NATIONAL TRANSPORT RESEARCH CENTRE

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THE VOLUME AND COMPOSITION OF TRAFFIC ON TERTIARY RURAL ROADS

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1. INTRODUCTION

This study sets out to determine the volume and composition of traffic on tertiary rural roads.* Historical trends in motorised and non-motorised traffic flows are analysed, and the accuracy of annual average daily traffic (ADT) estimates from random counts of varying duration is assessed.

The study forms part of a wider research programme which examines the relationship between traffic volume and composition and the choice of design standards and surface types.(2) It is the second in a series of studies in the programme.

2. BACKGROUND

Almost all types of highway planning require some form of traffic survey. The results from traffic surveys are an important input to the planning, design and appraisal of new road projects as well as the maintenance and upgrading of existing roads. For example, in the determination of sub-base thickness and design life the cumulative number of standard axles passing along the road is of central concern.(3)

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* these roads have been variously described as feeder, farm-to-market, district and village roads(1)

A variety of traffic data is required to meet different highway planning objectives. However it is essential that the data collected is carefully chosen and classified and the results obtained are as accurate as possible. Estimates of traffic, as well as many of the other criteria considered in the design and maintenance of roads, are subject to degrees of error. If estimates are inaccurate, investment will be made at sub-optimal times and either over-or under-investment will result.

If a small change in the estimate of one parameter will alter the decision under consideration, then the decision is said to be sensitive to changes in the estimates of that parameter. Howe found that decisions concerning the annual finance spent on maintaining each section of road, the economic justification of road improvements, and of particular relevence to this study design standards (and construction costs), were all sensitive to the estimates of traffic.(4)

Different traffic parameters also demonstrate varying degrees of regularity and magnitude: induced traffic and traffic levels on minor, lightly trafficked roads for example, have been found to be open to greater degrees of estimation error than, say 'normal' traffic and heavy flows on main roads.

In Pakistan, the provincial highway departments, and in particular Punjab Highway Department, have collected traffic data for a number of years. The data are collected on an annual census basis at fixed locations; on the more important national primary roads, 10-18 24-hour counts have been taken. At a few stations, permanent sites have been maintained and year round counts obtained.(5) However at the tertiary level, traffic counts on farm-to-market type roads are rarely conducted, or are taken on only a few days per year. Estimates of ADT based on this duration of counting are subject to wide margins of error.(6)

The problem can be seen in perspective when it is realised that the Government is embarking on a major farm-to-market road construction programme as part of its rural development efforts. Under the Sixth Five Year Plan 1983-88, a total of some Rs. 4.1 billion is expected to be allocated for tertiary rural roads including the construction/improvement of 10,000 km. of village roads.(7) An important part of the programme is the introduction of stage construction techniques. Initially, earth or shingle (water-bound macadam) roads are to be constructed. The addition of a bituminous surfacing will only be carried out when justified from a traffic point of view.

In addition to the choice of surface types, estimates of traffic volume and composition also have an important effect on the specification of design standards. For example, formation width (road surface plus shoulders) is primarily dependent on the volume of traffic expected. Gradients need to be chosen to balance the cost of construction against the operating cost of heavy vehicles ascending them. Right-of-way widths must be adequate to allow for the driving of cattle or other livestock in some areas,(8) as well as for pedestrians, cycle traffic and slow-moving vehicles.

Given the significance of the farm-to-market road programme in the Government's rural development efforts and the important role that traffic estimates are expected to play in the choice of design standards and surface types, it is essential that accurate traffic data are available on which to base planned investments so that resources are used efficiently.

From available evidence, little research work has been carried out in Pakistan on the relationship between traffic volume and composition and the selection of design standards and surface types. In general, only limited information is available on tertiary rural roads, while a recent national study excluded them altogether.(9) More

specifically, few attempts have been made to relate traffic volume and composition observed on tertiary rural roads to the design standards (and surface types) chosen for their construction.

In view of these shortcomings, this study sets out to provide some basic information on traffic volumes and composition, as part of a research programme which examines the relationships outlined above in more detail.

3. OBJECTIVES AND METHOD

The main objectives of this study are:

(a) to determine estimates of annual average daily traffic (ADT) on tertiary rural roads

(b) to identify the composition of this traffic and

(d) to assess the accuracy of the data used to estimate ADT flows

The review of tertiary rural road design standards has revealed that a considerable amount of traffic data is available in Pakistan, notably in Punjab Province. The data include estimates of average traffic volumes, in terms of mixed vehicles per 24-hour day and traffic composition on a large variety of provincial and national highways.

In view of this background, and in order to achieve the objectives set out above, existing data sources have been used as the basis for this study. Volumes are grouped in relation to traffic levels which broadly correspond to different road classes and design standards. Traffic composition is similarly grouped and changes in composition compared with changes in volumes.

An assessment of the accuracy of ADT estimates derived from these sources has been obtained with reference to extensive studies of traffic flow and variation carried out on rural roads in Kenya by the Transport and Road Research Laboratory (UK).

4. DEFINITIONS

4.1 Tertiary Rural Roads

Characteristically, tertiary rural roads are taken to represent low volume roads in predominantly agricultural areas.(10) They have been defined as special purpose roads, penetration roads, feeder roads and tertiary roads of a non-interurban character, existing primarily for land service.(11) They are also expected to be low cost.

In Pakistan the terms village, farm-to-market and district have all been used to describe low volume tertiary-level roads, with feeder being the most popular description. They are planned to meet the needs of the rural population by connecting villages, farms, markets and other establishments with the primary and secondary highway systems. Construction and maintenance responsibilities rest mainly with provincial highway departments and district councils. Traffic can include both motorised and animal-drawn vehicles. Typically they are from 5-15 km in length, though some may be as long as 100 km.(12)

For the purposes of this study, tertiary rural roads have been defined as feeder roads and agricultural sector roads under the responsibility of the provincial highway department. It should be noted that district roads under district councils also fall into the tertiary rural road classification but lack of compatible data on design/construction standards and traffic volumes has prevented their inclusion here.

4.2 Design Standards and Surface Types

There is no consistent set of design standards for tertiary rural roads in Pakistan, with federal and provincial

highway agencies each developing their own guidelines.* The approach adopted in this study is based on the Punjab Highway Department's recommendations,(13) to ensure compatibility with available traffic data (see 4.3) and consistency in the subsequent analysis.

The approach identifies different design/ construction standards in relation to a functional road classification. Basically three categories of road are identified-primary, secondary and feeder and these are broadly related to three sets of design standard-Class, I,II and III respectively. Feeder roads feed into primary and secondary systems.

Most of the feeder roads are designed/constructed to class III (the minimum) standards, when the annual average daily traffic lies between 101-500 vehicles. Class III standards include a right-of-way width of 33.5m, formation width of 9.8m, and design speeds of 80 km/hr for flat and 32 km/hr for mountainous topography. Pavement width designs are based on a standard of 3.7m (12'), while shoulders are designed to 3.0m (10').

Agricultural sector roads, constructed under the Sixth Plan's farm-to-market road programme, are also designed to minimum highway department standards, but have

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* see NTRC Report No. 78 for a review of these standards

a reduced formation width of 7.3-8.5m and pavement width of 3.0m(10'). They can be viewed as an intermediate class of construction between class III (feeder) roads and district council roads.

District roads represent the lowest level in the formal road hierarchy. They are developed on the basis of simple earth tracks, being progressively maintained and upgraded as traffic demand grows and funds become available. District roads may be selected (in terms of alignment), for improvement to provincial roads, eg. under the farm-to-market road programme, when class III standards would be adopted for design and construction.

Table 1 provides details of roads by length and surface type in Punjab province. District roads make up over 51% of total kilometres, while provincial roads, including agricultural sector roads, comprise about 35%. By comparison, national and municipal (urban) roads in aggregate constitute less than 14% of the total.

Feeder roads, which form part of the provincial road category, are constructed with a 3-coat bituminous surface treatment. This is brought out in the data which indicate that all provincial roads (excluding agricultural sector routes) are black-topped. A similar standard of surface treatment for agricultural sector roads is clearly envisaged by the provincial highway department.(14) Although some 18%

of these roads have an earth or shingle surface, by far the majority (82%) are black-topped. In contrast, over 75% of district roads have a basic earth surface, with only 19% having a black top.

4.3 Traffic Data

The principal data source used in the study is the Punjab Highway Department's annual traffic data summary.(15) The Department, through its Planning and Design Directorate, has been conducting a province-wide programme of manual classified and some automatic machine counts since 1965. Counts at over 350 stations on provincial roads were carried out in 1983. Duration of counting varies from year-round counts at permanent stations eg. Ravi Bridge, Lahore on the primary Grand Trunk (GT) Road, to single day 24-hour counts at temporary stations on tertiary agricultural sector roads.

Seven different categories of vehicles are counted as follows:

a) animal-drawn vehicles
b) motorcycles, scooters, rickshaws
c) motor cars
d) passenger buses
e) trucks
f) tractors/trailers
g) trailer units, NLC* trucks, tankers

Prior to 1980, data on bicycles were also collected.

* NLC: National Logistic Cell (a government freight transport agency)

Animal-drawn vehicles include horse-drawn tongas and bullock carts. Rickshaws are three-wheeled motorised vehicles, mainly carrying passengers in urban areas. The category of cars incorporates taxis, pick-ups and wagons (mini-buses). Trucks are mainly diesel-powered, with a 10-ton maximum loading capacity; in this study they are combined with category (g) which includes tankers and trailer units. Tractor/trailer combinations and animal-drawn vehicles are used for both passenger and freight transport, particularly in rural areas.

A total of 69 feeder roads have been identified in the Punjab,[16] for which 1983 traffic data are available. In addition, data were also collected for the first time in 1983 on 18 agricultural sector roads. For comparison of historical trends in volume and composition on feeder roads, together with information on bicycle flows, 1974* and 1979** data have also been analysed.

Annexures 1 and 2 provide details of feeder and agricultural sector roads respectively, along with information on number of traffic counts condected and resulting ADT estimates.

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* the earliest year for which count station numbering and location is compatible with 1983 data (64 stations)

** the latest year for which bicycle data are available (69 stations)

5. RESULTS

5.1 ADT Volumes

Traffic flow levels have been grouped in accordance with Punjab Highway Department's road classification recommendations which relate to three classes of design/construction standard. Feeder road designs approximate to class III standards with design flow levels of 101-500 vehicles per day.

Table 2 provides details of flow levels (motorised and non-motorised traffic)* on 69 feeder roads and 18 agricultural sector roads. The data indicate that there were no designated feeder roads in the Punjab with a traffic volume lower than 101 vehicles per day. Only 20% carried traffic volumes appropriate to their design class. On the other hand nearly 60% of feeder roads were carrying volumes of between 501-1500 vehicles per day and a further 20% carried volumes in excess of 1500 vehicles per day, which are more appropriate to higher design standards. ADT on feeder roads in the 101-500 flow range was 397 vehicles per day, and for the 501-1500 range, 970 vehicles per day. Mean flow on all all feeder roads was 1171 vehicles per day.

The data in table 2 also show that a majority of agricultural sector roads (67%) carried traffic volumes

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* excluding bicycles

appropriate to feeder road design standards, though only one of these roads carried less than 101 vehicles per day. In contrast nearly 28% carried volumes in excess of 500 vehicles per day, more appropriate to the higher design standards. ADT on agricultural sector roads in the 101-500 flow range was 260 vehicles per day, with a mean for all roads of 339 vehicles per day.

5.2 Traffic Composition

Traffic composition has been analysed according to the flow levels identified in 5.1. Table 3 presents results for feeder roads.

On roads with flows of 101-500 vehicles per day, motorcycles and scooters were the largest group (22.2%), closely followed by cars (21.1%). Trucks and truck/trailer units were the next highest (18.9%), while buses accounted for 16.3%. Animal-drawn vehicles and tractor-trailer combinations made up 12.0% and 9.5% respectively, and represented over a fifth of all vehicles in aggregate.

On feeder roads in the 501-1500 vehicles per day group, a similar traffic mix can be seen. Motorcycles and scooters, followed by cars were the two main modal categories making up 23.8% and 21.5% of total vehicles respectively. Somewhat surprisingly, animal-drawn vehicles was the third largest group with 17.0%, followed by trucks

and truck/trailer units (16.7%) and buses (13.8%). In aggregate animal-drawn vehicles and tractor trailer combinations accounted for nearly a quarter of total traffic.

Where flows reach levels of more than 1500 vehicles per day, motorcycle and car traffic increases at the expense of other modes. The two largest categories accounted for over 57% of total traffic, while trucks and buses in aggregate comprised 25%. Animal-drawn vehicles and tractor-trailer combinations were reduced to less than 20% in aggregate, though the former group still accounted for more vehicles than buses.

Overall the proportion of motorcycles/scooters and cars increased with increases in total traffic, while that of buses, truck/trailer units and tractor/trailer combinations declined. Animal-drawn vehicle flows were inconsistent, first increasing until volumes reached 501-1500 vehicles per day, before declining when higher volumes were attained. On 32% of all feeder roads (22 roads), animal-drawn vehicles represented the first or second largest modal group.

A somewhat different picture emerges when agricultural sector roads are analysed (table 4). On one road with a flow less than 101 vehicles per day, by far the majority were cars, followed by motorcycles and scooters. All other modes accounted for less than 10%. Traffic

composition on roads with flows in the feeder design range of 101-500 vehicles per day showed similar characteristics, with nearly 58% of the total being made up of cars (31.4%) and motorcycles (26.5%). Animal-drawn vehicles were the next largest group (18.5%), while trucks and buses made up less than 10% each. In aggregate animal-drawn vehicles and tractor-trailer combinations accounted for over a quarter of total traffic.

At the higher flow level, the two most popular groups were motorcycles and scooters (29.9%) and animal-drawn vehicles (28.5%). Cars and buses were next in size, making up 16.7% and 11.1% of the total respectively. Trucks accounted for only 5.4%, while tractor-trailer combinations comprised 8.4%. In aggregate, animal-drawn vehicles and tractor-trailers made up well over a third of traffic flows at this level.

In contrast to feeder roads, the proportion of animal-drawn vehicles, buses and tractor-trailer combinations on agricultural sector roads increased with increases in volume, while that of cars declined. The proportion of motorcycles/scooters shows a similar pattern to that on feeder roads in that it increased with increases in total traffic, while that of truck/trailer units declined. Only nearly 45% of agricultural sector roads (8 roads) animal-drawn vehicles represented the highest or second highest modal group.

5.3 ADT Flow Trends on Feeder Roads*

Table 5 presents data on total flows** on feeder roads for the years 1974, 1979 and 1983. In comparison with 1983 data, traffic flow levels in 1974 and 1979 were lower for all 3 design classes. In 1974, 36 of the designated feeder roads (56%) carried traffic volumes appropriate to their design class, though this had decreased by about one third to 23 roads (33%) by 1979. ADT flows in this group were 310 vehicles per day in 1974 and 336 vehicles per day in 1979, with an average growth rate over 1974-83 of 2.8%.

Correspondingly, in the higher design class where flow levels reach 501-1500 vehicles per day, there were only 24 feeder roads in 1974 (37% of the total), compared with 38 in 1979 (55%) and 41 in 1983 (59%). ADT flows here reached 763 vehicles per day in 1974 and 884 vehicles per day in 1979. Annual average growth over the period 1974-83 was 2.7%.

At the extreme flow levels, only 2 (1974) and 1 (1979) feeder roads carried traffic lower than 100 vehicles per day, when ADT was 79 and 72 vehicles respectively. While fewer feeder roads carried traffic volumes in excess of 1500 vehicles per day, ADT was similar, reaching 2358 vehicles per day in 1974 and 2316 vehicles per day in 1979.

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* No traffic data are available for agricultural sector roads prior to 1983.

** excluding bicycles

Tables 6 and 7 present traffic composition data for the years 1974 and 1979 respectively. On roads with flows in the 101-500 vehicles per day group, trucks were the largest individual category, accounting for 28.7% in 1974 and 34.1% in 1979. Second in importance were buses with 28.3% and 23.7% in 1974 and 1979 respectively. Animal-drawn vehicles madeup 20.5% in 1974 and 12.3% in 1979. Cars and motorcycles in aggregate comprised only 22.5% of the total in 1974 though this had increased to 29.9% by 1979.

At the higher flow level of 501-1500 vehicles per day, trucks (27.8%) were again the largest group in 1974, while animal-drawn vehicles (25.5%) were second. Motorcycles and cars in aggregate accounted for only 26.3% but by 1979 the proportion had substantially increased to 38.8%. Although in 1979 trucks and animal-drawn vehicles had marginally declined to 23.3% and 22.4% respectively, they still represented the largest groups.

Interestingly, at the highest flow level of over 1500 vehicles per day, animal-drawn vehicles (24.0%) represented the largest modal group in 1974, with trucks second (23.3%). By 1979 trucks were the largest group (26.5%) with motorcycles second (24.0%). Cars made up 19.6% of the total and animal-drawn vehicles 18.7%. On 27 feeder roads (42% of the total) in 1974, animal-drawn vehicles made up the largest or second largest modal group. By 1979, this

proportion was only slightly down at 36% (25 roads).

Trends in the composition of traffic by main modal groups*, are shown in tables 8-10. The proportion of animal-drawn vehicles is seen to increase with increases in total traffic until the highest flow levels are reached, though over time the relative proportions have decreased (table 8). Data on tractors/trailers indicate a decrease in proportions as flows increase.

The proportions of both motorcycles and cars increase in relation to increases in volume, (if 2 extreme values are excluded). In contrast to the animal-drawn vehicle category however, the proportions in the traffic stream also increase over time (table 9).

Trends in the composition of buses and trucks are shown in table 10. The proportion of buses declines with increases in traffic volume and decreases over time. If the lowest flow level (< 101 vehicles per day) is excluded, the proportion of trucks to total traffic also decreases with increases in flows. At 2 flow levels (< 101 vehicles and 501-1500 vehicles per day) the proportion of trucks decreases over time, while at the remaining 2 flow levels, the proportion increases from 1974 to 1979, before declining in 1983. Mean truck flows however have decreased over time.

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* selected in terms of their effect on highway capacity and design standards-see Annex 3.

5.4 Bicycles

Data on bicycle flows are available for 1974 and 1979 and are shown in table 11. Where bicycles are included in ADT estimates, flow levels are substantially increased. However at the lowest flow levels, bicycles comprised only 18.1% of the total in 1974 and even less in 1979 when they made up 5.3%.

Where traffic levels approximated to the feeder road design class, the proportion of bicycles to total traffic was much higher, accounting for 48.4% in 1974 and 31.9% in 1979. Surprisingly as total traffic increased, the proportion of bicycle flows also increased, to make up 49.0% in 1974 and 42.3% in 1979. Even at the highest flow level, on roads with ADT over 1500 vehicles per day, bicycles still represented a high proportion of the total, accounting for 41.6% in 1974 and 41.0% in 1979.

While bicycle flows generally increased as ADT levels increased, their relative proportion in the traffic stream declined over time.

6. ACCURACY OF ADT ESTIMATES

6.1 Variability of Traffic Flows

Only where continuous counts are made under perfect conditions can a true ADT or total year's flow be computed with the expectation of its being absolutely accurate. It follows that any count of less than one year's duration must be regarded as a sample and the estimate of ADT or total year's flow made from it will be subject to error. Generally speaking, the longer the period over which samples are taken and the greater the frequency with which resurveys are accomplished, the more accurate the data will be.

Characteristically, traffic flows vary over time eg. from hour-to-hour, day-to-day, week-to-week, season-to-season etc. Also at any instant in time, the nature of traffic varies from place to place, urban or rural, and on different types of road at any given place. An understanding of the variability of traffic is therefore important as it permits insight into the duration and frequency of surveys necessary to obtain a particular level of accuracy.

A considerable amount of research into the variability of traffic flows in relation to both volume and time has been carried out in Kenya by the UK. Transport and Road Research Laboratory. Automatic counters recorded rural traffic flows continuously for a 2-year period* at 28 rural sites on bitumen, gravel and earth surfaced roads.

* regarded as not really long enough to reach firm conclusions

For a given duration of counting, repeated samples were drawn from actual flows recorded at each site in one complete year. From each estimated daily flow (ADT_E), the true value (ADT_T) was subtracted to give the error of estimate. The resulting errors were divided by ADT_T and multiplied by 100 to give the proportional error in percentage terms, for comparitive purposes.

Thus:

$$\text{proportional error of estimate} = 100\left(\frac{ADT_E - ADT_T}{ADT_T}\right) \text{ percent.}$$

Table 12 gives the errors in ADT estimates obtained from repeated random counts of varying durations in the Kenya study. Figures in brackets show errors for continuous counts of equivalent duration. The data indicate that repeated counts gave more accurate estimates of ADT than continuous counts of the same duration, the advantage increasing with the number of repetitions.

Generally, the errors in estimates fell as both the duration of counting and the ADT increased. There was a fall in errors when the duration of counting was extended from four weekdays to one full week, particularly at the high flow levels, ie. on roads serving regional or district centres with distinct weekend travel patterns. On the other hand, large errors were associated with counts of only a few days duration on low volume roads.

6.2 Accuracy of ADT.Estimates in Punjab Province

Table 13 provides details of the number of 24-hour counts carried out on feeder and agricultural sector roads in Punjab province in 1983. These are actual counts based on a count programme summarised in table 14. The majority of stations on feeder roads are designated semi-permanent(type V), with one 24-hour manual count in each quarter of the year (total 4). All stations on agricultural sector roads are temporary (type VI), with only one manual count being taken per year. On a few feeder roads, permanent (type IV) or semi-permanent (type III) stations are established, with manual counts for one week in one month and one day in each of the remaining 11 months (total 18) being planned. Exact dates of counts were not available.

Evidently the 1983 programme was not completed as scheduled, possibly due to experimental errors at individual sites, lack of resources and for other reasons.(17) However, the availability of data on the number and duration of counts together with the estimates of ADT, allows for a comparison with the Kenya data, bearing in mind the different road and traffic conditions found in Pakistan.

On the one agricultural sector road in the Punjab with a flow level of less than 75 vehicles per day, errors in the ADT estimate of over 60% may be expected. The vast majority of agricultural sector roads experience flows in the

75-600 daily traffic ranges errors in ADT. estimates for single 24-hour counts on these roads however, could still be of the order of ± 40%.

At 56% of stations on feeder roads, single daily counts were repeated 4 times per annum. Where flow levels reached 201-600 vehicles per day, errors in ADT estimates of about 20% could be possible, while at the higher flow levels, lower errors of around ± 14% could be expected. At the highest flow levels and for counts repeated four times, the errors in estimates would approach ± 10%. On the other hand where counts of only 2 or 3 days (rather than the programmed 4 days) were conducted, larger errors would probably be found.

On the 22% of feeder roads where counts were made for more than 4 days per year (ie. 1x4+ repetitions), errors in ADT estimates could be expected to be smaller than those observed above, though precise details of count programming are not available. For example it has not been possible to determine whether counts of 7 days or longer included one full week's count, 7 separate daily counts or some combination of weekly and daily counts.

6.3 Desirable Accuracy of Estimates of Traffic Flow

In the USA. the accepted standard is that there should be only a 1 in 20 chance (5 percent level of probability) that the error of estimate will exceed ± 10 per cent at any

sample count site carrying over 500 vehicles per day. For roads with lower flows, errors of up to ± 20 per cent are acceptable.(18)

It might be felt that developing countries cannot afford such high standards, since the more accurate estimates should be, the greater will be the cost in obtaining them. Conversely, Howe argues that accuracy standards should tend towards higher rather than lower limits, even for roads with low traffic flows. This view is particularly relevant in relation to the Pakistani farm-to-market road programme and the adoption of stage construction techniques.

The farm-to-market programme involves the upgrading of district-type roads and tracks to agricultural sector type-roads. Initially earth or shingle roads are provided, depending on soil conditions and there after bituminous surfacing is added when justified from a traffic point of view. A reasonable standard of traffic estimation is therefore required, even for roads with low traffic flows. Lowering the confidence limits at which estimates are judged does not seen to be worthwhile, since the results rapidly lose any significance.

If ± 10% is taken as an acceptable limit of accuracy for ADT estimates, it is likely that none of the counts examined here would fall within desirable levels, particularly on roads with low volumes. The highest levels

of accuracy can be assumed where 12 daily counts were conducted on one road with a flow range of 601-1000 vehicles per day and where 10 daily counts were carried out on roads with over 1000 vehicles per day. At these stations, errors in ADT estimates of the order of 12-15% could be expected. Howe points out that if made manually, neither simple random counts nor replicated random counts of any practicable duration can provide estimates of ADT within acceptable limits.

6.4 Variation in Traffic Characteristics for Roads of the Same Classification

It is also desirable to know whether roads of the same classification have similar traffic characteristics. To examine this possibility, an analysis of traffic volumes approximating to feeder road design standards (ADT < 500 vehicles per day) was carried out. Results are given in table 15.

As may be expected the variability of total traffic was relatively low, given the ADT limit examined. The largest variation is observed in the number of trucks, followed by animal-drawn vehicles, buses, motorcycles and tractors/ trailers. The lowest variation was found in the number of cars. It may be concluded therefore that for the majority of vehicle types on feeder roads with less than 500 ADT, there is wide variation in flows from one road to another and that some roads can experience extreme values.

7. SUMMARY AND CONCLUSIONS

The Government under the Sixth Plan proposes to implement a large programme of tertiary rural road construction including farm-to-market roads. Important variables in the selection of design standards and surface types for these roads include the volume and composition of traffic. In order to provide information on these variables, traffic flow and composition characteristics of 69 feeder roads and 18 agricultural sector roads in Punjab province have been examined.

The study revealed that a majority of feeder roads carried traffic volumes which were more than double their ADT design flow of 101-500 vehicles per day. The mean flow of 1170 vehicles per day is more appropriate to secondary road design standards. On most agricultural sector roads, which are designed to lower standards than feeder roads, volumes had already reached levels where higher standards could be applied. On a third of these roads, ADT was over 500 vehicles per day.

When data on all forms of motorised and non-motorised transport were available, bicycles were found to constitute the largest group, making up 40% of traffic on feeder roads. Animal-drawn vehicles, the other main mode of non-motorised travel, were also found in large numbers on some roads. In 1983 they accounted for nearly 15% of all traffic on feeder roads and about 25% on agricultural sectors roads. Flows of non-motorised

vehicles tended to increase as ADT increased up to 1500 vehicles per day, though since 1974 the proportions of these vehicles relative to other modes have declined.

The most important motorised modes on both feeder and agricultural sector roads were cars and motorcycles, which in aggregate comprised about a half of total traffic in 1983. The proportions of these vehicles have steadily increased with increases in volume since 1974, though on agricultural sector roads, the proportion of cars decreased as total volumes increased.

The proportions of buses and trucks in the traffic stream have declined since 1974, when in aggregate they made up about 50% of the total on feeder roads. By 1983 the proportion was 28% on feeder roads and 16% on agricultural sector roads. The proportions of buses and trucks also decreased as total volumes increased, though on agricultural sector roads the proportion of buses increased as flows increased up to 1500 ADT.

In terms of the accuracy of ADT estimates, errors of the order of ± 10-20% can be expected from the majority of counts conducted on feeder roads. For counts on agricultural sector roads, errors in ADT estimates of about ± 40% are probable. On all roads with volumes of less than 500 ADT, variation in ADT flows was about ± 40%. For individual modes however, (trucks, animal-drawn vehicles and buses), variation

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Table 1. Roads in Punjab Province by Length and Surface Type 1983

Road Responsibility	Length by Surface Type (Km) Black-top	Brick Paved/Shingle	Earth	Total
Provincial	11,476.07	-	-	11,476.07
-Agricultural Sector	2,174.83	58.42	412.31	2,645.56
District	3,855.65	956.64	15,866.64	20,678.93(1)
National	1,046.24	-	-	1,046.24
Municipal	3,862.83	356.42	310.80	4,530.05(1)
Total	22,415.62	1,371.48	16,589.75	40,376.85

(1) data for 1981.

Source: Road Statistics, Punjab Highway Department 1983.
Transport Bulletin (Supplementary No. 1) ,NTRC Report 74, 1981.

Table 2. Average Daily Traffic[1] Volumes on Feeder and Agricultural Sector Roads 1983

Flow Level (Vehicle/day)[2]	Design Class	Feeder Roads No	Feeder Roads ADT	Agricultural Sector Roads No	Agricultural Sector Roads ADT
< 101	-	-	-	1	66
101-500	III	14	397	12	260
501-1500	II	41	970	5	584
> 1500	I	14	2535	-	-
		13	2050[3]		
Mean Flow		69	1171	18	339

(1) exc. bicycles

(2) 24-hour counts

(3) excludes one station with 8837 ADT

Source: Summary of Traffic Data for Punjab Highways 1983, Punjab Highway Department.

Table 3. Traffic Composition by ADT Flow Level on Feeder Roads 1983

Flow Level (vehicles/day)	Animal-Drawn Vehicles %	Motorcycles, Scooters, Rickshaws (1) %	Motor Cars %	Buses %	Trucks Trailer Units (2) %	Tractors/ Trailers %	Total Flow No.
< 101	-	-	-	-	-	-	-
101-500	12.0	22.2	21.1	16.3	18.9	9.5	5559
501-1500	17.0	23.8	21.5	13.8	16.7	7.2	39768
> 1500	11.9	28.8	28.6	10.3	14.7	5.7	35485
	(12.1	24.9	28.5	11.4	16.7	6.3	26648 (3)
Mean	14.4	25.9	24.6	12.4	16.0	6.7	1171

(1) motorised 3-wheel passenger vehicle

(2) includes MLC double truck, tankers

(3) excludes one count with ADT 8837 vehicles

Source: Summary of Traffic Data for Punjab Highways 1983, Punjab Highway Department.

Table 4 Traffic Composition by ADT Flow Level on Agricultural Sector Roads 1983

Flow Level (vehicles/day)	Animal-Drawn Vehicles %	Motorcycles Scooters, Rickshaws (1) %	Motor Cars %	Buses %	Trucks, Trailer Units (2) %	Tractors/ Trailers %	Total Flow No.
< 101	-	25.8	65.2	3.0	-	6.0	66
101-500	18.5	26.5	31.4	7.3	8.9	7.4	3117
501-1500	25.5	29.9	16.7	11.1	5.4	8.4	2918
> 1500	-	-	-	-	-	-	-
Mean	23.1	28.1	24.8	9.0	7.1	7.9	339

(1) motorised 3-wheel passenger vehicle

(2) includes NLC double truck, tankers

Source: Summary of Traffic Data for Punjab Highways 1983, Punjab Highway Department.

Table 5. Average Daily Traffic(1) Volumes on Feeder Roads 1974-1983

Flow Level (Vehicles/day)(2)	1974		1979		1983	
	No.	ADT	No.	ADT	No.	ADT
< 101	2	79	1	72	-	-
101-500	36	310	23	336	14	397
501-1500	24	763	38	884	41	970
> 1500	2	2358	7	2316	14	2535
Mean Flow	64	537	69	835	69	1171

(1) excludes bicycles

(2) 24-hour counts

Source: Summary of Traffic Data for Punjab Highways 1974, 1979 and 1983, Punjab Highway Department.

Table 6 Traffic Composition by ADT Flow Level on Feeder Roads 1974

Flow Level (vehicles/day)	Animal-Drawn Vehicles %	Motorcycles, Scooters, Rickshaws %	Motor Cars %	Buses %	Trucks %	Total Flow No.
< 101	12.7	3.2	14.5	44.3	25.3	158
101-500	20.5	7.7	14.8	28.3	28.7	11157
501-1500	25.5	10.2	16.1	20.4	27.8	18307
> 1500	24.0	19.1	20.0	13.5	23.3	4716
Mean	23.0	10.6	16.2	22.2	27.4	537

(1) data on tractors/trailers not available

Source: Summary of Traffic Data for Punjab Highways 1974, Punjab Highway Department.

Table 7. Traffic Composition by ADT Flow Level on Feeder Roads 1979

Flow Level (vehicles/day)	Animal-Drawn Vehicles %	Motorcycles, Scooters, Rickshaws %	Motor Cars %	Buses %	Trucks %	Total[1] Flow No.
< 101	1.4	26.4	16.6	41.7	13.9	72
101-500	12.3	13.0	16.9	23.7	34.1	7727
501-1500	22.4	17.8	21.0	15.5	23.3	33582
> 1500	18.7	24.0	19.6	11.2	26.5	16213
Mean	20.0	18.9	20.1	15.4	25.6	835

(1) data on tractors/trailers not available

Source: Summary of Traffic Data for Punjab Highways 1979, Punjab Highway Department.

Table 8. Proportion of Animal-Drawn Vehicles and Tractors/Trailers by ADT Flow Level on Feeder Roads 1974-83

Flow Level (vehicles/day)	% of total traffic			
	Animal-Drawn Vehicles			Tractors/Trailers
	1974	1979	1983	1983
< 101	12.7	1.4	-	-
101-500	20.5	12.3	12.0	9.5
501-1500	25.2	22.4	17.0	7.2
> 1500	24.0	18.7	11.9	5.7
Mean	23.6	20.0	14.4	6.7

Source: Summary of Traffic Data for Punjab Highways, 1974, 1979 and 1983, Punjab Highway Department.

Table 9. Proportions of Motorcycles and Cars by ADT Flow Level on Feeder Roads 1974 - 83

Flow Level (vehicles/day)	% of total traffic Motorcycles			Cars		
	1974	1979	1983	1974	1979	1983
< 101	3.2	26.4	-	14.5	16.6	-
101-500	7.7	13.0	22.2	14.8	16.9	21.1
501-1500	10.2	17.8	23.8	16.1	21.0	21.5
> 1500	19.1	24.0	28.8	20.0	19.6	28.6
Mean	10.6	18.9	25.9	16.2	20.1	24.6

Source: Summary of Traffic Data for Punjab Highways, 1974, 1979 and 1983, Punjab Highway Department.

Table 10. Proportions of Buses and Trucks by ADT Flow Level on Feeder Roads 1974 - 83

Flow Level (vehicles/day)	% of total traffic					
	Buses			Trucks(1)		
	1974	1979	1983	1974	1979	1983
< 101	44.3	41.7	-	25.3	13.9	-
101-500	28.3	23.7	16.3	28.7	34.1	18.9
501-1500	20.4	15.5	13.8	27.8	23.3	16.7
> 1500	13.5	11.2	10.3	23.3	26.5	14.7
Mean	22.2	15.4	12.4	27.4	25.6	16.0

(1) inc. trailer units, NLC trucks, tankers

Source: Summary of Traffic Data for Punjab Highways, 1974, 1979 and 1983, Punjab Highway Department.

Table 11 : Bicycle Flows on Feeder Roads 1974 and 1979

Flow level (Vehicles(1)/ day)	1974 ADT(1)	1974 ADT(2)	1974 Bicycles % of ADT(2)	1979 ADT(1)	1979 ADT(2)	1979 Bicycles % of ADT(2)
< 101	79	96	18.1	72	76	5.3
101-500	310	601	48.4	336	494	31.9
501-1500	763	1495	49.0	884	1533	42.3
> 1500	2358	4038	41.6	2316	3925	41.0
Mean	537	1028	47.8	835	1408	40.7

(1) exc. bicycles

(2) inc. bicycles

Source: Summary of Traffic Data for Punjab Highways 1974, 1979 Punjab Highway Department.

Table 12: Errors in ADT Estimates from Repeated Random Counts of Varying Duration (per cent)

Flow Level (vehicles/day)	Repetitions	Duration of Counting: Number of Weekdays 1	2	3	4	1 Week
< 75	1	62	52	47	44	36
	2	47 (52)	36	31	29	24 (33)
	3	34 (47)	28	26	24	18
	4	26 (46)	24	22	20	16 (31)
75-200	1	43	37	35	31	27
	2	28 (37)	23	24	21	18 (24)
	3	24 (35)	19	17	16	14
	4	19 (32)	17	16	14	12 (20)
201-600	1	40	36	33	32	26
	2	33 (36)	28	25	22	18 (24)
	3	23 (33)	22	18	17	14
	4	22 (33)	20	16	15	12 (20)
601-1000	1	30	29	29	26	21
	2	19 (29)	16	18	17	14 (18)
	3	16 (29)	16	16	14	11
	4	14 (27)	11	12	12	10 (14)
>1000	1	31	29	29	25	16
	2	18 (29)	18	17	15	13 (14)
	3	16 (29)	16	15	13	12
	4	14 (29)	11	12	11	7 (12)

Note: Figures in brackets are for continuous counts of an equivalent duration.

Source: Howe JDGF. A Review of Rural Traffic - Counting Methods in Developing Countries, 1972.

Table 13. Summary of Traffic Count Programme in Punjab Province 1983 Feeder and Agricultural Sector Roads by Duration of Count and Flow Level

Flow Level (vehicles/day)	Duration of counting (No. of 24-hour counts)												Total Feeder Roads
	1*	2	3	4	5	6	7	8	9	10	11	12	
< 75	1	-	-	-	-	-	-	-	-	-	-	-	-
75-200	5	1	-	-	-	-	-	-	-	-	-	-	1
201-600	11	-	6	7	3	1	-	-	-	-	-	-	17
601-1000	1	1	4	12	-	1	1	-	-	-	-	1	20
> 1000	-	-	3	20	2	-	2	-	2	2	-	-	31
	18*	2	13	39	5	2	3	-	2	2	-	1	69

* agricultural sector roads

Source: Punjab Highway Department, Summary of Traffic Data for Punjab Highways 1983.

Table 14 Description of Traffic Count Stations in Pakistan

Station No. and Type	Description of Counts	
	Machine Counts	Manual Classified Counts
(I) Permanent	Continuously for the year (Econolite Graphic Traffic Counting Machine)	One week in each quarter and one day in the remaining eight months (Total= 36 daily counts)
(II) Permanent	Continuously for the year (Junior Digital Traffic Counting Machine)	One week for one month and one day in each of the remaining 11 months (Total=18 daily counts)
(III) Semi-Permanent	Alternate quarters(Junior Digital Traffic Counting Machine)	One week for one month and one day in each of the remaining 11 months . (Total=18 daily counts)
(IV) Permanent	-	One week for one month and one day in each of the remaining 11 months (Total=18 daily counts)
(V) Semi-Permanent	-	One day in each quarter of the year (Total=4 daily counts)
(VI) Temporary	-	One day in the year (Total=1 daily count)

Source: M. S. Swati and M. K. Idris. Traffic Factors for Pakistan 1982.

Table 15. Variability of Traffic on Roads < 500 ADT
Punjab Province 1983

Vehicle Type	% of Total	Arithmetic Mean ($\bar{x}$)	Standard Deviation(σ)	$\sigma/\bar{x}$
Animal-Drawn Vehicles	14	47	39	0.8
Motorcycles, Scooters	24	76	55	0.7
Cars	26	83	36	0.4
Buses	13	43	32	0.7
Trucks	15	49	52	1.1
Tractors/ Trailers	9	28	19	0.7
Total:		319	127	0.4

Note: no. of feeder roads = 14

no. of agricultural sector roads = 13

total roads <500 ADT = 27

Annex 1 Feeder Road Inventory Punjab Province 1983

Sl. No.	Station No.	No.of 24-hour counts	Section of Road/ Location	Section Length (km)	ADT(1)
1.	201-502	4	Murree-Barian/km 1	10	939
2.	201-505	4	Rawalpindi-Chakri/km 5	43	889
3.	201-506	4	Rawalpindi-Kahuta/km 13	29	2161
4.	202-504	4	Basal-Attock/km 111	50	338
5.	202-505	4	Basal-Pindigheb/km 112	32	294
6.	202-508	4	Talagang-Jabba/km 43	43	745
7.	203-501	4	Jhelum-P.D Khan/km 5	79	923
8.	203-502	4	Dina-Mangla/km 5	16	2597
9.	203-503	4	Chakwal-Talagang/km 72	47	1526
10.	203-504	4	Choha Saiden Shah/Chakwal km 53	34	889
11.	203-505	4	Sohawa-Chakwal/km 66	71	613
12.	204-301	4	Rasool Barrage Link/km 1	02	901
13.	204-503	3	Chak Mano-Qadirabad/km 1	16	498
14.	204-504	4	Gujrat-Bhimber/km 5	35	1425
15.	204-505	4	M.B. Din-Rasool/km 13	14	1327
16.	204-506	4	Rasool-Kharian/km 40	39	2710
17.	204-508	4	Gojra-Malikwal/km 1	24	373
18.	205-301	7	Bhai Phero-Khunda More/km 8	21	645

(1) excludes bicycles

Sl. No.	Station No.	No.of 24-hour counts	Section of Road/ Location	Section Length (km)	ADT(1)
19.	205-501	4	Lahore-Wahga/km 14	18	8839
20.	205-502	4	Lahore-Badian/km 14	24	1743
21.	205-503	4	Lahore-Harike/km 1	23	1444
22.	205-504	3	Raiwind-Manga/km 1	15	408
23.	205-506	4	Niazbeg-Raiwind/km 17	25	1907
24.	205-508	4	Kasur-Hussainiwala/km 56	13	1172
25.	205-509	4	Raiwind-Kasur/km 3	28	677
26.	205-510	3	Raiwind-Lulliani/km 1	17	464
27.	206-301	6	Marala Barrage/km 19	20	376
28.	206-403	9	Wazirabad-Samberial/km 22	24	1303
29.	206-404	10	Samberial-Sialkot/km 26	22	1741
30.	206-501	4	Duska-Pasrur/km 1	29	1216
31.	206-502	4	Motra-Badiana/km 1	18	940
32.	206-503	4	Samberial-Daska/km 15	17	1767
33.	206-505	4	Sialkot-Zafarwal/km 6	40	1264
34.	206-506	4	Sialkot-Pasrur/km 6	32	2459
35.	206-507	4	Pasrur-Narowal/km 1	31	875
36.	206-508	3	Narowal-Zafarwal/km 3	26	723
37.	207-501	4	Shahdara-Maqboolpura/km 1	32	1356
38.	207-502	3	Mangtanwala-Nankana/km 1	17	477

Sl. No.	Station No.	No.of 24-hour counts	Section of Road/ Location	Section Length (km)	ADT(1)
39.	207-503	5	Sheikhupura-Muridke/km 31	23	1008
40.	207-504	4	Muridke-Narowal/km 1	77	955
41.	208-501	4	Gujranwala-Alipur/km 3	37	1432
42.	209-502	4	Luk More-Jawerian/km 23	35	390
43.	210-503	3	Ghulaman-Rangpur/km 23	31	350
44.	210-504	2	Bhakkar-Darya Khan/km 365	16	858
45.	212-503	3	Rajana-Summandri/km 92	48	1764
46.	212-504	3	Rajana-Pir Mahal/km 93	16	1157
47.	212-505	4	Jaranwala-Syedwala/km 3	26	1356
48.	212-506	4	Faisalabad-Satiana/km 6	26	2547
49.	213-502	4	Abdul Kakim-Pir Mahal/km 150	42	542
50.	213-501	5	Tibba-Mailsi/km 1	35	528
51.	213-504	4	Burewala-Mian Channu/km 1	18	496
52.	213-505	3	Mian Channu-Abdul Hakeem/km 3	35	1325
53.	214-505	5	Sahiwal-Pak Pattan/km 43	47	1144
54.	215-504	4	KD. Qureshi-Kot Adu/km 29	45	1022
55.	215-507	3	Fatehpur-Karor/km 1	24	505
56.	215-509	3	Chowk Azam-Leiah/km 28	26	802
57.	215-511	3	Chowk Azam-Garh Maharaja/km 27	69	879

Sl No.	Station No.	No.of 24-hour counts	Section of Road/ Location	Section Length (km)	ADT(1)
58.	216-303	2	Kotla Nasir-Chacharan/km 132	8	158
59.	217-403	9	T.M. Pannah-Punjnad/km 512	37	1733
60.	217-302	6	Vehari-Hasilpur/km 14	50	603
61.	217-501	4	Bahawalpur-Yazman/km 3	31	1155
62.	217-504	5	Ahmadpur East-Uch Sharif/km 3	25	481
63.	218-501	4	Fortabbas-Yazman/km 1	80	538
64.	218-505	4	Chistian-Haroonabad/km 1	49	730
65.	219-405	12	Khanpur-R.Y. Khan/km 148	30	939
66.	219-406	10	Khanpur-Liaquatpur/km 142	64	1993
67.	219-501	5	Liaquatpur-Janpur/km 10	17	456
68.	219-502	4	Khanpur-Zahirpir-km 3	23	1236
69.	219-503	3	Khanpur-Nawankot/km 1	19	833

Source: Summary of Traffic Data for Punjab Highways 1983, Punjab Highway Department.

Annex 2 Agricultural Sector Road Inventory Punjab Province 1983

Sl. No.	Station No.	No.of 24-hour counts	Section of Road/ Location	Section Length (km)	ADT(1)
1.	201-616	1	Taxila-Thatta Khalil/km 1	10.5	387
2.	201-617	1	Khalsa-Sood/km 19	10.0	187
3.	202-602	1	Saghar-Tamman-Shah Modh.Wali Road	32.2	66
4.	205-607	1	Sundar-Raiwind/km 1	14.9	244
5.	206-608	1	Sialkot-Bhagowal-Philora Road/km 8	16.9	428
6.	207-608	1	Morraday Kilan-Mangtanwala/km 1	6.8	147
7.	208-601	1	Hafizabad-Sukheke/km 28	29.3	392
8.	209-619	1	Chak No. 132/SB-Chak No.135/SB	3.9	189
9.	209-620	1	Bhagtanwala-Chak 46/SB	11.3	526
10.	211-602	1	Rodu Sultan - Uch Gul Imam/km 1	12.1	116
11.	212-603	1	Chak Jhummra-Shah Kot Via Chak No. 156/R.B.	19.3	379
12.	212-604	1	Chak Jhummra-Sangla Hill	16.1	573
13.	213-612	1	Multan-Budhla Sant/km 8	10.4	730
14.	213-613	1	Multan-Dunyapur/km 1	20.9	513
15.	215-607	1	K.D. Qureshi-Jatoi Road/km 1	56.3	208
16.	215-608	1	Chak No.518/TDA-Pir Jaggi Road	9.6	196
17.	217-605	1	Mehrabwala-Chak No. 2440/DNB to Sahiwala Head Raj Khan/km 5	18.8	576
18.	219-610	1	Janpur-Thull Hamza/km 4	11.0	244

(1) excludes bicycles

Source: Summary of Traffic Data for Punjab Highways 1983, Punjab Highway Department.

Annex 3. Highway Capacity

The term highway capacity relates to the ability of a road to accommodate traffic. It is sometimes expressed in terms of passenger car units (pcu), which are identified by expressing buses, trucks, animal-drawn vehicles etc. in terms of the number of passenger cars they would displace under the prevailing road and traffic conditions.

The following pcu. equivalents have been identified by the Punjab provincial highway department.

	Type of Vehicle	PCU rating
1.	Bicycle	0.5
2.	Motorcycle, Scooter, Rickshaw, Car	1
3.	Passenger bus, truck	3
4.	Tractor trailer, trailer unit, NLC double truck, tanker	5
5.	Animal-drawn vehicle	7

Source: Punjab Highway Department, Summary of Traffic Data for 1980 and Highway Design Manual 1971.