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Abridgment

Changes in Traffic Speed and Bunching Near Transition Points Between Two- and Four-Lane Rural Roads

C. J. HOBAN AND K. W. OGDEN

The results of several field experiments conducted to measure changes in traffic performance caused by transitions from two to four lanes on rural highways are reported. Vehicle speed and bunching data were recorded at a number of points upstream and downstream of a transition. A microprocessor-based recorder unit and flat metal-and-rubber detector strips were used. The results show that changes in traffic performance with position occur more rapidly on entering a four-lane road than on merging into two lanes. The effects of a change in road quality at the transition were isolated. The results are applicable to the study of rural overtaking lanes and the validation of simulation models and may also be of interest in the study of rural transition points and temporary detours.

Several field experiments were conducted as part of a simulation study of the performance of rural overtaking lanes. The aims of the experiments were (a) to provide validating data for two- and four-lane simulation models and (b) to investigate directly the changes in traffic parameters that occur in transition between two- and four-lane rural road sections (1).

The experiments were designed to measure traffic mean speed and bunching at a number of points along the road in order to determine equilibrium performance and the rate of change of this performance attributable to the transition in road type. Although the data represent only a limited range of traffic conditions at two sites, the results should be of interest in the study of rural traffic behavior, especially in relation to passing lanes, lane transitions, and temporary detours.

This paper reviews variations in mean speed and bunching with distance downstream of a four- or two-lane merge point or a two- to four-lane demerge point on a rural highway, at various flow rates. The effects of variations in road quality are also briefly discussed.

DATA COLLECTION AND REDUCTION

Field observations were made at two sites near Frankston, Australia, an outer suburban center about 40 km from Melbourne (see Figure 1). Three experiments were conducted between July and October 1978. In all, more than 30 000 vehicle observations were made over 15 h, or 50 traffic-h if each recording station is considered separately. Only Sunday traffic was recorded; this included a significant proportion of recreational traffic but few trucks.

The physical layout of each site and the positions of the stations used for recording are shown in Figure 2. It should be noted that vehicles in Australia travel on the left side of the road. The merge site involved a divided four-lane arterial road merging into a two-lane, two-way carriageway in mildly undulating terrain. The Victoria state speed limit of 100 km/h applied throughout, and curves on the two-lane road section limited overtakings. At the demerge site, a narrow two-lane road with a 90-km/h speed limit joined a newly constructed freeway with a 100-km/h speed limit.

Vehicle speed and headway data were measured by using flat metal-and-rubber detector strips in pairs, coupled to a microprocessor-based recorder unit that stored the information on cassette tape. About 6 km of two-core wire was used to connect recording stations over 2 km of road. Because of wire limitations, some stations were recorded for shorter periods of time than others. Data on opposing traffic were also collected at the merge site.

The field data were later analyzed by using 5-min sample periods to give average values of the following parameters:

V = mean speed (km/h),
F = mean percentage following ("bunching"),
Q = flow rate (vehicles/h),
$Q2$ = opposing-flow rate at the merge site (vehicles/h), and
X = position downstream of the merge or demerge point (m).

Vehicles were defined as following if their headway from the preceding vehicle was ≤ 3 s. The term "bunching" is used in this paper to refer to the mean percentage of vehicles following in bunches (F). To provide a common basis for comparison, data from two-lane, one-way road sections were artificially merged into a single stream.

DATA ANALYSIS

The aim of this analysis was to establish relations between traffic mean speed and bunching and position

Figure 1. Location of field experiments.

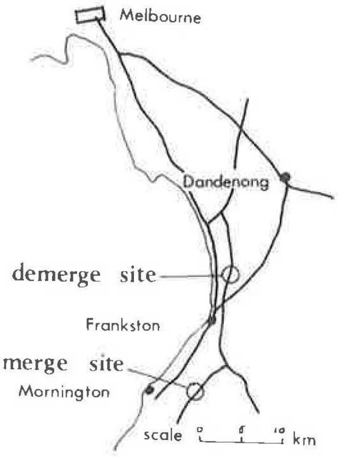
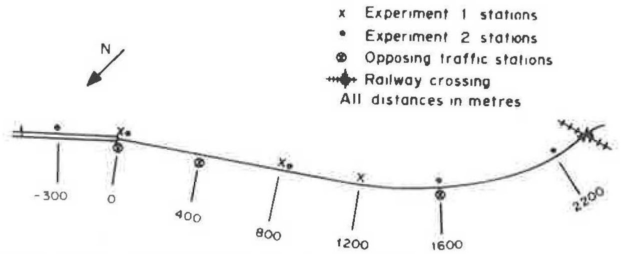
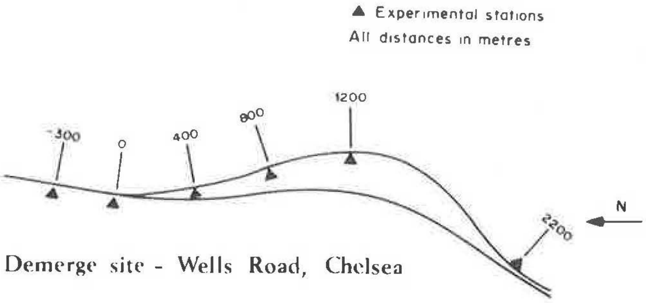


Figure 2. Layout of field experiments.



Merge site - Moorooduc Road, Mt. Eliza



Demerge site - Wells Road, Chelsea

on the road (measured downstream from a merge or demerge point). Intuitively, these relations should be approximately S-shaped, since traffic parameters change from one equilibrium level to another.

V and F, however, are known to vary with Q; in fact, the whole V-X or F-X relations may vary with Q. For the low to medium flow rates considered here, the effect of flow on V has been shown to be linear by Leong (2), Duncan (3), and others. A similar relation between F and Q seems appropriate.

A two-stage analysis procedure was thus adopted. First, for each road type (divided and undivided), at each site, a linear relation of V and F with flow was found. In preparation for the second stage, these relations were used to standardize the field data to the values that would have occurred at fixed flow rates of 400, 800, 1200, and 1600 vehicles/h. The second stage of the analysis was then to establish nonlinear relations for V and F with position, at each flow rate.

Standard regression analysis programs were used to fit relations to the data. Two useful parameters of these analyses are the coefficient of determination (R^2), which gives the proportion of variation in the dependent variable explained by the regression, and the standard error (S_y), which can be used to derive 95 percent confidence bands for the result. Traffic behavior varies widely between individual drivers and vehicles, so that not all of the variation will be attributable to changes in Q and X. It should be noted that R^2 and S_y values are found for mean parameters of 5-min sample periods. All of the relations presented are significant at the 5 percent level.

It was noted earlier that, in addition to the data collected at a succession of stations downstream of the merge point, data were also collected at several stations in the opposing lane. Data for these stations may be taken as representing an equilibrium state for the two-way, two-lane section of the road, since the opposing vehicles had traveled for several kilometers along a relatively uninterrupted two-lane road.

Accordingly, the analyses for the merge situation were repeated, and data from the opposing-flow stations were inserted at a point 5000 m downstream of the merge point; this somewhat arbitrary distance was selected because it was considered that equilibrium conditions would have been reached at that stage. Tests showed that the extended data supported the trend found over the first 2200 m.

RESULTS

Analysis showed that the influence of opposing flow (Q2) on V and F was very small for the two-lane, two-way roads. This is a surprising result that disagrees with the findings of the Highway Capacity Manual (4) and Luk (5). It probably reflects the limited range of flows recorded at each field station and the fact that opposing-flow readings were in some cases taken upstream or downstream of a particular station. Nevertheless, the best relations that could be obtained for this data set were based on one-directional flow only.

Relations for V and F with position are shown in Figures 3-6. Data points are not shown in these figures, but the 95 percent confidence limits indicate the range of data values found. Although the polynomial regression lines are clearly only an approximate indication of the true relations, they are quite useful for comparisons.

Figure 3 shows a quite rapid decrease in bunching with position at the demerge site and a similar trend at all flows. The corresponding sharp increase in mean speed is shown in Figure 4. In both figures, roughly half of the transition occurs within 500 m of the demerge points. Figure 5 shows a more gradual increase in bunching at the merge point, where the transition was half completed only after 2 km downstream. A similar transition in mean speed is shown in Figure 6.

Figures 3 and 5 show that bunching increased considerably with increasing flow. In Figures 4 and 6, mean speeds are shown to increase only slightly with flow. This is because speeds at a given point are drawn from a desired-speed distribution that is independent of flow and an increase in bunching merely gives greater weight to the lower speeds in the distribution. The form of the V-X and F-X relations is very consistent over a wide range of traffic-flow rates.

Whereas bunching is affected only by the transition between two lanes and four lanes, mean

Figure 3. Mean percentage following versus position at demerge site.

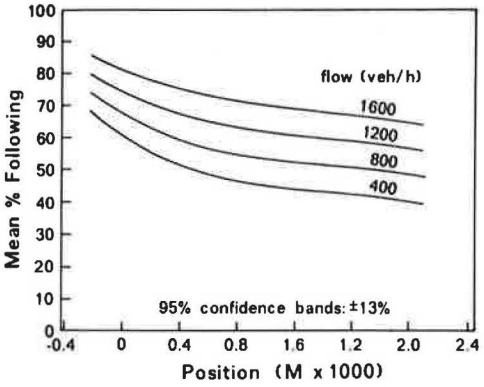


Figure 4. Mean speed versus position at demerge site.

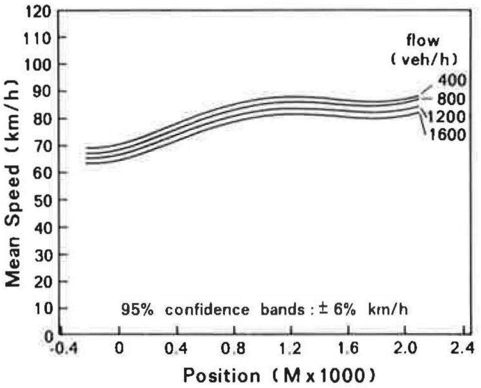


Figure 5. Mean percentage following versus position at merge site.

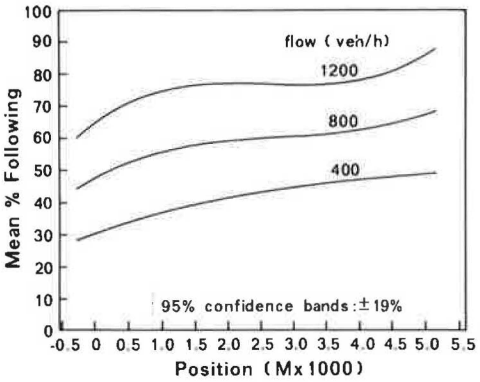


Figure 6. Mean speed versus position at merge site.

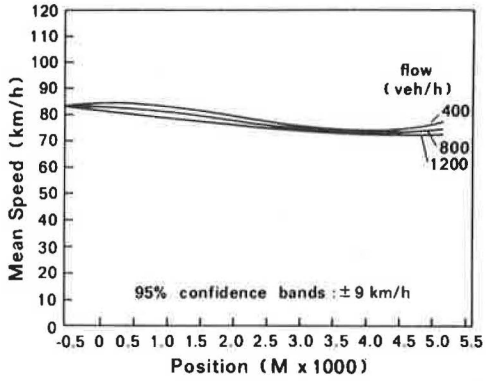


Figure 7. Effects of bunching and desired speed at demerge site.

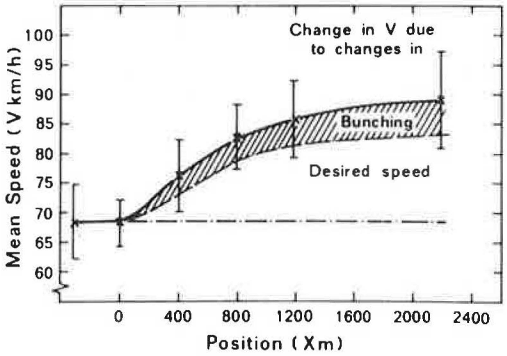
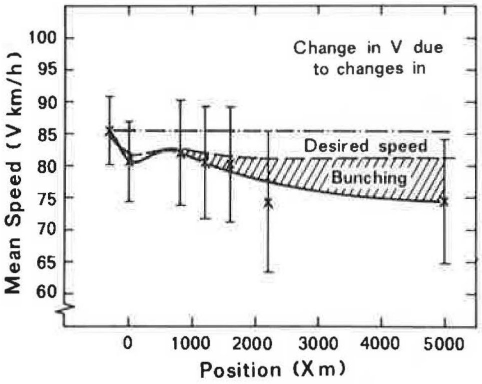


Figure 8. Effects of bunching and desired speed at merge site.



speed is also affected by changes in road quality over the transition. Leong (2) and others have shown that desired traffic speeds vary with such road-quality measures as pavement width, shoulder width, and alignment. Marked differences in the quality of adjacent road sections--e.g., at the demerge site--may have a substantial effect on the transition in mean speeds.

If the desired-speed distribution is known, the mean speed can be found for any degree of bunching. Conversely, the mean desired speed can be estimated for given values of V and F, provided the form of the distribution is known. Hoban (6) describes how this method can be used to isolate the two components of the mean-speed transition.

Figures 7 and 8 show the effect on mean speed of changes in bunching (because of a change in the number of lanes) and desired speeds (because of differences in road quality). The isolation of desired-speed effects, which vary from site to site, is important in examining variations in traffic that are directly attributable to a change in the number of lanes available to traffic.

The effect of changes in desired speed at the demerge site is shown in Figure 7 to account for more than two-thirds of the transition in mean speeds. Figure 8 shows a much smaller change in desired speeds at the merge site, which reflects the greater similarity in quality of the two road sections. In both figures, the transition in desired speeds took place over approximately 1 km. The data points in Figures 7 and 8 are corrected to 800 vehicles/h, and 95 percent confidence limits are shown.

CONCLUSIONS

The results of the work reported in this paper show clearly that the transition in speed and bunching at a demerge site is considerably more rapid than that at a merge site. Traffic moving from a two-lane road onto a multilane road experiences an improvement in performance that is almost complete within 1 km downstream of the demerge. In the reverse situation, where traffic merges into two lanes, the transition is a gradual one that takes place over several kilometers.

Bunching was found to increase substantially with flow, especially on the two-lane road sections. This led to moderate decreases in mean speed as flow increased. Surprisingly, the form of the V-X and F-X relations was almost unchanged over a wide range of flow rates.

The transitions shown for bunching were directly caused by the change from two lanes to four, or vice versa. The transitions in speed, however, were also affected by changes in road quality. This effect was shown to be quite substantial at the demerge site where the two- and four-lane road sections were of very different quality. Once the effects of road quality are removed from the V-X relation, the remaining transition is entirely attributable to the change in the number of lanes.

ACKNOWLEDGMENT

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Abridgment

Development of a New Traffic-Flow Data-Collection System

LAWRENCE JESSE GLAZER AND WILLIAM COURINGTON

A recently developed hardware-software package for performing "floating-car" or "speed-and-delay" traffic-flow studies is described. The Traffic Recording and Analysis System closely approximates an ideal system. It uses a microcomputerized data recorder that almost totally automates the data-collection process. An enormous amount of data can thus be gathered by one person. No special training or computer background is required. The device uses little power, is truly portable, and is packaged in a rugged metal attaché case. The processing of data from digital cassette tapes is also almost totally automated. An IBM/360 computer analyzes the raw data and produces camera-ready printouts and digital plots. The information presented includes distance, travel time, speed, number of stops, delay time, fuel consumption, air pollution emissions, and vehicle operating costs. Digital plots available are time-speed profiles, speed contour maps, and speed perspectives. Heavy automation of data collection, analysis, and presentation means lower cost per study and thus greater productivity within existing budgets.

Traffic-flow studies have been an important traffic engineering tool for several decades, but currently used techniques are still rather primitive and limiting. Historically, the most common criterion used in measuring the quality of traffic flow has been travel time, which has sometimes included a measure of delay. But circumstances have changed drastically in the past decade, and new demands are now being made on the traffic engineer and the transportation evaluator.

Since automotive air pollution became a major social issue in the late 1960s, traffic engineers have increasingly been required to defend transportation projects with respect to air pollution impacts. Since the 1974 oil embargo, automotive energy consumption and the energy impacts of traffic improvements have also become critical social issues. The current emphasis on cost-effective transportation system management is likewise requiring more detailed project evaluations.

In all of these areas, the tools available to the practicing traffic engineer for measuring the benefits of traffic-flow improvements--including energy savings and reductions in air pollution--have not kept pace with increasing demands. Furthermore, the current economic and political environment is shrinking the budgets that make it possible to do