (1 + \frac{PF}{100 - PF} \cdot \frac{1}{f_{HV}})^{-a}$$

in which "a" is a parameter of the model, f_{HV} a heavy-vehicle adjustment factor and PF the percentage followers. The advantage of relating the average speed to percentage followers is that it is probably not necessary to take other factors, such as percentage no-passing zones, into account since these would be already accounted for by percentage followers.

PTSF Estimation

The following are a number of issues that have been identified with the estimation of percent time spent following:

- **Different results**. The one issue discussed previously in this document is that the two procedures produce different estimates for PTSF. Consideration should be given to remove the two-way segment procedure and to retain only the procedure for directional segments.

- **BPTSF**. Equation 20-17 for estimating BPTSF on directional segments appears to provide reasonable logical results. The equation should, however, be tested for extreme values of traffic flows (both low and high) and directional distributions (0/100%) to ensure that it is accurate over the full range of conditions. Where possible, field observations should be used for the calibration and validation of the equation rather than computer simulation.

- **PTSF**. Equation 20-16 for estimating PTSF is not always logical since it can produce estimates greater than 100% (particularly when the traffic flows are unbalanced). This is probably because percentages are added together - something which can result in a percentage greater than 100. A possible approach that can be investigated is to adjust parameters "a" and "b" of Equation 20-17 for percentage of no-passing zones rather than to add an adjustment to BPTSF.

- **Shoulder width.** The HCM procedure does not provide for adjustment factors that account for the use of wide paved shoulders for passing purposes. Such adjustment can be made by relating the parameters "a" and "b" used in Equation 20-17 to paved shoulder width (or preferably shoulder plus lane width).

Alternative modelling approach

Perhaps the most serious limitation of the HCM procedure is that it cannot be used for the analysis of complex circumstances. This is a major issue when passing and climbing lanes are being considered as measures of improving the level of service. Consideration should therefore be given to the development of a procedure that can be used for such analysis.

The above issue was the main motivation for the development of the macroscopic simulation model in South Africa. This model can be used to analyse relatively complex combinations of passing and climbing lanes. Unfortunately, the method has the disadvantage that it cannot be applied manually due to the large number of calculations involved. There is, however, a possibility that a simpler approach can be developed which could be applied manually (or at least by means of a computer spreadsheet).

The approach that can be considered is to subdivide the two-lane highway into homogeneous segments. A homogeneous segment is defined as one that either allows or disallows passing, but not both, and on which other factors such as gradient and curvature are constant over the length of the segment. The procedure would then estimate the percentage followers at the end of each successive segment, taking into account the percentage followers at the start of the segment. The percentage followers would either increase or decrease over the length of the highway.

The largest percentage followers would occur at either the start or the end of a segment (depending on whether it increases or decreases over the length of the segment). The approach can therefore be used to establish the worst level of service over the length of a highway. Additional procedures can be developed to estimate the average percentage followers over each segment.

An approach should be considered in which an "equilibrium percentage followers" is first estimated by means of a formula similar to the one given in Equation 20-17 of the HCM. On no-passing segments, the equilibrium percentage followers would be 100% (except when shoulders are sufficiently wide allowing some level of passing).

The equilibrium percentage followers would only be reached when a segment is very long. On short segments, the percentage followers would tend to converge to, but not reach, this equilibrium. An equation such as the following can then be used to estimate the percentage followers at the end of a segment:

$$PF_2 = PF_e \cdot (1 - (1 - \frac{PF_1}{PF_e}) \cdot e^{-a \cdot L})$$

In which:

PF_1 = Percentage followers at the start of the segment

PF_2 = Percentage followers at the end of the segment

PF_e = Equilibrium percentage followers

L = Length of the segment

a = Parameter of the model

The above approach requires that the percentage followers must be known at the start of the two-lane highway being analysed. This percentage can be estimated by starting the analysis some distance ahead of this location. A guesstimate can then be made of the percentage followers at the start of this section, and the proposed procedure applied to determine the percentage followers at the start of the highway.

The proposed approach has the advantage that it also provides an opportunity for taking the impact of intersections into account. Traffic signals, for example, would tend to increase the percentage followers at an intersection (except when it is already high). This percentage can be estimated and taken as the percentage followers at the start of the segment following the traffic signal. The above procedure can then be used to establish the percentage followers at the end of the segment.

The main advantage of the proposed approach is that it would be possible to analyse relatively complex combinations of passing and climbing lanes. It would also be possible to take the impact of intersections into account.

The proposed method would require extensive research and development, but if successful, would be of great value in the analysis of two-lane highways.