DESIGN HOUR FOR RURAL ROADS

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ABSTRACT

Traditionally, rural roads in South Africa have been designed for the traffic volume that occurs in the 30^{th} highest hour of the year. Many urban roads, however, have been designed (or evaluated) for the highest peak-hour traffic volume that occurs during a "normal" week of the year.

Urban roads have a relatively flat annual traffic flow distribution and the differences between the traffic volumes in the 30^{th} and 100^{th} highest hours as well as the highest normal peak-hours are usually not significant. Rural roads, however, can show significant peaks during the year with the result that the 30^{th} highest hour traffic volume can be significantly higher than the volume that occurs in the normal peak hour.

The 30 highest hours of a year in rural areas typically occur during school holidays, and then only during a few specific weeks of the year. It is therefore probably not economical to design roads to provide a high level of service during such hours, and a relatively low level of service for these hours may have to be accepted as an economic necessity (particularly when the 30^{th} highest traffic flow is high relative to average flows). An alternative approach, discussed in the paper, is to design a road to provide a higher level of service during the highest "normal" peak hour, and to check whether the level of service is acceptable during the 30^{th} highest hour.

1. INTRODUCTION

One of the most important traffic flow parameters in the design of a transportation facility is the hourly volume chosen for the design. The size as well as the type of the facility that is required depends on the traffic volume (and composition) that is expected to use the facility during the design hour.

A road that is designed to accommodate only the average hourly volume would be overloaded half the number of hours in the year, which would lead to high user costs and therefore would not be economical. On the other hand, however, it would also not be economical to design for the highest flow that can be expected as the facility would be under-utilised for all but one or two hours during the year. The selection of an appropriate hour for evaluation and design is therefore a compromise between providing an adequate level of service during most hours of the years and economic efficiency.

Ideally, the design hour should be selected on the basis of a cost-benefit evaluation. In practice, this is not often (if ever) undertaken, and a standard design hour is often specified. One of the problems with economic analysis is the selection of monetary values for items such as travel time and the convenience provided by a facility (as expressed in terms of level of service). Another problem is that, although a facility may be economically feasible, funds would not always be available for the construction of the facility with a high design standard, with the result that a lower level of service must be accepted. Considerable judgement must therefore be exercised in the selection of the most

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appropriate design hour.

The customary practice in South Africa is to base rural highway design on the 30th highest hour volume of a year. According to the Highway Capacity Manual (TRB 2000), the customary practice in the United States is to base rural highway design on an hour between the 30th and the 100th highest hour of the year. The point, however, is made that the arbitrary selection of an analysis hour cannot be a rigid criterion on which to base judgements.

In contrast with rural roads, urban roads in South Africa are often designed for the highest peak-hour traffic volume that occurs during a "normal" week of the year. Traffic impact assessments, for example, are undertaken for such an hour with the purpose of establishing the mitigating measures required to accommodate a proposed development (NDOT, 1995).

The purpose of this paper is to discuss the alternative design hours used in practice as well as the different approaches followed for urban an rural roads. An alternative approach is discussed in the paper that can be used for both urban and rural roads.

2. ANNUAL DISTRIBUTION OF HOURLY TRAFFIC FLOWS

The annual distribution of hourly traffic flows is normally studied by plotting hourly traffic flows (as a percentage of the AADT) from the highest to the lowest against the number of hours a particular volume is exceeded during the year as shown in Figure 1. Two curves are shown in the figure, one for all days of the year (8760 hours) and the second that only applies to the normal days of the same year. The curves are typical of rural roads that carry high volumes of holiday traffic.

A somewhat more useful approach is to plot hourly flows as a proportion of the AADT and the numbers of the hours as a percentage of the total number of hours in a year (8 760). Examples of such graphs are shown in Figures 2 to 5. The graphs are effectively cumulative probability distributions of hourly flows.

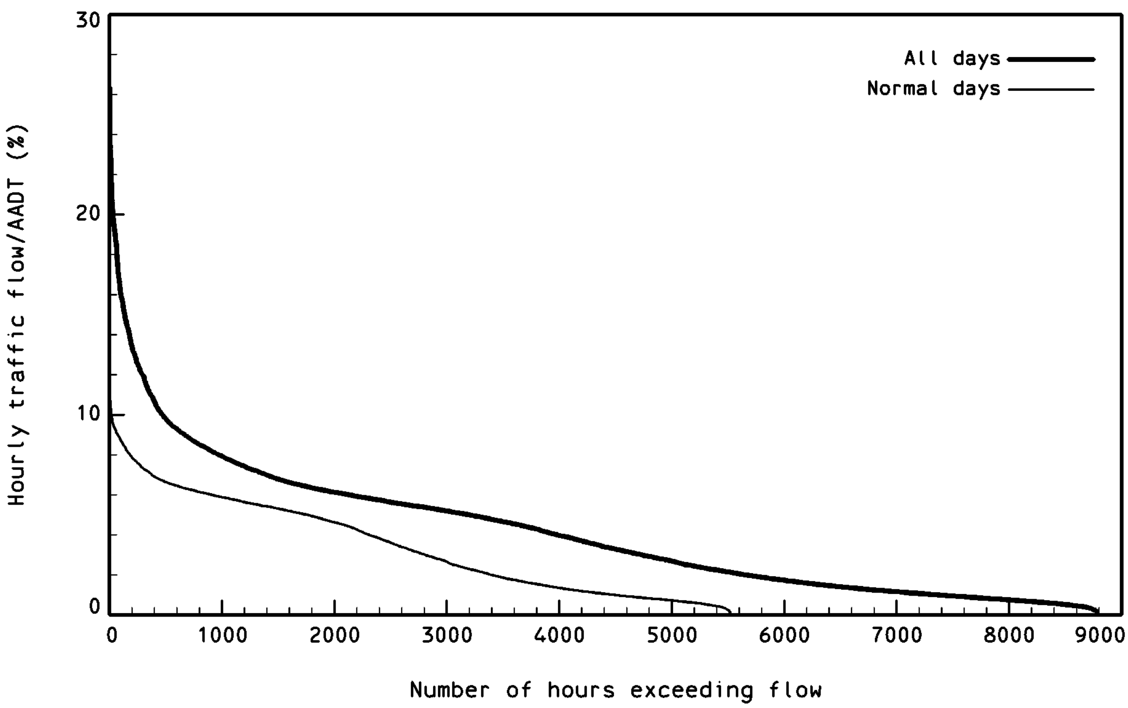


Figure 1. Traffic flow peaking characteristics.

The annual peaking characteristics of traffic volumes have been extensively investigated in South Africa by Jordaan (1985) and Papenfus (1992). Mathematical equations have been developed for the probability distributions that depend only on a few relatively simple parameters. These equations can be used to estimate traffic flow during a particularly design hour of the year. The purpose of this paper, however, is not to discuss these probability distributions, but rather to discuss the design hour during which the traffic volume should be estimated.

The flow distributions given in Figures 2 to 5 are examples of distributions that were found using traffic data obtained from the Comprehensive Traffic Observations (CTO) database of the South African National Road Agency Limited. A wide range of distributions was found, varying from the flat distribution shown in Figure 2 to distributions with a high level of peaking as shown in Figures 4 and 5. It is not possible to show all the traffic patterns obtained during the study, but the patterns in the figures are fairly representative of many patterns found on urban and rural national roads. The patterns shown in the figures are adequate for the purposes of this discussion.

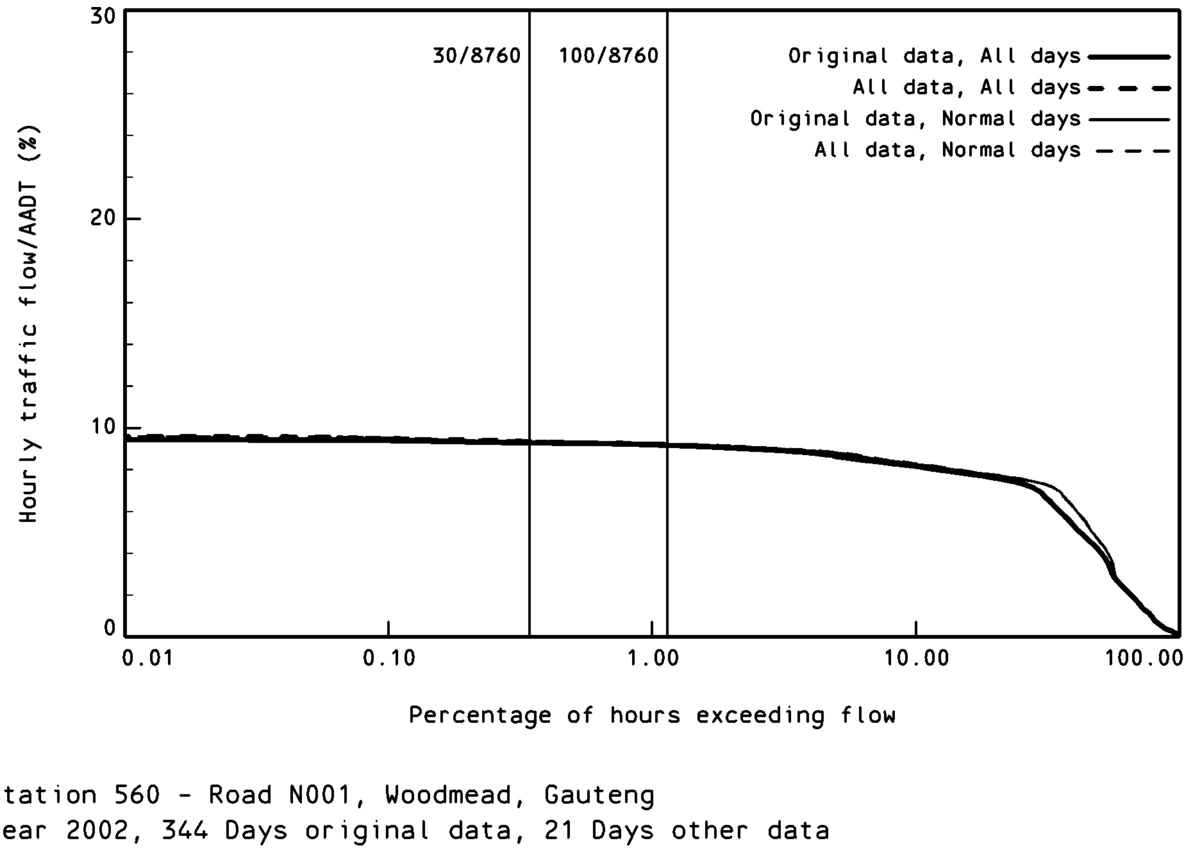
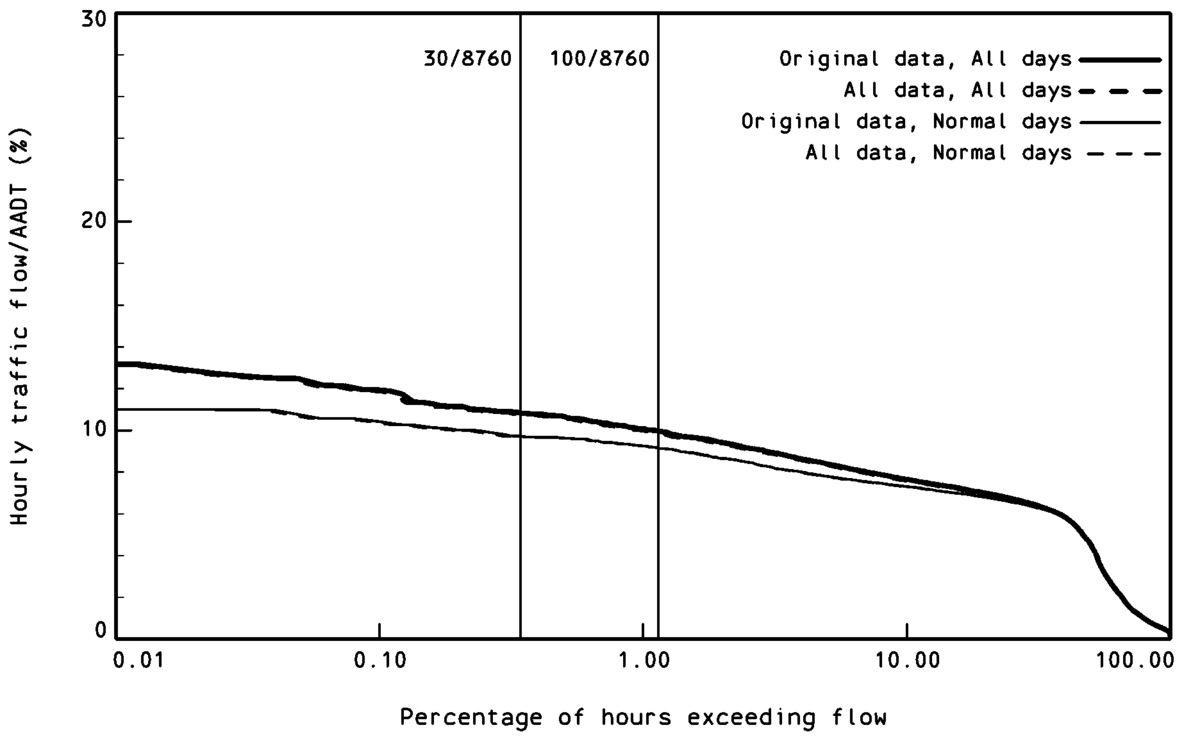
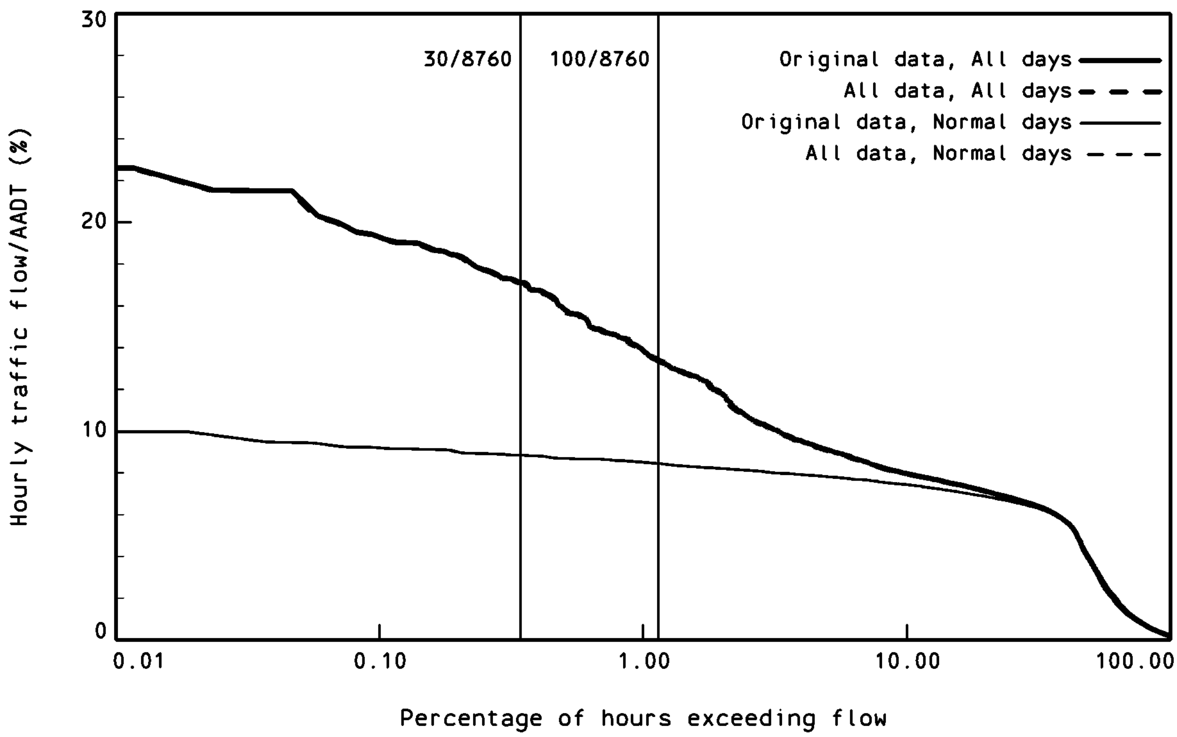


Figure 2. Peaking characteristics - road in urban area.



Station 150 - Road N002, Mtubatuba, Kwa-Zulu Natal
Year 2001, 341 Days original data, 24 Days other data

Figure 3. Peaking characteristics - rural road with low traffic peaking.



Station 1075 - Road N020, Port Edward, Kwa-Zulu Natal
Year 2002, 358 Days original data, 7 Days other data

Figure 4. Peaking characteristics - rural road with high traffic peaking.

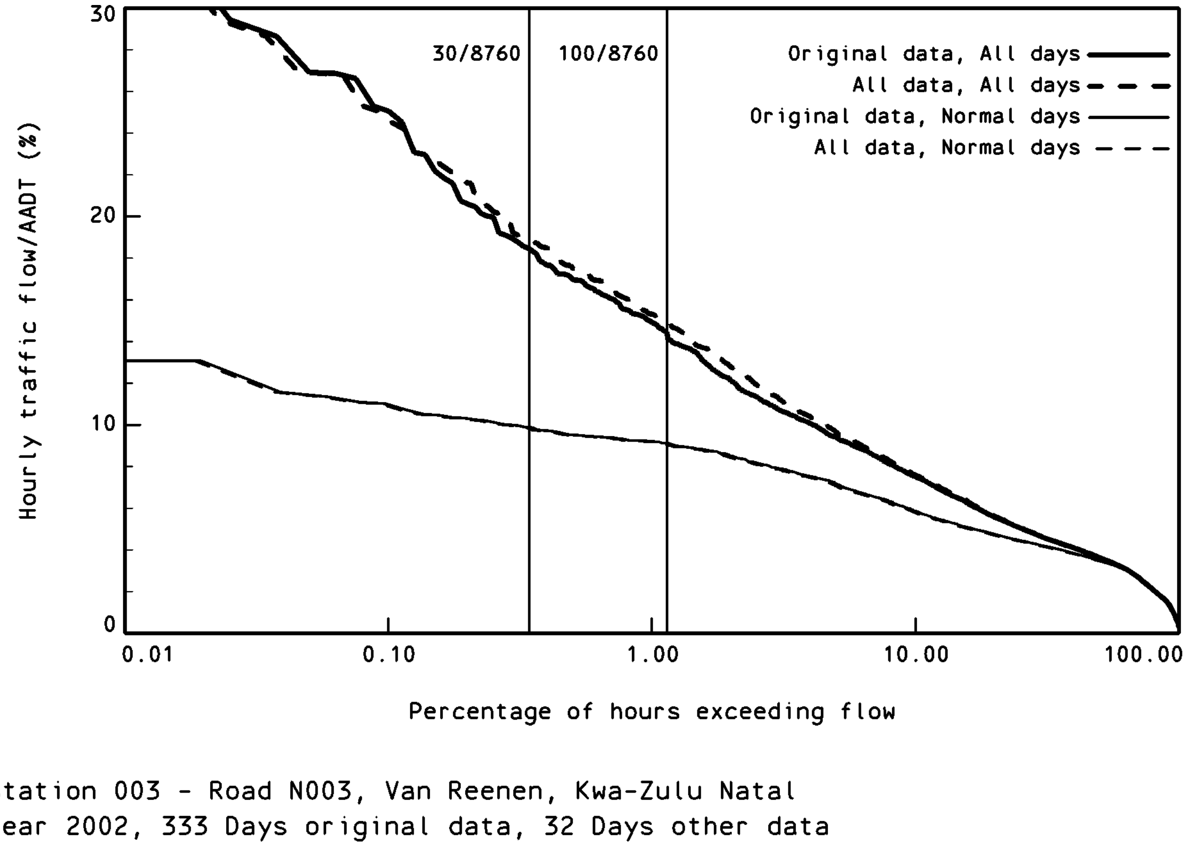


Figure 5. Peaking characteristics - rural road with high traffic peaking.

The different figures show traffic patterns for normal days and all days of the year (similarly as shown in Figure 1) as well as for "original" and "all" data. The "all" data curves represent the original traffic counts obtained from a counting station supplemented by traffic counts obtained from a "mother" counting station. Counts were supplemented when data were not available for the full 365 days of the year. Generally this supplementation had a relatively minor impact on the distributions, particularly when the number of days with missing data was relatively small.

The "normal days" indicated in the figures are those during which the traffic patterns are relatively stable. On normal days, the traffic patterns may differ for the seven days of a week, but the patterns remain relatively stable from week to week. "Exceptional" days are those on which the traffic patterns differ significantly from normal days. In South Africa, such days normally include public and school holidays, but there are other factors that can also contribute to exceptional traffic patterns. These include poor weather, road closures, etc.

In order to investigate the annual traffic distributions further, hourly volumes were also plotted for a period of one year as shown in Figures 6 to 8. The scale of the graphs is small, but it is still possible to recognise the weekly traffic patterns over the full 12 months of the year.

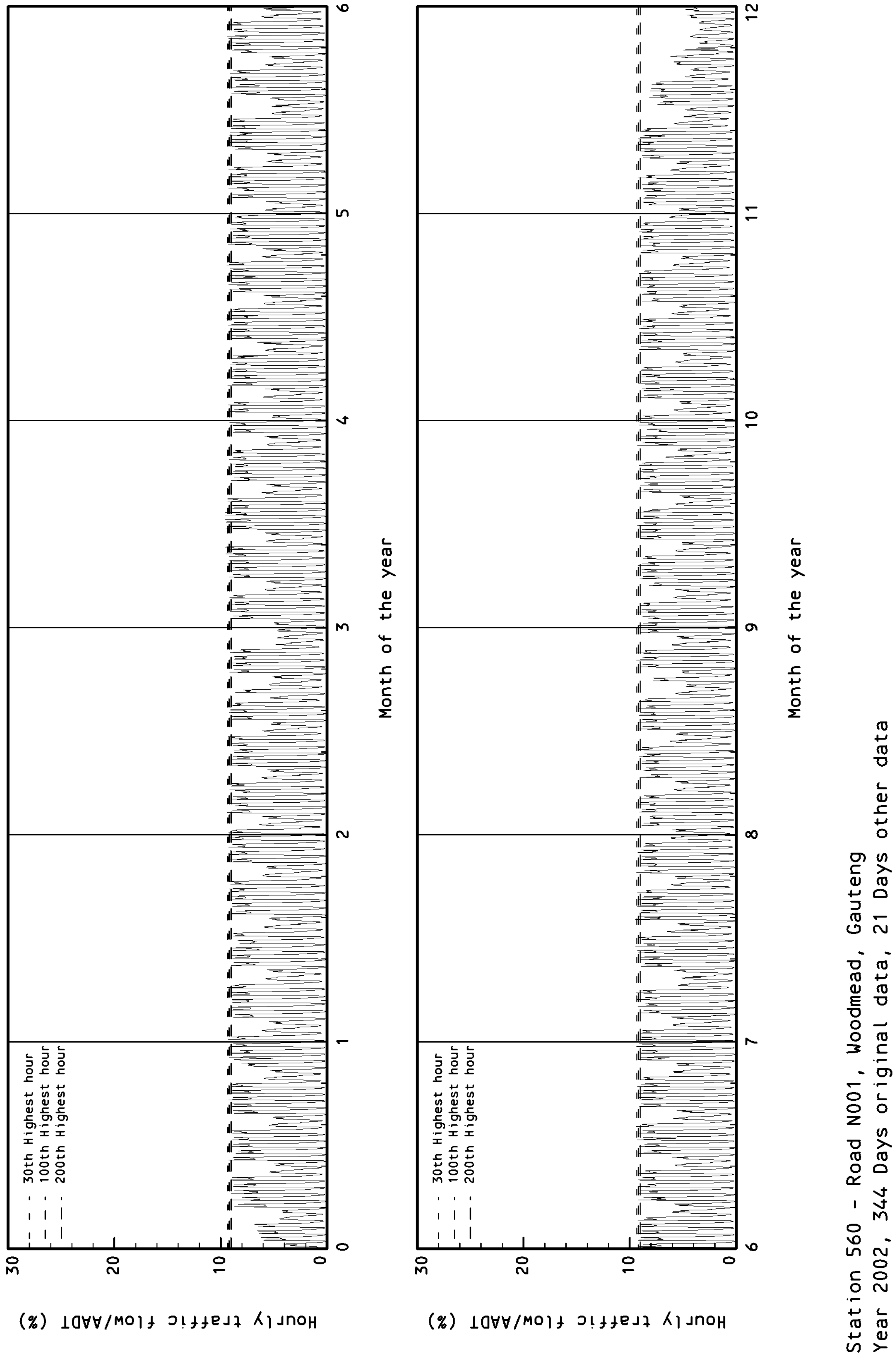


Figure 6. Annual traffic flows - road in urban area.

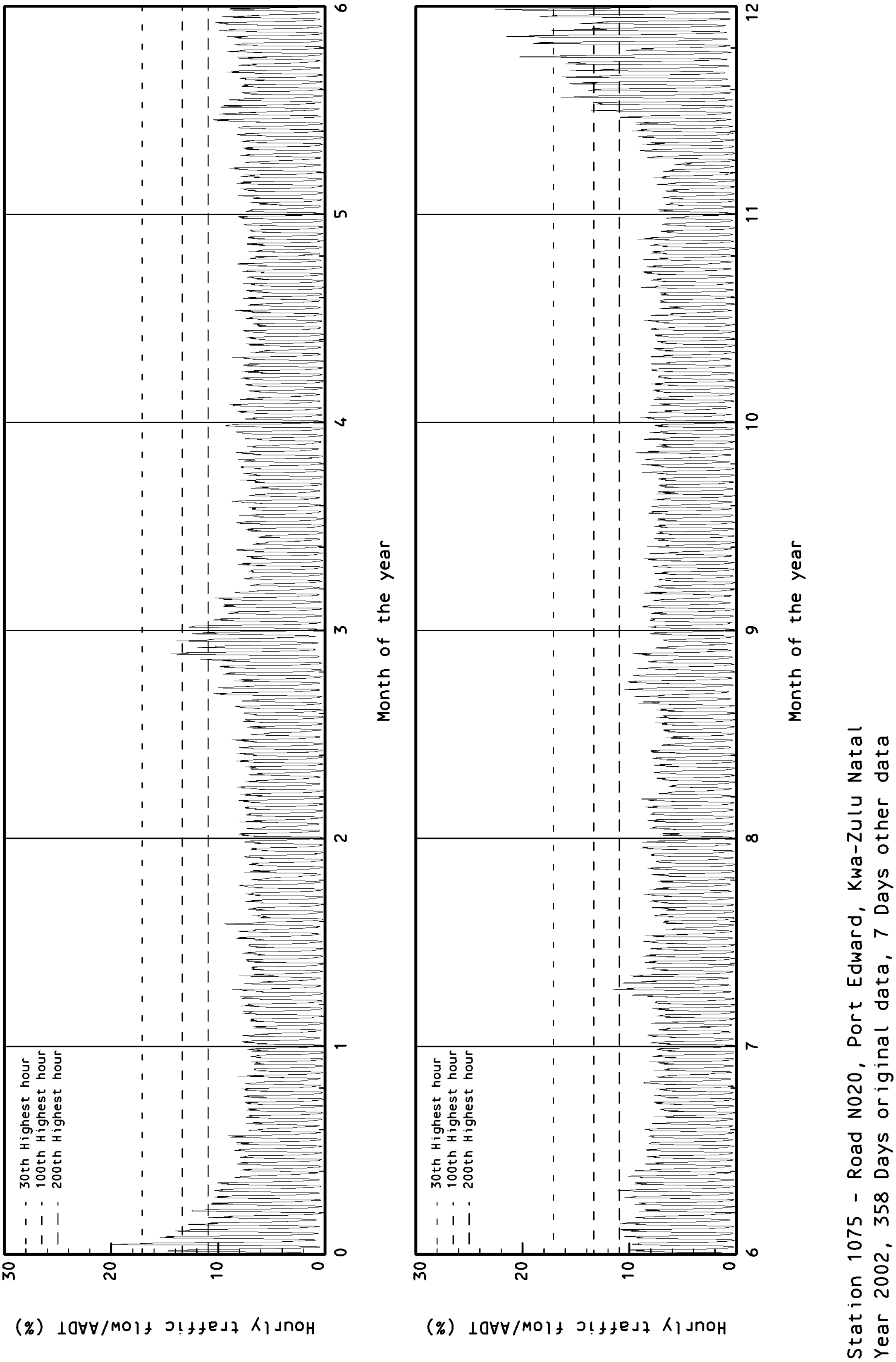


Figure 7. Annual traffic flows - rural road with high traffic peaking.

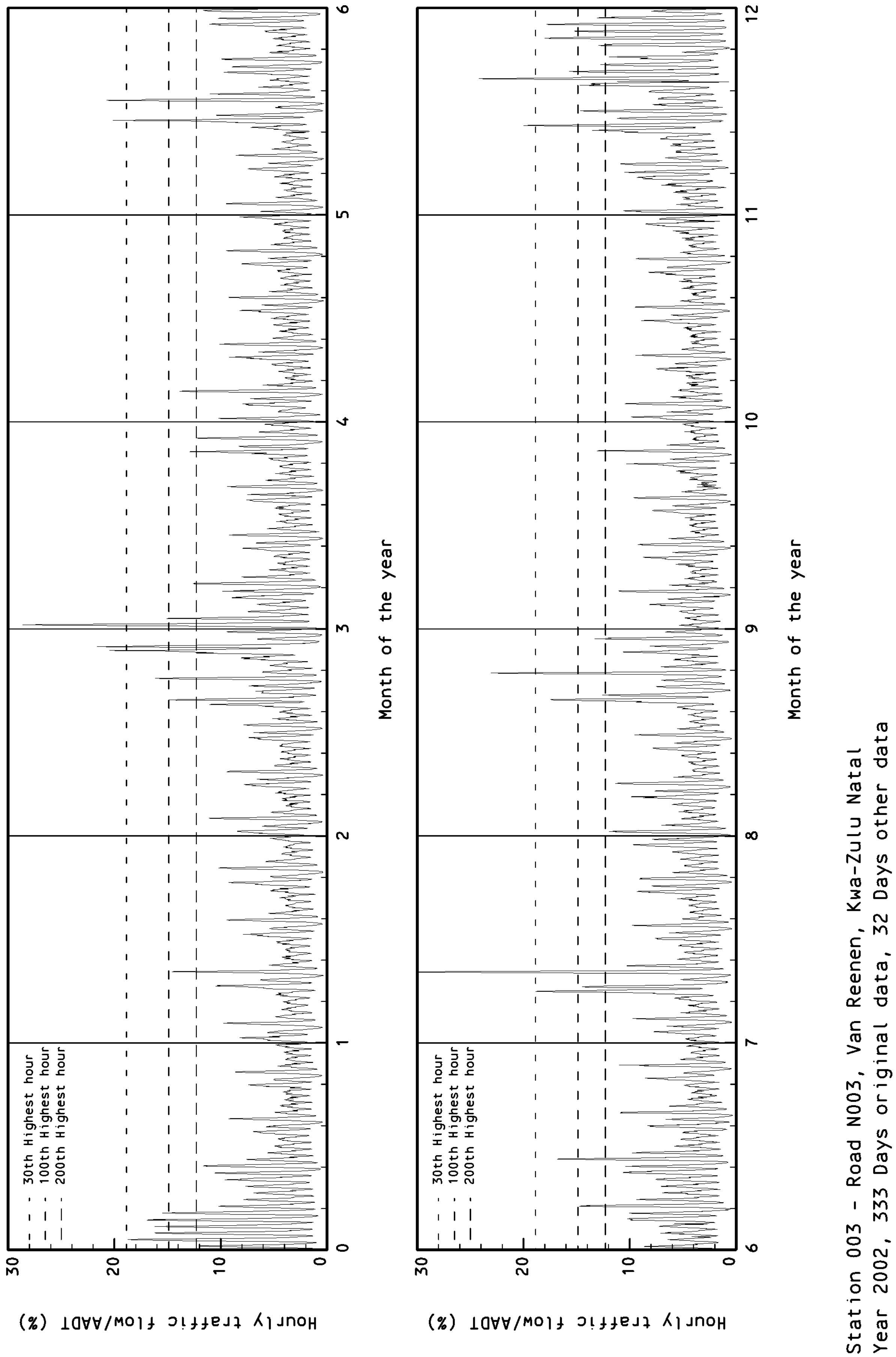


Figure 8. Annual traffic flows - rural road with high traffic peaking.

3. DISCUSSION OF FLOW DISTRIBUTIONS

The investigation into the traffic patterns has shown that although traffic flows can vary significantly from road to road, it is possible to recognise some general trends and patterns. As can be expected, traffic patterns on normal days were found to be relatively stable with little fluctuation from week to week throughout a year. Traffic patterns may be different on the seven days of the week, while traffic volumes may vary over the 24 hours of the day, but the weekly patterns remain fairly constant from week to week. The distributions shown in Figure 2 to 5 show that the normal day distributions are relatively flat and that there is little variation in traffic volume over many of the normal peak hours of the year.

Most of the deviations from the normal traffic patterns were found to occur during public and school holidays. As shown in Figures 6 to 8, some of the largest deviations were found during the December and January holidays, but deviations can also occur during other holidays of the year. The extent of the deviations varies from road to road. One some roads, the deviation is positive indicating that traffic volumes are higher during holidays compared with normal days (see examples shown in Figure 7 and 8). On other roads, however, a negative deviation was found indicating lower traffic volumes during holidays (an example is shown in Figure 6).

Generally it was found that traffic volumes on urban roads are typically lower on holidays than on normal days (e.g. Figure 6). The exception would be urban roads that form part of holiday routes or where the specific town or city is a major holiday destination.

The largest increases in traffic volumes were mostly found on rural roads, particularly those roads that form part of holiday routes (e.g. Figures 7 and 8). Some rural roads have low levels of peaking, but these are typically not those located on major holiday routes.

4. PROPOSED DESIGN HOUR

The analysis of traffic flow patterns has shown that high traffic peaks (30th highest hour volumes) typically occur on roads that carry school holiday traffic. On such roads, it is unlikely that it would be economically feasible to provide a high level of service during all hours of the year, and drivers must therefore be prepared to accept a reduction in the level of service during such periods. It is more likely that a design would be economically justifiable if it provides for an acceptable level of service over most but not all of the year.

The analysis has also shown that traffic patterns on some rural roads are relatively flat. On such roads, a higher level of service over most of the year can be more readily be justified.

The Highway Capacity Manual (TRB, 2000) recommends an approach in which two different design hours are used for the following purposes:

- A lower volume hour for the design of the road.
- A higher volume hour during which the acceptability of the design is checked.

According to the Highway Capacity Manual, the usual practice in the United States is to select a design hour between the 30th and 100th highest hours. One possible approach would therefore be to design the road for the 100th highest hour of the year, but to check the design for acceptable operations during the 30th highest hour. The problem with this approach is that the 100th and even the 200th highest hours can still occur during a holiday period, as shown in Figures 7 and 8.

An alternative approach proposed in this paper is based on the consideration that a facility should at least provide an acceptable level of service during the normal peak hours of the year. This approach has now been accepted in South Africa as fairly reasonable in urban areas and it is proposed that this approach should also be extended to rural areas. Even in situations where the use of a higher hour of the year is economically justified, it is often argued that a country such as South Africa cannot afford such designs.

The proposed approach consists of the following:

- Design the road to provide a higher level of service during the highest "normal hour", the hour during which the traffic volumes are highest during a week of normal days.
- Check that the level of service during the 30^{th} highest hour is acceptable.

On roads with a relatively flat flow distribution, such as in urban areas, there would be very little difference between the normal and 30^{th} highest hour traffic volumes and there would thus be no need for the second step of the process. The proposed approach therefore corresponds with current practice for urban roads. For rural roads, however, the proposed approach could constitute a major departure from current practice.

The impact of the approach would be that the design standard will be higher for roads that with a flat peaking distribution than for roads with high traffic peaks. Roads on which capacity upgrading were not previously warranted on the basis of the 30^{th} highest hour, may now require upgrading on the basis of traffic flow during the normal day peak hour. The impact on roads on which capacity upgrading was previously warranted on the basis of the 30^{th} highest hour depends on whether the design standard for the 30^{th} highest hour is changed. There would be little impact on upgrading needs if this standard is not changed.

An advantage of the proposed approach is that estimates of traffic volumes can more readily be obtained. Previously, long-term traffic counts were required to estimate the 30^{th} highest hour volume or a model such as developed by Jordaan (1985) or Papenfus (1992) had to be used for such purpose. These models require some estimate of parameters and it is therefore likely that the estimated traffic volumes may be inaccurate. A further problem is that models are not available for more complex applications, such as the estimation of turning volumes at intersections. If the proposed approach is accepted, then such volumes can be directly obtained from traffic counts undertaken during the normal day peak hour.

5. CONCLUSIONS

The analysis of traffic flow patterns has shown that high traffic peaks typically occur on roads that carry holiday traffic. On such roads, it is unlikely that it would be economically feasible to provide a very high level of service during all hours of the year, and drivers must therefore accept a lower level of service during such some hours. The Highway Capacity Manual (TRB, 2000) therefore recommends that an hour with lower volume should be used for the design of the road, but that the design should be checked for acceptable operations during a higher volume hour.

The approach proposed in this paper is to design a road for a relatively high level of service during the highest "normal" hour, but to check whether the level of service is acceptable during the 30^{th} highest hour. This approach can be used for both urban and rural roads, although it may not be necessary to check urban roads for the 30^{th} highest hour volume.

6. REFERENCES

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BIOGRAPHY

Dr Christo van As is a transportation engineer specialising in traffic and safety engineering. He is currently a specialist consultant for ITS Consulting engineers and is also a part-time professor at the University of Pretoria where he was involved since 1980 in the presentation of the post-graduate subjects such as Traffic Flow Theory and Statistical methods.

He has completed a number of research reports for various organisations, including the National Department of Transport and the South African National Road Agency. He is a co-author of the Volume 3, Traffic Signal Design of the Road Traffic Signs Manual as well as the National Guidelines for Road Access Management in South Africa. He has also recently completed a major research study on the capacity of rural two-lane highways on which the presentations are based.

In 2000 he received the Chairman's award of the Division Transportation Engineering of the South African Institute of Civil Engineering for contributions to the profession.