Simulation Study of Guidelines for Rural Road Improvements

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ABSTRACT

The rural traffic simulation model TRARR was used to evaluate a range of options for improving traffic performance on two-lane rural roads in Australia. The options include auxiliary lanes, widening to four lanes, and reconstruction on an improved alignment. Simulated travel times, bunching rates, and overtaking rates are presented for these options for a range of terrains and traffic volumes. Benefit-cost analysis was used to derive a volume warrant for each option, based on construction costs and reductions in travel times and accidents. Minimum volume warrants of 385 to 6,800 vehicles per day were found, depending on the terrain, the existing road standard, and the type of road improvement considered. Practical warrants are likely to be higher than these minimum values, but the relative rankings appear to be robust.

The rural traffic simulation model TRARR (1) was developed at the Australian Road Research Board and is now being used by a number of organizations in Australia and New Zealand. In recent years the model has been applied to several case studies of specific two-lane road sections to evaluate various road improvement options.

The case studies have considered widely different terrains and design standards, with different traffic volumes and compositions. The improvement options have included reconstruction on improved alignment, the provision of auxiliary lanes, and upgrading to four-lane divided-road standard (2-4). A structured simulation experiment that was undertaken to develop a broad set of guidelines for rural road improvements using a common basis is described.

TRAFFIC SIMULATION

Detailed descriptions of the TRARR simulation model are given elsewhere (5,6). The model has been calibrated to some extent, and its output is reasonable and consistent. A thorough validation is currently in progress, and Figure 1 shows a typical comparison of observed and simulated traffic performance. The figure shows observed traffic bunching over 15-min periods, compared with the mean and range of simulated bunching results for the same road and traffic conditions. A vehicle was considered to be following in a bunch if its headway to the preceding vehicle was less than 3.5 sec.

Overall results to date suggest that the model tends to overpredict traffic bunching on two-lane roads and underpredict that on four-lane roads. The model may therefore overestimate delays on an existing road and the expected benefits of various improvement options. The errors, however, do not appear to be large compared with other uncertainties in the evaluation of road projects.

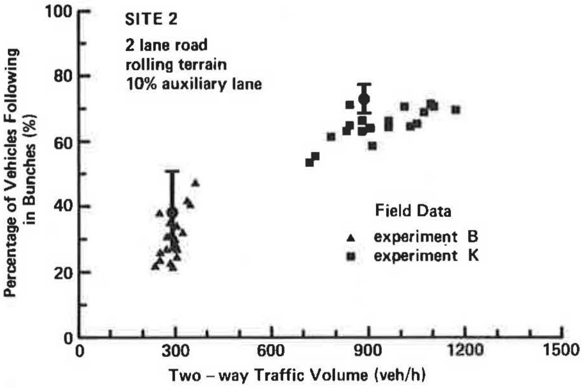

FIGURE 1 Comparison of observed and simulated traffic bunching: site 2.

SIMULATION STUDY FRAMEWORK

Road Alignment and Terrain

Three 12-km road segments were chosen:

1. Straight level road (SLR): an idealized perfect road with no grades, curves, barrier lines, or restrictions on sight distance or speed.
2. Maroondah Highway, Victoria (MHV): a segment of rural highway in rolling terrain with 110 km/hr design speed. Seventy-eight percent of the road has sight distance less than 450 m, and 26 percent has grades in excess of 4 percent.
3. Bass Highway, Tasmania (BHT): a segment of rural highway with fairly low geometric standards and few opportunities for overtaking. This segment has an average highway speed of 71 km/hr and 98 percent of sight distance less than 450 m; 46 percent of its length has grades over 4 percent.

Road Improvement Options

The first option to be simulated on each road was the existing condition. Seven improvement options were then considered, as shown in Figure 2. The first four of these are 500-m auxiliary lanes at various spacings. The remaining three provide for widening to four lanes over part or all of the road length. The effects of improved road alignment may be investigated by comparing the three different road segments chosen for analysis. The investigation of auxiliary lane and partial four-laning options was strongly recommended in previous studies (3,4).

Traffic Conditions

Traffic volumes of 200, 800, and 1,600 vehicles per hour were simulated, with 2:1 directional split and

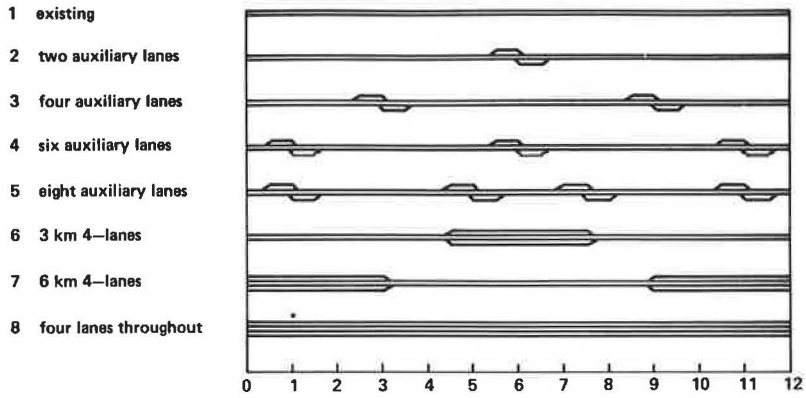

FIGURE 2 Road improvement options.

10 percent trucks in the traffic stream. The simulation time and settling down times were varied so as to observe approximately the same 3,000 vehicles for each terrain, road option, and traffic volume.

SIMULATED TRAFFIC PERFORMANCE

Travel Time

Figure 3 shows the travel time over 12 km for each simulated case. On the existing road (option 1), travel times increase with traffic volume and with decreasing standard of road alignment. Travel times are then reduced in varying degrees by road improvement options 2-8. Several points may be noted.

1. The road improvements yield the greatest travel time savings where the existing road alignment is poorest;
2. Travel time savings generally increase with traffic volume;
3. Four-lane roads show no increase in travel times with increasing traffic volumes up to 1,600 vehicles per hour;
4. Improvement options 2-7 offer intermediate levels of traffic performance between two-lane and four-lane roads.
5. The options of improved road alignment are shown in Figure 4. The existing Maroondah Highway, for example, offers lower travel times than the Bass Highway with closely spaced auxiliary lanes.

Time Spent Following in Bunches

The mean percentage of journey time spent following (at headways less than 3.5 sec) is shown for each case in Figure 4. Time spent following reflects the degree of traffic bunching along the road and is a useful measure of the quality of service as perceived by the driver.

At 200 vehicles per hour, bunching on the straight level road is generally below 10 percent. This rises to 15-30 percent on the Maroondah Highway, and 25-55 percent on the Bass Highway. Even at this low traffic volume, it would appear that bunching can be quite substantial on roads with poor geometric standards. In all cases, bunching rises substantially with increasing traffic volume, although the extent of bunching is still quite dependent on road alignment. As might be expected, simulated bunching on four-lane roads is quite low over the range of traffic volumes considered.

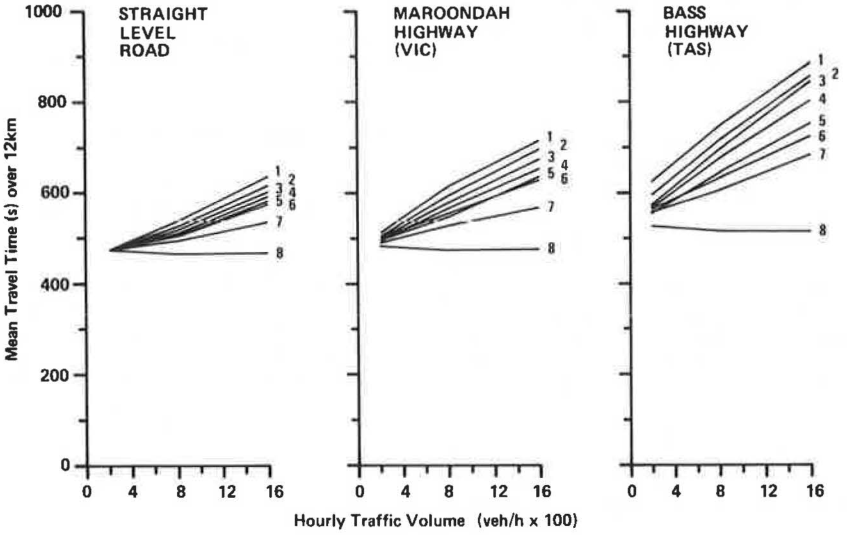

FIGURE 3 Simulated travel times.

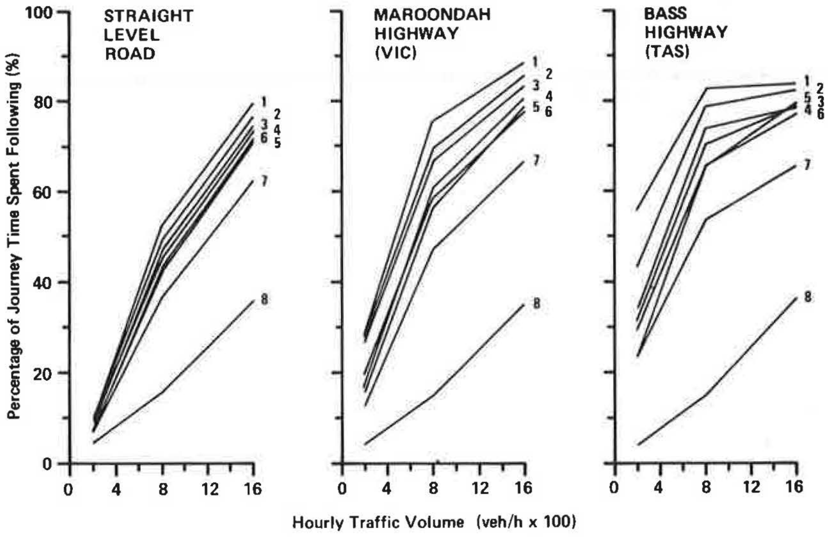

FIGURE 4 Simulated percentage of journey time spent following.

BENEFIT-COST ANALYSIS

The benefit-cost analysis procedure is described in some detail elsewhere (7). Benefit-cost (B/C) ratios were calculated for 36 road improvement options for a range of average annual daily traffic (AADT) volumes. The ratios ranged from 0.0 to 19.0, depending on terrain, improvement type, design standard, and traffic volume.

Table 1 gives, for selected options, the minimum volume warrant, Qw, which is defined as the initial-year AADT volume for which the benefit-cost ratio is 1.0. The values of Qw in Table 1 vary widely, from 385 to 6,800 vehicles per day, and terrain has a strong influence on these results. The minimum warrant for a pair of auxiliary lanes, for example, is 385 vehicles per day on the Bass Highway, 1,335 vehicles per day on the Maroondah Highway, and 2,570 vehicles per day on the straight level road.

TABLE 1 Estimated Minimum Volume Warrants for Selected Options

	Initial-Year AADT (veh/day)		
Option	Bass Highway, Tasmania	Maroondah Highway, Victoria	Straight Level Road
8 percent auxiliary lanes	385	1,335	2,570
25 percent auxiliary lanes	625	1,670	3,200
25 percent four lanes	1,670	3,500	5,430
Four lanes throughout	3,670	5,000	6,800
Major realignment	3,330	6,500	

DISCUSSION

The B/C analysis is based on a number of uncertain assumptions regarding construction costs, accident reductions, traffic growth, and other parameters. Sensitivity analysis (7) showed that the values of B/C and Qw are sensitive to changes in these assumptions, but the relative rankings of various options are robust. The uncertainties in evaluation assumptions appear to be larger than any likely errors in the simulation model predictions, so that the TRARR model is quite suitable for use in this type of analysis.

The model, however, appears at present to have a bias that leads to overestimation of the benefits of improvements on two-lane roads. The minimum volume warrants in Table 1, therefore, probably underestimate true minimum warrants. Practical minimum warrants are probably higher still, because these are usually based on B/C ratios greater than 1.0.

Despite these reservations, the results in Table 1 indicate that short auxiliary lanes offer a low-cost road improvement option that can be warranted at quite low traffic volumes. The use of auxiliary lanes and four-laning on existing alignments may in many cases be preferable to realignment on substandard two-lane roads.

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