GOVERNMENT OF PAKISTAN
PLANNING AND DEVELOPMENT DIVISION
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HIGHWAY SPEED SURVEY
1978

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GOVERNMENT OF PAKISTAN
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NATIONAL HIGHWAYS SECTOR
PROJECT PLANNING UNIT

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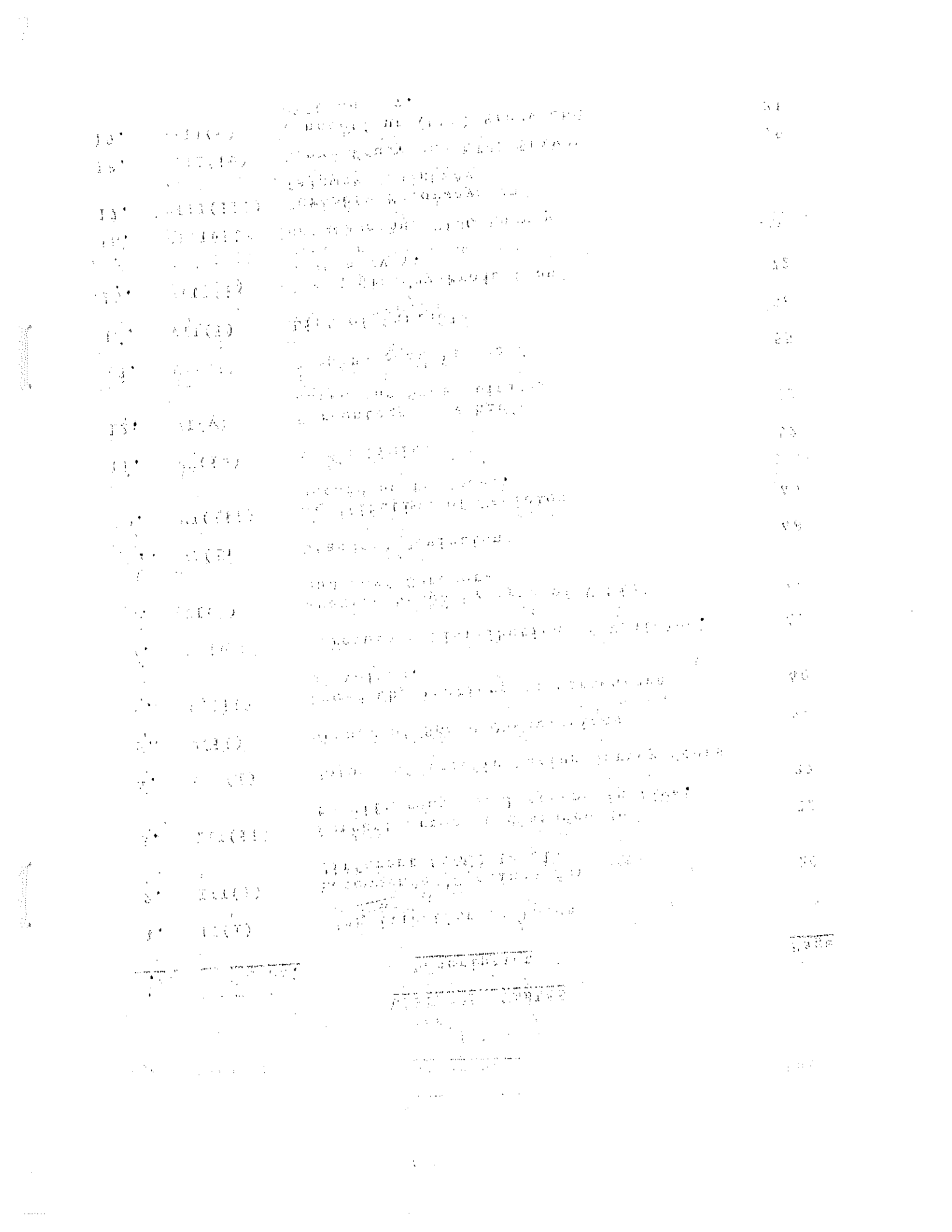


Chapter - I

INTRODUCTION

Increase in Vehicles and Road Networks

The last few decades have witnessed a tremendous increase in the number of motor vehicles all over the world. Simultaneously, the improvements in the methods of road construction and maintenance have resulted in expansion of hard surfaced road networks. The two together have placed at the disposal of mankind greatly increased abilities to move at higher and higher speeds and over wider geographical areas.

Pakistan is no exception to the above. During the last 1/3rd of a century, the length of hard surface roads has increased from 8,000 Km in 1947 to 33,000 Km in 1980 - a more than 4 times increase. The number of Motor Vehicles on road have increased from 30,000 in 1947 to more than 630,000 in 1980 - an increase of more than 20 times. This has tremendously increased geographical coverage and speed of movement of vehicular traffic in the country. The importance of vehicular traffic has therefore increased considerably for policy and planning purposes.

Importance of Speed

The speed of movement is central to many problems of transport. For example, the highway operating speeds, among other things, effect the following:

(a) Vehicle operating costs and through them investment in construction and improvement of highways.

(b) Wear and tear of roads and thereby cost of maintenance.

(c) The design and strength of road and bridge structures.

(d) Flow and capacity of the roads.

(e) Travel times and operating schedules of public service vehicles.

(f) Inter Modal distribution of traffic.

(g) The size of road markings, traffic signs and signals.

(h) Traffic management and safety measures.

The above list is only indicative. There are numerous other aspects where speed is of dominant importance.

Requirements of Various Agencies

The users, operators and public agencies responsible for planning, development, regulation and control of transport services are all interested in vehicle operating speeds. The interest of public authorities is in fact as old as the motor vehicle itself. Originally such an interest might have been due to their concern for safety of other users. However, with the increasing use of motor vehicles, other operational and economic considerations have assumed greater importance.

The information is now needed by various agencies for a variety of purposes. For example the agencies concerned with planning and development of infrastructure and transport services need the information for appraisal of highway investment projects, inter modal distribution policies etc. The agencies concerned with construction and maintenance of highways need the information for design of road and bridge structures, maintenance policies, determining capacities and speed flow relationships, design and size of road markings. The agencies concerned with operation of transport services, need the information for estimating operating costs and schedules, etc. Besides, enforcement agencies need the information for control of speed limits for road safety. In addition to above, the information also provides an important input for the transport models of various types and is of general interest to students of traffic engineering and transport economics.

Speed Cost Relationships

Among other things, the relationship between speed and costs is of particular importance and needs to be further elaborated. Various cost components behave differently with change in speed. For example, the fuel consumption is high both at very low and high speeds and is lowest at medium speeds.

Other physical cost components like, oil consumption, wear and tear of tyres, brakes, parts etc, increase with speed. On the other hand, time based costs like interest, depreciation, wages, as well as the value of time for drivers and passengers decrease with increase in speed. The end result would depend upon relative weights of physical and time based, cost components.

The place of value of time in operating costs is of significant importance. In the developed countries, 30 to 50% costs are in terms of value of time. This is, however, much less in developing countries where per capita income is low. In these countries physical cost components are more important.

However, both physical and time based cost components vary with speed, therefore, the operating speeds provide an important input in the vehicle operating costs which form basis for cost benefit analysis for the appraisal of Highway projects.

Investment Appraisals

Most of the investments in transport are aimed at increasing speeds of movement and reducing time and cost of travel in general. Particularly, the investment on highways are justified on the basis of savings in vehicle operating costs which vary with speed. Information on operating costs at varying speeds is available from technical literature of

vehicles and through various other studies. Therefore, estimates of operating costs for various roads can be made if information on speeds is available. In the absence of reliable information, various agencies concerned with planning and development of highways, while preparing transport projects, assume any speed levels for the existing and proposed facilities and calculate operating costs and savings using studies made in other countries. Such appraisals remain un-realistic and subject to errors of un-known extent.

Speed Information

Costs and Benefits of transport projects are based on operating speeds. The information on existing speeds can be obtained easily by actual measurements. However, what is not known is the speed that will result after improvement. There is therefore need for general information on speed for different types of roads which could be used to determine benefits of improvements etc. a general survey of highway operating speeds was called for.

Need for the Survey

In order to provide reliable estimates of vehicles operating speeds on highways in Pakistan for the appraisal of transport projects in general and highway projects in particular and to serve the needs. Various agencies concerned with planning, development of infrastructure and operation of transport services, a general survey of vehicle operating speeds has been carried out by the National Transport Research Centre. The results of the Survey are presented in this report.

CHAPTER - II

SCOPE AND COVERAGE

Data Collected

The survey collected information on spot speeds at selected points and volume of traffic both classified according to type of vehicle, with hourly intervals. Besides, width of the road sections was also measured at the observation points which were selected to represent the entire length of given road sections, as far as possible.

The specimen of forma used for recording speed observations and volume counts are given at the end(Annex-VIII). The scope and coverage of the survey are explained in this Chapter. The method used are explained in the next chapter.

Selection of Roads.

The survey covered 56 road sections in the Province of Punjab. A list of such roads indicating location of the survey point, pavement width at the survey point, date and time of observation is given at Annex-I. The roads have been arranged in order to width and where the width is the same, according to date of observation. The roads have been identified by the names of places at either end of the section, the place first named being nearer to survey point.

The confinement of the survey to the Province of the Punjab and particularly proximaty of Islamabad is mainly due to administrative convenience and ease of supervision. The later .....

aspect was more important for efficiency and accuracy of data. Administrative boundaries would hardly make any difference in operating speeds. The type of road is more important here. The data pertaining to one type of road is more important here. The data pertaining to one type of road will be applicable to similar roads at other places as well. It would therefore not make any difference if the data is collected in one Province or the other.

Location of Survey Points:

Operating speeds are effected by a large number of factors including type of vehicle, condition of road, volume of traffic, composition of traffic, e.g proportion of slow moving traffic and most important of all, training, experience and behaviour of the driver, etc. However, the most important economic and engineering factors effecting the speed of vehicles are the type of road and volume of traffic. In order ot isolate the effects of these two factors it was necessary to eliminate the influence of other factor such as rise, fall, curvatures etc. Accordingly, the survey points were located outside the built up areas where the road was level, tangent. Inter-sections, turns, bridges, culverts, or any other structures likely to detract the attention of drivers were avoided in order to find free moving speeds. Care was also taken that the survey points are typical of the road section and there is no such thing as to cause accelleration or slowing down in speed.

Survey Timings

The bulk of information was collected during the month of April and May, 1978. The observations were made in clear daylight, commencing usually between 0800 and 0900 hours and concluding between 1800 and 1900 hours. At some stations, the survey commenced or ended earlier.

Extreme weather can also effect the speed of vehicles particularly storms and rainfalls. During the survey period there was no such abnormal factor. In the early part of the survey, the summer was mild in the District of Rawalpindi and Jhelum. However, the part, the weather was quite warm in the District of Sahiwal, Jhang and Sargodha.

Classification of Roads.

The roads covered in the survey varied in width from 30 ft to 8 ft. For analysis of data, the roads were classified into four categories according to width of surface as follows:

Table II (i)

Classification of Roads

Category	Description/Specifications	No. of Road Sections
I	4 Lane Divided 30 ft or above width each way	2 road Sections included only Islamabad Highway
II	22-30 ft. wide undivided	11 road Sections
III	Two lane 18-22 ft. wide	29 road Sections
IV	Single Lane 8-12 less than 18 ft. wide.	14 road Sections
	Total	56 road Sections

Category III was first divided into two groups, one consisting of 17 road sections 20-22 ft. wide roads and the other covering 12 aoad sections of 18-12 ft. wide. As the difference between the two categories was quite small, these were combined together.

The width of road can vary over short distances. A road may be two to four lane wide near the city and get narrow as the distance from the city increases. The width recorded in the survey is that found at the observation point. At certain places, the pavements were so broken that it was difficult to find the precise width. There could be a difference of one to two feet depending upon whether the measurement is made at the broken edges or not. However, at such places two to three measurements were taken and average width was noted.

It would be seen from Annexure-I that some road sections appear more than once with alternating the names of places at the two ends. This is due to the fact that on such roads more than one observations were made, and the name of the place nearer to each observation point was given first. For example, on Sheikhupura/Faisalabad road one observation was made near Sheikhupura and the other near Faisalabad. In the first case, the name of road section has been described as Sheikhupura-Faisalabad Road and in the second case as Faisalabad-Sheikhupura Road. Incertain cases more than one observations were made at the same end of the road. In such cases, the same name appears more than once. Each survey point has been treated as a separate road section.

Classification of Vehicles

The classification of vehicles used for recording Volume Counts as well as for speed measurements, is briefly described below:

(i) Animal Drawn Vehicles: In this category there are two main types of vehicles viz; Bullock Carts and Tongas. The bullock cart has two large wooden wheels and is pulled usually by two animals. Some designs have place for one animal only. They move at 3 to 4 miles per hour speed. The Tongas are horse drawn vehicles with two large wooden spoked wheels with rubber band. It has a capacity for 4 to 6 passengers and moves at 8-10 miles per hour speed.

(ii) Pedal Cycle: Usual Cycles manually operated.

(iii) Motor Cycles: This category included Motor Cycles, Scooters, mopeds and rickshaws (Three wheeled vehicle). The last mentioned vehicle would be found on intercity roads very rarely. Therefore, separate calssification was not provided for these types of vehicles.

(iv) Cars: This category included all motor cars whether for private use or for hire i.e. taxis. Most of the cars in this country are small size ranging between 1200-1600 c.c. Larger cars more than 2000 c.c. are far and few. This is due to higher import duties on larger cars in Pakistan.

(v) Wagons: Mini buses, Pick ups, Light Commercial vehicles whether carrying passengers or goods. However, the greater proportion of vehicles in this category is of wagons which are mostly Ford Transit.

(vi) Buses: Buses on intercity roads are with very few exceptions, Bedford Six Cylender Diesel. Majority of these buses are on long chasses. However, some proportion is of relatively smaller size on short chasses. The registered capacity of the former is 52 passengers and of the latter 42 passengers.

(vii) Trucks: Trucks are also mostly Bedford Six Cylinder Diesel. They have maximum loading capacity of 10 tons. However, overloading is common. Tankers are also included in this category. Multi axle trucks are very rare.

(viii) Others: This category covers all other vehicles not included in the above classification. Most of the vehicles in this category are tractors with or without trailers.

The above classification corresponded closely to the vehicle fleet found on intercity roads. Volume counts covered all categories including Animal Drawn Vehicles and Padal Cycles while speed observations covered vehicles at (iii) to (viii) only.

Chapter - III

METHODOLOGY

Methods of Speed Measurements:

Various methods are available for the measurement of vehicle speeds and traffic flows. The use of one method or the other would depend upon the purpose in hand, type of information needed and the type of equipment used among the various sophisticated meachines available. For example, the regulation and enforcement of speed limits would require spot speeds. On the other hand, for determining level of service or effect of congestion, average speed on a road section would be needed.

Most of the speed measurements can be divided into two categories viz long base or short base. The long base measurements are made where information on journey time or journey speed and traffic delays is needed. On the other hand, short base measurements are made where information is needed on spot speeds, cruising speeds, free moving speeds or instant speeds. The methods for the two types of measurements are briefly described below so that the scope and methodology used for the survey are better appreciated.

Long Base Measurements:

The methods most commonly used for long base measurements are the Registration Number and Moving Observer Methods. These are briefly described below.

Registration Number Method:

Two observars equipped with synchronised watches are stationed at points between which journey times are to be measured. They will note down Registration numbers of vehicles and their time at which they pass each point. Subsequent comparison of records made by the two observers enables the estimation of journey time and speed over the road section.

Traffic can be sampled if the vulume is high. One method of sampling is to record only those registration numbers which end with a specified digit. This method is suitable where the distance is large at least more than half a mile.

Moving Observer Method:

As observer in a car can travel along the traffic stream on the given road section. This will give average journey time and speed for the section. This practice is followed on congested roads in urgan areas.

The observing car can also follow different vehicles on a road section and record there speeds. This practice has been used for speed measurements on rural roads and motor ways. Several other variations of the method have been used.

Short Base Measurements:

The methods and equipment used for short base measurements include speedometer, single/double observer method, enoscope, pressure, strips, radar, electronic equipment, areal photography etc. These are briefly described below, the method used in our survey being explained in more detail.

Speedometer:

The meter of the vehicle indicates speed at any time and place. It provides the closest approximation to spot speeds. A limitation of this method is that only the driver of a vehicle can see the speedometer. It is not accessible to out siders. However, an observer in a test vehicle can follow other vehicles and note their speeds. It may be added that as a vehicle moves, the needle of the Speedometer moves around depending upon changes in acceleration. When such movements are large, it may be difficult to determine the exact speed. Therefore, this method is not suitable when average speeds over a long route are needed. However, a test vehicle may follow vehicles found on the road for a while and note the speed. However, when the road section is small it may be difficult to follow other vehicles and to turn the test vehicle back and foth. In such cases, other methods may be more suitable.

Single Observer Methos:

The simpleat method for the measurement of speed of road vehicles on a small section is to mark a given distance on the road and record the time taken by vehicles to traverse this distance by means of a stop watch. The observer can be positioned at an elevated place between the two points so that the markings on the road are clearly visible to him. The observer can start the stop-watch as a vehicle enters the marked region and stop the watch when the vehicle leaves that portion and note the time. This has many advantages. The observations can be made at any place and the type of vehicle is recognised which is difficult with automatic machines. It costs less for surveys and studies of short duration.

One of the limitations of this method are that it give speed over a very small portion of the road which may or may not be representative of the road. section. For average speeds over longer sections other mehtods may have to be used.

This mehtod of observation is however subject to errors of parallax and fractional misjudgement particularly when working on short distances where a difference of even one second can make a large error in speed.

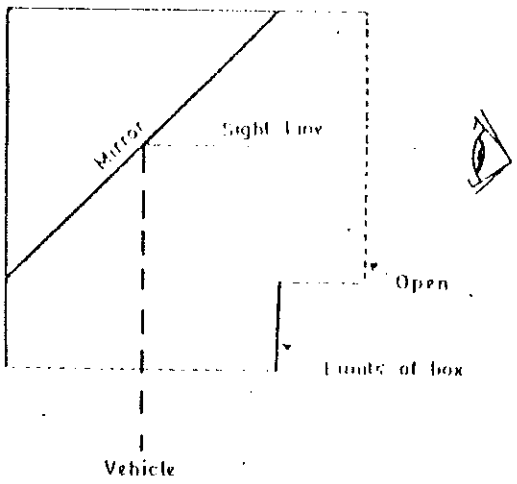
Two Observers:

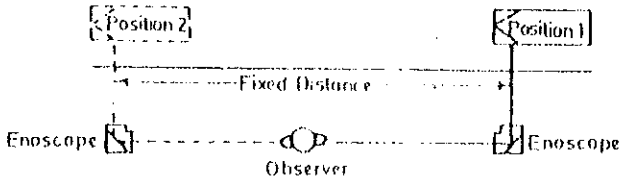
To reduce such errors of parallax, the distance between the two points can be incressed by placing two observers at each end. One observer can give signal to the other by waving his hand or a flag or lighting a torch as a vehicle passes near him end the second observer can start stop watch which he will stop when the vehicle reaches him. This will increase the time and reduce the errors of misjudgement. However, this method is also inefficient. The fractional misjudgement can increase due to reaction time of two observers. Besides, this method will be suitable only where the traffic volume is low as otherwise it would be difficult for the second observer to recognise the vehicle for which signal was given by the first observer. In such a case a signal observer will remain more suitable.

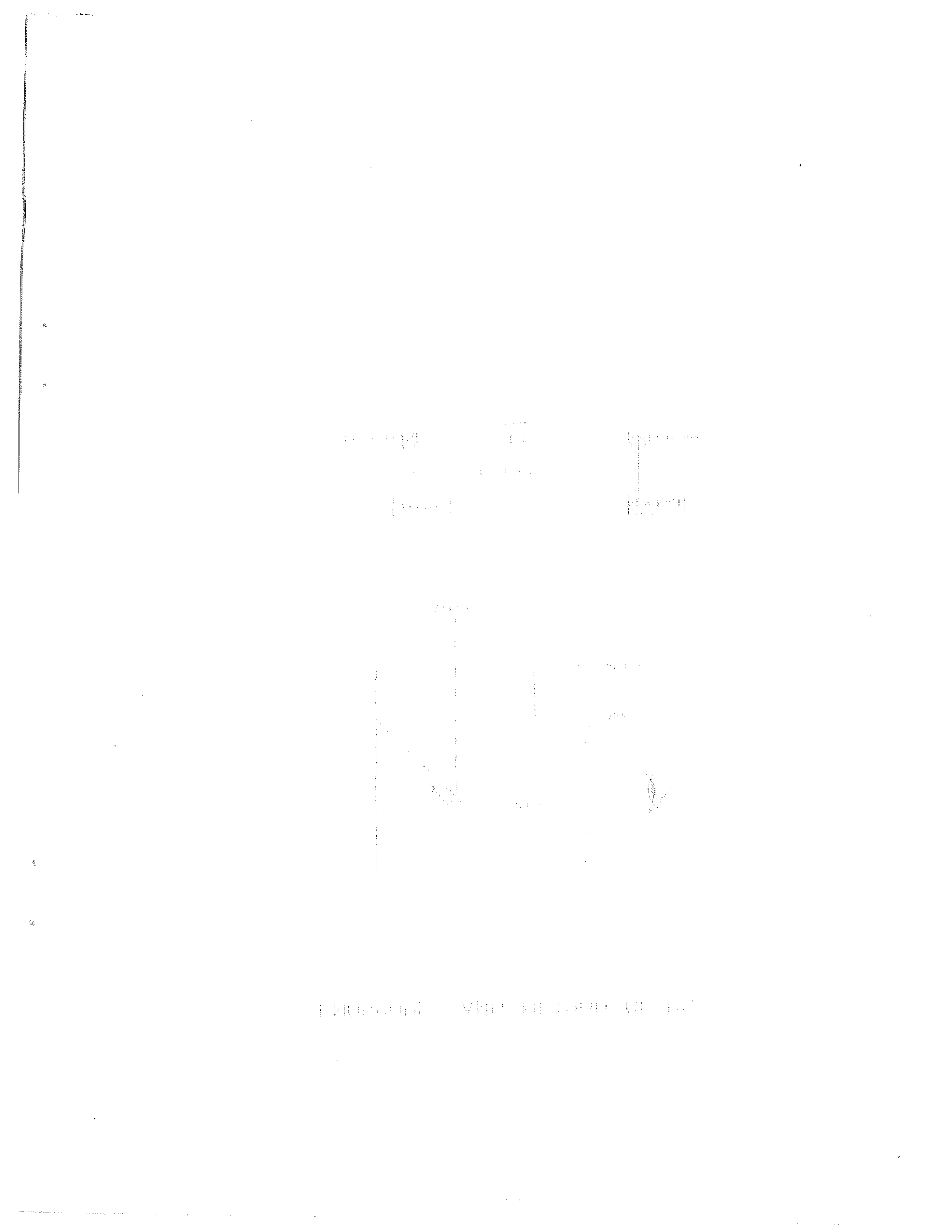
Enoscope:

To reduce the error of parallax, a very simple and small instrument i.e 'Enoscope' is used. This is a simple mirror box which when placed on the road side, bends the line of sight of the investigator to right angles to the path of movement of the vehicle as it enters or leaves the zone of measurement. As a vehicle passes, it casts a shadow on the mirror, and the stop watch is started or stopped. If the investigator

ENOSCOPE, AND METHOD OF USE







stations himself opposite one end of the zone, only one mirror box is needed. If two are used, the investigator may be anywhere between them. The design and use of the Enoscope are shown in the accompany of graph.

The Enoscope is not satisfactory in heavy, multi lane traffic because of difficulty in associating the observed shadow flash with a particular vehicle. Also it is sometimes difficult to conceal the mirror box and investigator from passing traffic. It is also liable to error due to reaction time for starting and stopping the watch. The difference of even one second can make considerable difference if the distance is small.

Automatic Equipment:

In order to avoid errors due to visual observation (Parallax) and manual operation of stop watch, equipment with Pressure-Contact Stripes, either pneumatic or electric, may be used. The passage of a vehicle actuates the stop watch. However, on multilane roads with high volume of traffic, such devices will give confusing results.

Radar:

More advanced methods employ radar transmitter receiver units which automatically record speeds. A graphic recorder can be attached with the radars. The equipment is however very expensive and not readily available in Pakistan.

Photography:

Time series of photographs similar to those employed in motion pictures have been used in special cases concerned with detailed analysis of the time space relationships in traffic. By projecting the film on especially prepared grid screens, the distance values are read. These are divided by the constant time differential between exposures to find spot speeds.

Recommended Spacings:

The visual observations whether with the help of Enoscope or otherwise and manual watch operations are liable to fractional error in recording time. Such an error can be reduced to within 3% to 5% by adopting the appropriate distance depending upon the speed of vehicles. The recommended spacings are as below.

Table III (i)

Recommended Spacing for different speed levels

Speed	Distance
25 mph	88 ft
40 mph	176 ft
60 mph	352 ft

The above distances are a multiple of 1.468 and can be varied accordingly. One of the advantages of above recommended distances is that they provide a constant number which when divided by the time taken by a vehicle to traverse the distance gives speed per hour. For example, the constant number for a distance of 88 ft is 60. If a vehicle takes 8 seconds to cross the distance, the speed will be 60/3 = 20 mph. Similarly, with 352 ft distance the constant number is 240 which when divided by the time taken by the vehicle will give speed in miles per hour. If the time is 6 seconds, the speed will be 40 mph and so. However, with the availability of small computers and calculating machines, any distance and time can be converted into speed without any problem of calculation.

Method Used:

The speed measurements for the survey were made manually by a Single Observer Methods. This method was more suitable for the purpose in

hand as the observers could be placed at any place. The method was also least expensive as the observations did not call for much experience and expertise. Brief instructions were sufficient. Besides, any of the equipment for speed measurements whether using pressure strips or radar type were not available and budgetary constraints did not allow expenditure on such equipment.

The procedure followed for speed measurements was as follows. Two white paint lines were drawn across the road section at a distance of 352 ft apart. An observer was positioned at an elevated place between the two markings with a stop watch. He would watch the on coming vehicle, start the watch as soon as the front wheels enter the marked line and stop the watch when the front wheels of that vehicle cross the second line. The time was recorded in seconds upto one decimal point in the form at Annexure I.

The distance of 352 ft. is recommeded for speeds over 40 mph for maximum accuracy. A larger distance would be less clearly visible while the shorter distance would result in larger error in recording time. The range of error due to measurement is further examined below.

Level of Accuracy:

As the speed measurements have been made manually the individual observations are not likely to be as accurate as one can have with electronic or

mechanically operated devices. Most of the stop watches have a division of .2 seconds. The difference in recording time is therefore likely to be one decimal point.

A simple calculation will show that a vehicle running at a speed of 25 mph will traverse a distance of 88 ft in 2.4 seconds and a difference of .1 second in recording time will result in an error of 4.0% in speed in mph. The error at the other speeds of 40 mph and 60 mph and with varying distances of 88 ft, 176 ft and 352 ft will be as follows:

Table III(ii)

Percent Error in distance due to difference of .1 second in time.

Speed	88 ft	176 ft	352 ft
25	4.1	2.0	1.0
40	6.6	3.3	1.6
60	10.1	5.0	2.5

It will be seen that for distance of 88 ft, the likely error due to a difference of .1 second in time will be 4.1% for vehicles at 25 mph, 6.6% for vehicles at 40 mph and 10.1% for vehicles at 60 miles per hour. When the distance is increased to 176 ft, the likely error is reduced to 2.0%, 3.3% and 5.0% for speeds of 25, 40 and 60 miles per

hour respectively. For a distance of 352 ft, the likely error will be further reduced to 1.0%, 1.6% and 2.5% at 25 mph, 40 mph and 60 mph respectively.

It would be seen th t higher speed levels are more sensitive to errors in time recording. A difference of one decimal point of second will result in a difference of 1% in speed per hour when the speed is 25 miles per hour. The error would be of 1.6% at 40 miles per hour and 2.·% at 60 miles per hour.

However, as a large proportion of vehicles falls in 30-50 miles per hour speed range, the likely error would be in the range 1.5% to 2%.

The random variations in recording time would cancel each other. Moreover, when the data is classified into groups, differences within the groups are absorbed into class intervals except those overlaping the class limits. These too would also cancel each other. Even otherwise their effect would be very small. The results would therefore be accurate with less than $\pm$ 2.0% variation.

Volume Counts:

In addition to speed measurements, information was also collected about the volume of traffic at places where speed observations were made. The method of making volume counts and the one used for the survey are briefly explained below.

Methods:

Volume counts can be made manually, by simple automatic machines and by more sophisticated electronic equipment. The use of one type of machine or the other will be determined largely by the purpose. The suitability of different methods for various purposes is briefly explained below.

Manual Counting:

This is the simplest method of measuring traffic flows. It involves counting all vehicles that pass a fixed point on a road. It requires no special skills, no setting up of machines, counting can be shifted from location to location at will. Vehicles can be classified according to type, according to time, etc. This is the cheapest method for short surveys. For surveys of longer duration, like the permanent counting stations, the manual counting becomes ardous and more expensive. In such cases automatic counting machines are more suitable. These can be supplemented by manual counts on sampling basis for vehicles classification.

The other draw backs of Manual Counting are its monotony, possibilities of missing the vehicles and miss-classification. Various agencies have, however, devised different types of forms to

overcome the monotony. In order to reduce the possibilities of miss-classification, description of vehicles is supplemented by sketches and photographs for easy recognition. A similar form was used in our survey.

Using this type of Form with upto 10 classes of vehicles, a normal Enumerator can deal with upto 800 vehicles per hour and an intelligent enumerator can, for shorter periods, count upto 2000 vehicles per hour.. However, it is best not to exceed 600 vehicles per hour. In our survey, except for the Islamabad Highway, hourly traffic volume did not approach this level.

Hand Tallies:

Re-settable hand-held counters, usually called hand tallies, are a useful aid to manual counts where a limited number of vehicel classification is sufficient. These hand tallies consist of a four-figure counter unit actuated by the movement of a push-button. The counters can be used singly or several linked together. The single hand tally is most frequently used for a straight forward count of total flow on a road as for carrying out a comparative check count at an automatic counter site. The multiple hand tally is commonly used for taking a classified count of total flow while other data are being collected, e.g. vheicle speeds. It can also be used in counting and classifying the opposing traffic streams in journey time surveys

by the moving-observer method. Vehicles overtaking or being over-taken by the test vehicle can also be counted in the same way.

Automatic Machines:

Automatic counters can be used continously over long periods and will count the number of axles passing a given point. The automatic counters can classify the numbers according to date and time. However, it is not yet possible to classify traffic according to type of vehicle. Therefore, supplementary manual counts are made when information of this nature is required.

the most advantageous use of traffic counters can be made in the measurement of long-term trends in flows at "permanent" counting sites like bridges etc.

The essentials of an automatic traffic counter are a means of detecting the passage of a vehicle and a device for counting. The detectors are of several types e.g. Positive contact, pneumatic, hydraulic, magnetic, photo electric, wire, capacitor, radar, ultrasonic or infraed. All the detector type counting machines merely record the number of axles.

The main draw backs of detector type counting machines are that vehicles cannot be classified in any way and vehicles with more than two axles cannot be compensated such as articulated trailers.

Besides, Vehicles running side by side cannot be distinguished so that there is under estimation on multilane highways.

When vehicles need to be classified, the machine counts are supplemented by manual counting on sample basis.

Method Used:

The Volume Counts for this survey were made manually. An observer other than the one recording speed, was posted near the place where speed measurements were made. Vehicles were classified into eight categories viz. Animal drawn vehicles, padal cycles, motor cycles, cars, wagons, buses, trucks and other vehicles. The form used contained separate columns for each category of vehicle. Every column had pre printed numbers which were crossed by the observer as a vehicle passed before him. Distinction was not made in the direction of traffic. For easy recognition and to reduce error of mis-classification, the description of vehicle types was supplemented by photo sketches. The specimen of form used is given at (Annexure IX).

Chapter - IV

DEFINITIONS AND CONCEPTS

Definition of Speed

The concept of speed involves movement of an object over some distance and this will require some time. The speed is thus the ratio of distance travelled to time of travel. More precisely, it is defined as

$$v = \frac{s}{t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (i)$$

Where 's' stands for velocity and represents speed of travel,

's' Stands for spece and represents distance of travel, and

't' is time of travel.

Given any two of the variables, the third can be found by solving the above equation.

Speed can be expressed in any size of units viz,, miles or kilometers per hour, feet or meters per second etc, etc. Speed can also be expressed either in terms of distance per unit of times as miles per hour or feet per second, or in terms of time per unit of distance as so many minutes to travel a distance of so many miles, meters etc.

In the case of motor vehicles, speed is most commonly expressed in terms of miles or kilometers per hour. Vehicle speedometers also indicate speed per hour.

The other expression of speed viz., time per unit of distance is used for ground measurements of speed. A given distance is usually fixed and time taken to traverse this distance is recorded. This is then converted into miles km/hour or ft/sec. etc.

There are different concepts of highway operating speeds. One are based on the length of distance used for speed measurements. These can be divided into two main groups. One are short base measurements and the other are long base measurements. Which have already been described in the preceeding chapter. The difference between the two groups is made by the length of distance used for measuring speed. There is however no clearest line of demarcation to indicate where one group begine and the other ends. On the one extreme, there is the spot speed which the speedometer of the vehicle indicates at any point in time and space. On the other extreme are the times recorded by observers at two ends of a road.

The other concepts are based on whether distance or time are used as a base. In the former case the distance is fixed and time taken by the objects varies as was the case in this survey. Alternatively, time can be fixed and distance traversed can vary as is expressed for speed in miles or kilometers per hour or ft per second.

There are still other concepts based on the methods of computation used. One method provides space mean speed and the other time mean speed.

Some of the frequently used concepts are briefly explained in the following paragraphs.

Spot Speed:

The speed has been defined as the ratio of distance to time. There should be some distance which will be travelled over some time however small it may be. It is most probable that speed over a given distance will either be increasing, decreasing or constant. However, by dividing the distance by time, we get an average speed. The distance used for measuring the speed may be quite small or large. However, when the distance gets smaller and approaches zero, the resulting speed is called the spot speed. The spot speed is thus speed at a point in space and moment in time. It may also be called the instant speed. The closest approximation to spot speed is provided by the speedometer of the vehicle which indicates speed at any moment of time and point in space. Measurements made by radar and electronic equipment also provide spot speeds. For manual measurements minimum distances for spot speeds extend upto hundreds of feet so as to be visible to an observer.

Journey Speed:

This is the average speed maintained by a vehicle over a given distance between the two journey points.

The distance may consist of a road section which may be of small length in an urban area but of several miles in rural areas. The time spent at stops on the way is excluded.

The difference between spot speed and journey speed is of degree only rather than of nature. In both cases, the speed is an average of distance for a unit of time. There are no hard and fast rules to determine the limit of distance for journey and spot speeds. The minimum length of distance will depend upon the capability of measuring instruments.

Time and Space Mean Speeds:

Speed measurements are often made in time units with distance being fixed, as so much time to cover a given distance. When more than one observations are involved and an average is required, there will be two methods of calculating this average. One is to average the individual times and then convert this average into speed as miles per hour. The second method is to first convert the individual times into speed as miles per hour and then calculate their average. The former will be the

Time Mean Speed and the latter Distance Mean Speed. The average speed calculated by the two methods would be slightly different as the arithmatic and harmonic means are.

The significance of the two concepts is that highway operating speeds are usually measured in time per unit of distance but are most commonly expressed in terms of distance per unit of time. A certain distance is first marked and time taken to traverse that distance is measured. This is then converted into speed inmiles per hour, etc. If the times taken by vehicles are first averaged and then converted into distance, resulting average speed would be different from the speed if it is calculated by first converting the time into distance and than averaging the same. An example will make the point clear.

Example

If three vehicles take 4, 5 and 6 seconds to cross a distance of 352 ft respectively, the time and space mean speeds will be as follows.

Time Mean Speed:

$4 + 5 + 6 = 15 \div 3 = 5$ seconds

5 sec. for 352 ft = 48 miles per hour.

Space Mean Speed:

Time Seconds.	Speed MPH
4	60
5	48
6	40
Total:	148

Average: 49.3

The same result will be obtained by having Harmonic Mean of time values and then converting it into speed in miles per hour as below:-

$$\text{Harmonic Mean} = \frac{3}{\frac{1}{4} + \frac{1}{5} + \frac{1}{6}} = 4.86 \text{ seconds}$$

$$= 49.3 \text{ mph}$$

It would be seen from the above example that when the time mean speed was 48 MPH the distance mean speed worked out to be 49.3 mph. The distance mean speed is always more than the time mean speed as the harmonic mean is larger than the arithmatic mean. For a mathematical proof, reference may be made to Appendix 2, Chapter 3 of Research on Road Traffic by TRRL 1965.

In the case of motor vehicles, the distance mean speed is mort relevant as it is most commonly understood.

Chapter - V

THE DATA

Choice of Variables:

The information collected included two main variables viz. vehicle speeds and traffic volume. The volume affects speeds. It is also one of the significant factors determining investment on roads and expenditure on maintainence. Besides, the volume on a road constituted statistical popultation of which speed observations were a sample. The information on volume of traffic was therefore collected alongwith speed observations. Besides, road widths at survey points were also measured for investigating relationships between speed, volume and width. The main features of the data collected are briefly described in this chapter.

Types of Roads:

All roads covered in our survey were undivided except for the Islamabad Highway which was a two lane divided highway. In this case, each side of the road was considered as a separate section. With the segregation of traffic in two directions the vehicles do not have to negotiate the on coming traffic. Their speed and capacity of the road, therefore, increases. The speeds on divided highways are therefore relatively higher than on un-divided roads. The average speeds on

the Islamabad Highway were higher than on other roads. However, the data is not sufficient to generalise the effect of divided highways on operating speeds.

Gradients:

The road sections covered in the survey are mostly level in the plain areas. Minor grades found were not of much importance. Information on grades was therefore not obtained.

It may be added that the slope of the road influences speeds which will be relatively less in the rising direction than on the falling direction. Various other studies give rates of change in speed with respect to changes in grades. Therefore, on the basis of basic data of speed on a paved level tangent road, it would be possible to find variations in speed according to grade by using ratios obtained in other studies. It would however be useful to obtain such data for Pakistan at a later stage.

Traffic Composition:

The volume and speed observations relate to survey hours which commenced between 8 to 9 a.m and concluded between 6 to 7 p.m. The volume and its composition would therefore be quite different from average daily traffic which covers 24 hours.

The day time traffic is different from night traffic. The extent of difference has however not been examined. The reasons for such a difference are that local and short distance passenger traffic by buses and private cars is found at day time, mostly during business hours, only. Absence of this traffic at night increase the proportion of goods traffic.

Out Line of Data:

A brief out line of the survey data and its important features are briefly given below.

Traffic Volume:

The detailed data on volume of traffic and number of speed observations acoording to type of vehicle, for each survey station are contained in Annexure II. A summary of data indicating volume of traffic for main road categories is given below.

Table V (i)

Volume of Traffic During Survey Hours

A. No. of Vehicles

Road Cat.	Cat.I	Cat.II	Cat.III	Cat.IV	All Cat.	Percentage of Total
No.of Rd.Sec.	2	11	29	14	56	
M/Cy.	1740	921	1558	507	5,126	(11.0)
Car	4,634	5,174	3,287	731	13,826	(29.6)
Wagon	1,919	1,530	698	274	4,423	(9.5)
Bus	550	4,534	6,330	1,132	12,546	(26.8)
Truck	80	4,668	4,247	752	9,747	(20.8)
Others	3	220	664	193	1,077	(2.3)
Total	8,926	17,047	17,186	3,589	46,748	(100)
%	19.1	36.4	36.8	7.7	100	

B. Average Hourly Volume

No. of Rd.Sec.	2	11	29	14	56
M/Cy.	97	10	7	4	10
Car	257	55	12	6	28
Wagon	107	16	3	2	9
Bus	31	48	23	10	25
Truck	4	50	16	6	19
Others	-	2	2	2	2
Total	496	185	63	30	93

It would be seen from the above that on all the 56 road sections, the total volume of traffic during survey hours was 46,748 vehicles. This works out to 93 vehicles per hour on the average.

In terms of Hourly Volume which are relevant for travel speeds, there were 496 vehicles per hour on category I roads, 185 vehicles per hour on category II roads (more than 22 ft wide) 63 vehicles per hour on category III (18 to 22 ft wide) and 30 vehicles per hour on category IV roads (single lane).

The largest proportion of vehicles consisted of cars (29.6%), which were followed by buses (26.8%) trucks (20.8%), motor cycles (11.0%), Wagons (9.5%) and other vehicles (2.3%).

According to road categories, category I which included only Islamabad Highway, accounted for 19.1% of traffic covered during survey hours. Category II roads which covered main roads, mostly sections of G.T Road and the like, covered 36.4% vehicles. Category III roads which included 29 road sections of 19 ft to 22 ft wide covered 36.8% vehicles. Category IV roads, 14 in number less than 18 ft wide, covered the remaining 7.7% traffic.

It may be restated here that the volume of traffic indicated above relates to day time traffic during survey hours. The proportion of different categories of vehicles in the above volume would be different from the proportion in the ADT which covers 24 hour volume as the composition of traffic at night time is different from day time.

Speed Observations:

The number of speed observations according to types of vehicle contained in Table (ii) for each road section are summarised below.

Table V(ii)

Number of Speed Observations

Road Cat.	Cat.I	Cat.II	Cat.III	Cat.IV	All Cat.	Percent-age.
No.of Rd.Sec.	2	11	29	14	56	
M/Cy.	372	467	1213	356	2418	(9.3)
Car	1146	1968	2439	575	6128	(23.6)
Wagon	708	654	515	214	2091	(8.0)
Bus	309	2652	4895	1006	8862	(34.1)
Truck	27	2110	3047	616	5800	(22.3)
Other	-	125	420	136	681	(2.6)
All	2565	7976	12539	2903	25980	(100)
Percent-age	(9.9)	(30.7)	(48.3)	(11.1)	(100)	

It would be seen that in all 25,980 speed observations were made on 56 road sections. Of these, about 10% were made on the Islamabad Highway, (Category I) about 31% on category II roads, more than 48% on roads of category III and 11% observation on roads of category IV which consisted single lane roads.

According to type of vehicle, the speed observations included 9.3% motor cycles, 23.6% cars, 8.0% wagons, 34.1% buses 22.3% trucks and 2.6% other vehicles.

Speed Observations as Proportion of Traffic:

As indicated before, speed observatinns did not cover 100% traffic volume. This was not necessary either. Only one observer was placed on a road section. He could observe and record speed of only one vehicle at a time. During this process several vehicles would pass by the observer. Thus only a porportion of vehicles was covered in speed observations. The variations in the proportion of vehicles covered in the speed observations according to type of vehicle and road category are shown in the following table:-

Table V(iii)

Speed Observations as Percentage of Volume(%)

Road Cat.	Cat.I	Cat.II	Cat.III	Cat.IV	All Cat.
M/Cy	21.3	50.7	62.4	70.2	47.1
Car	24.7	38.0	74.2	78.6	44.3
Wagon	36.9	42.7	37.8	78.1	47.3
Bus	56.2	58.5	77.3	88.8	70.6
Truck	33.7	45.2	71.7	81.9	59.5
Others	-	56.8	63.2	70.4	63.0
Total	28.7	46.8	73.0	80.9	55.6

It would be seen that variations between road categories are quite significant. On the Islamabad Highway (Category I) only 28.7% vehicles were covered. The proportion was increased to 46.8%, 73.0% and 80.9% on category II, III and IV roads respectively. The trend for individual types of vehicles is the same.

The number of speed observations are inversly proportional to volume of traffic. When the volume is high, the speed observations are proportionately less and vice-versa. For example, on Islamabad Highway where the volume of traffic was 496 vehicles per hour, speed observations were only 28.7% of volume. On the other extreme, the speed observations are 81% of volume for category IV roads where the volume is 30 vehicles per hour. This is entirely due to the method used for making speed observations.

At places where the volume of traffic was very low, it was not possible to cover all the traffic. The main reason is that vehicles come in bunches and in such a case only one of the vehicles could be observed and noted. Thus, only a proportion of traffic could be covered. It is not necessary to cover 100% of the traffic either. A reasonavle sample is enough to serve the purpose.

It would also be noted that speed observations as a proportion of volume also vary according to type of vehicle. The proportion of vehicles included in the speed observations is highest for Buses which are 70.6% of volume, Trucks are about 60%, wagons 47.3%, motor cycles 47.1%, cars 44.3% and other vehicles 6.3%. The trend for all road categories is the same.

Normally, the proportion of vehicles covered under speed observations should be the same for all types of vehicles except for random variations. However, it appears from the above that certain type of vehicles e.g. buses have been covered relatively more than other types. This aspect has been further examined below.

The following table shows the percentage distribute of vehicles according to type under traffic volume and speed observations.

Table V(iv)

Percentage Distribution of Vehicles

Type of Vehicles	Traffic Volume	Speed Obs.
M/Cycles	11.0	9.3
Cars	29.6	23.6
Wagons	9.5	8.0
Buses	26.8	34.1
Trucks	20.8	22.3
Other Veh.	2.3	2.6
T o t a l:	100	100

If the sample were truely representative, the distribution of speed observations would be the same as for traffic volume. There are however differences between the two distributions.

The largest difference is between buses which are 26.8% in traffic volume and 34.1% speed observations. Thus their proportion has increased by 7.3% points. On the other hand the proportion of cars has declined by 6% points from 29.6% in traffic volume to 23.6% in speed observations. The differences in other categories of vehicles are small.

Buses seem to be slightly over represented in speed observations and this seems at the cost of cars. The possible reason could be that buses are of larger size than other traffic and more conspicuous hence they attracted the attention of the observer more than other vehicles. Another possible reason could be that when vehicles are in bunches, the speed of only one vehicle can be recorded. The buses operating on schedule would be more evenly spread from each other and would be less in bunches. Hence more of them are covered. The opposite would be true for cars. Trucks are also over represented by 1.5% and motor cycles under represented by 1.7%. The decrease in the proportion of cars and motor cycles is also the result of increase in the proportion of buses and trucks.

Whether such differences are statistically significant or not was examined by means of a Chi Square test. It indicated that differences between the two proportions were no statistically significant. (I)

The difference in the proportion of vehicles covered should not make any difference in the resulting speeds as the number of observations in each category are sufficiently large and provide a reasonable sample.

The methodology used provides, within broad limits, a variable sampling porportion i.e. where the population is large the sample size is small and where the population is small, the sample size is large.

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(1) $X^2 = \frac{C\ (O-E)^2}{E}$

$X^2_{(Calc)} = 3.81$ is less than $X^2_{0.05} = 11.07$ (5 d.f.).

Hence difference between the two distributions not significant.

Chapter ~~IV~~ VI

THE RESULTS

The main results of the survey relating to operating speeds are contained in Annexure III which gives average speeds of different type of vehicles for each road section covered in the survey.

An average can consist of widely different values. To have an idea of the spread of individual speed values around the average, standard deviations have also been calculated and are shown within brackets below the average. This will enable further analysis of data which the users may like to make.

In addition, percentage distribution of vehicles according to speed with five mile class intervals ranging from 20 to 60 miles per hour for individual vehicle types and for road categories are also given in Annexure IV. This data is also shown graphically in frequency distribution curves.

The data is mostly self explanatory. Salient features are however briefly described below.

Mean Speeds:

The average speeds for different types of vehicles on various categories of road were as follows:

Table VI (i)

Average Speeds by Type of Vehicle and Road Category

Road Category	Cat.I (4 lane div)	Cat.II (22' &over)	Cat.III (18'-22')	Cat.IV (less than 18')	All Cat.
M/Cy	38.7	33.8	31.2	29.8	32.7
Car	50.5	46.9	42.9	37.2	45.1
Wagon	47.7	43.5	38.4	33.7	42.5
Bus	45.7	42.7	39.4	32.2	39.9
Truck	-	33.8	32.0	28.9	32.4
Other	44.9	16.0	15.6	14.6	15.5
All Veh.	47.2	40.5	36.7	31.8	38.3

Variation Between Road Types:

Looking at different categories of roads, the highest speeds were found on the Islamabad Highway Dual Carriageway (Cat.I) where the average speed for all types of vehicles combined was 47.2 miles per hour. The speeds on this road for each type of vehicle are higher than any other road category. The average speed on roads in Category II (more than 22 ft wide but un-divided) falls to 40.5 miles per hour, a decrease of 6.7 miles per hour. The average speed on category III road (18 to 22 ft wide) falls by another 3.8 miles to 36.7 miles per hour and on category IV roads which are all single lane less than 18 ft wide, falls by further 4.9 miles t, 31.8 miles per hour. In other words, we can say that improvement of a road from 12 ft to 18 ft width will increase the speed by 15.4% from 31.8 to 36.7 miles

per hour and the two lane divided highway will further increase the speed by 16.5%. The precise relationships between the speed and road width have been further examined in the next chapter.

The change in speed of all vehicle types is the largest between category I and II. Obviously, the separation of opposing traffic flows causes the largest increase in speed. The second largest difference is between category III and IV where the difference is of 4.9 miles per hour only.

Variations Between Vehicles Types:

Looking at individual vehicle types, highest speed is shown by cars, 45 miles per hour. This is followed by wagons with 42.5 miles per hour. Buses have an average speed of nearly 40 miles per hour. Trucks have however a much lower speed of 32.4 miles per hour and so are motor cycles with 32.7 miles per hour. The 'other vehicles' which mostly include tractors have a speed of 15.4 miles per hour.

The speed of each vehicle type varies with road category. The speed of cars varies between 50.0 mph on Category I roads and 37.2 miles per hour on single lane roads. Similarly, the speed of wagons varies between 47.7 and 33.7 mph between category I and IV roads. Similar is the case for Buses. Their

speed is 45.7 mph on Category I and 32.2 mph on Category IV. Trucks are not allowed on the Islamabad Highway (Category I). The variations in their speed are not much between category II to IV and range between 33.8 and 28.9 miles per hour only.

Standard Deviations:

A measure of the spread of individual values around the mean is provided by the Standard Deviation which is defined as

$$SD = \sqrt{\frac{E(X - \bar{X})^2}{n}}$$

This gives average deviations from the mean. The Standard Deviation divided by its mean provides the Coefficient of Variation. A summary of Standard Deviations and Coefficients of variations for vehicle types and road categories are given below.

Table VI (ii)

Standard Deviations

Type of Vehicle	Mean Speed	S.D.	Coefficient of Variation %
M/Cycles	32.6	7.3	22.4
Cars	45.0	9.4	20.8
Wagons	42.4	7.8	18.4
Buses	39.9	6.9	17.3
Trucks	32.3	5.8	18.0
Other Vehicles	15.4	3.4	22.0
Road Categories:			
Category I	47.2	8.6	18.2
Category II	40.5	9.1	22.5
Category III	36.7	8.7	23.7
Category IV	31.8	8.2	25.8
All Veh. & Road Cat.	38.3	9.6	25.1

It is evident from the above that Standard Deviations are between 17.3% and 25.8% of Means. The values for vehicle types are lower than for road categories.

Frequency Distributions:

A more detailed view of the proportion of vehicles at different speed levels is provided by the frequency distributions. These are shown in Annexure IV which gives distribution of vehicles according to speed for each type of vehicle under each category of road with a class interval of 5 mph. A summary of the same is contained in the following Table where class intervals have been increased to 10 mph to simplify the analysis.

Table VI (iii)

Distribution of Vehicles According to Speed

Class Interval	M/Cy.	Cars	Wagon	Bus	Truck	All	%
Upto 20 mph	44	5	7	30	75	161	0.6
20-29.9 mph	862	275	118	654	1899	3800	15.0
30-39.9 mph	1108	1488	608	3404	3158	9762	38.6
40-49.9 mph	341	2336	932	4065	627	8301	32.8
50-59.9 mph	58	1579	406	703	41	2787	11.0
60+over mph	5	448	24	11	-	488	1.9
Total:	2418	66128	2091	8862	5800	25299	100

Road Category	I	II	III	IV	All	%
Upto 20 mph	1	19	55	86	161	0.6
20-29.9 mph	30	786	2064	920	3800	15.0
30-39.9 mph	463	2682	5338	1279	9762	38.6
40-49.9 mph	986	3118	3776	423	8304	32.8
50-59.9 mph		1054	791	59	2887	11.0
60+over mph	199	194	95	-	488	1.9
All	2,562	7976	12,119	2767	25,299	100

It would be seen that the lower class limit of 20 mph includes 0.6% of vehicles. These include 47% trucks, 27% motor cycles, 19% buses and the remaining 7% cars and wagons. Other vehicles are not included in the speed distributions. Average speed of these vehicles is 15 mph and 95% of them are below 20 mph speed.

The speed range 20-29 miles per hour included 15% of vehicles of which 50% are trucks, 23% motor cycles, 17% buses, 7% cars and 3% wagons. The speed range 30-39 covers 38.6% vehicles. Of these 35% are trucks 32% buses, 15% cars, 11% motor cycles and 6% wagons. The next speed range 40-49 miles per hour contains 33% of vehicles of which 4% buses, 28% cars, 11% wagons, 8% trucks and 4% motor cycles. The speed range 50-59 includes 11% vehicles of which 57% are cars, 25% buses, 15% wagons, 2% motor cycles and 1.4% trucks.

The upper speed limit of 60 mph and over includes 1.9% of vehicles and 92% of them are cars 5% wagons and 3% buses and motor cycles. None of the trucks is in this speed range.

Looking at individual vehicle types it would be seen that 2.6% of motor cycles exceed 50 mph speed, 16.7% exceed 40 mph and 46% exceed 30 mph. The other 54% are below 30 mph speed. Among cars, 7.3% are at speeds exceeding 60 mph 33% exceed 50 mph, 71% exceed 40 mph and the remaining 29% are below 30 mph. Among the wagons 1% are above 60 mph, 20% above 50 mph, 65% above 40 mph, 94% above 30 miles per hour. The remaining 6% are below 30 mph speed. Among buses, 0.7% are above 50 mph, 54% above 40 mph, 92% above 30 mph. The remaining 8% are below 30 mph. As regards, trucks, only 0.6% are above 50 mph 11.4% above 40 mph 66% above 30 mph and the other 34% below 30 mph.

Looking at individual road categories, it would be seen that on caterory I roads, 3/4th of the vehicles operate in the speed range of 40-60 mph, on category II and III roads similar proportion of vehicles operates at 30-50 mph and on category IV roads about 80% of vehicles operate at speeds between 20-40 miles per hour.

The proportion of vehicles exceeding 60 mph speed is 7.8% on category I roads, 2.4% category II roads, 0.8% on category III and none on category IV roads which are all single lane. The proportion of vehicles exceeding 50 miles per hour is 42% on Category I-16% on Category II, 8% on Category III and 2% on Category IV roads.

Speed Limits:

The distribution of vehicles according to speed may be compared with speed limits which are prescribed according to type of road and type of vehicle under traffic rules as follows:-

Table VI (iv)

Speed Limits(MPH)

Type of Vehicle	Main Roads	Secondary Roads
Car	60	50
Buses & Trucks	50	40
M/Cycles	45	35

The classification of roads into Main and Secondary is not quite clear. It is therefore not possible to determine as to which of the roads covered in the survey are main and which are secondary roads.

Therefore, the proportion of vehicles on all categories of roads exceeding speed limits for both Main and Secondary roads are shown. For purposes of comparing speed limits Category I and II roads may be treated as main roads and others as secondary roads.

Table VI (v)

Percentage of Vehicles Exceeding Speed Limits

Main Roads	Cars	Buses	Wagons	Trucks	M/Cy.
Speed Limit MPH	60	50	50	50	45
Proportion of Vehicles Exceeding Limits	Percentage of Vehicles				
Category I	15.4	30.4	41.0	-	18.3
Category II	9.2	12.6	16.3	0.9	6.8
Category III	3.6	5.6	5.8	-	2.8
Category IV	-	0.6	1.4	-	1.1
Secondary Roads					
Speed Limit MPH	50	40	40	40	35
Proportion of vehicles Exceeding Limit	Percentage of Vehicles				
Category I	56.7	85.4	87.0	-	69.9
Category II	39.3	70.3	73.5	16.6	41.3
Category III	22.8	50.7	41.7	8.8	27.0
Category IV	8.5	16.2	23.4	5.3	20.7

Obviously Category I roads would be the main roads. On this Category, 15% cars, 30% Buses, 41% Wagons and 18% Motor Cycles exceed the speed limits for main roads. On Category II roads, 9% cars, 13% Buses, 16% Wagons and 0.9% trucks exceed speed limits for main roads. The proportion of vehicles exceeding limits for Secondary roads on this category of roads is 39% cars, 70% Buses, 74% Wagons, 17% trucks and 41% motor cycles. On Category III, is the vehicles exceeding speed limits for main roads are 3.6% cars, 5.6% buses, 5.8% Wagons and 2.8% Motor Cycles. No trucks on these roads exceed speed limits for main roads. However, the vehicles exceeding speed limits for secondary roads are 22.8% cars, 50.7% buses, 41.7% Wagons and 8.8% trucks. On Category IV roads, very few vehicles exceed speed limits for main roads. They include only 0.6% of Buses 1.4% Wagons and 1.1% motor Cycles. The vehicles exceeding speed limits for secondary Roads are 8.5% cars, 16.2% Buses, 23.4% Wagons, 5.3% trucks and 20.7% motor cycles.

85th Percentile Speed:

The 85th percentile speed is of special interest from the Traffic Engineering point of view. This is also regarded as the optimum speed or the design speed and is used for regulation purposes as well.

The 85th percentile speeds according to type of vehicle and category of road are as follows:

Table VI(vi)

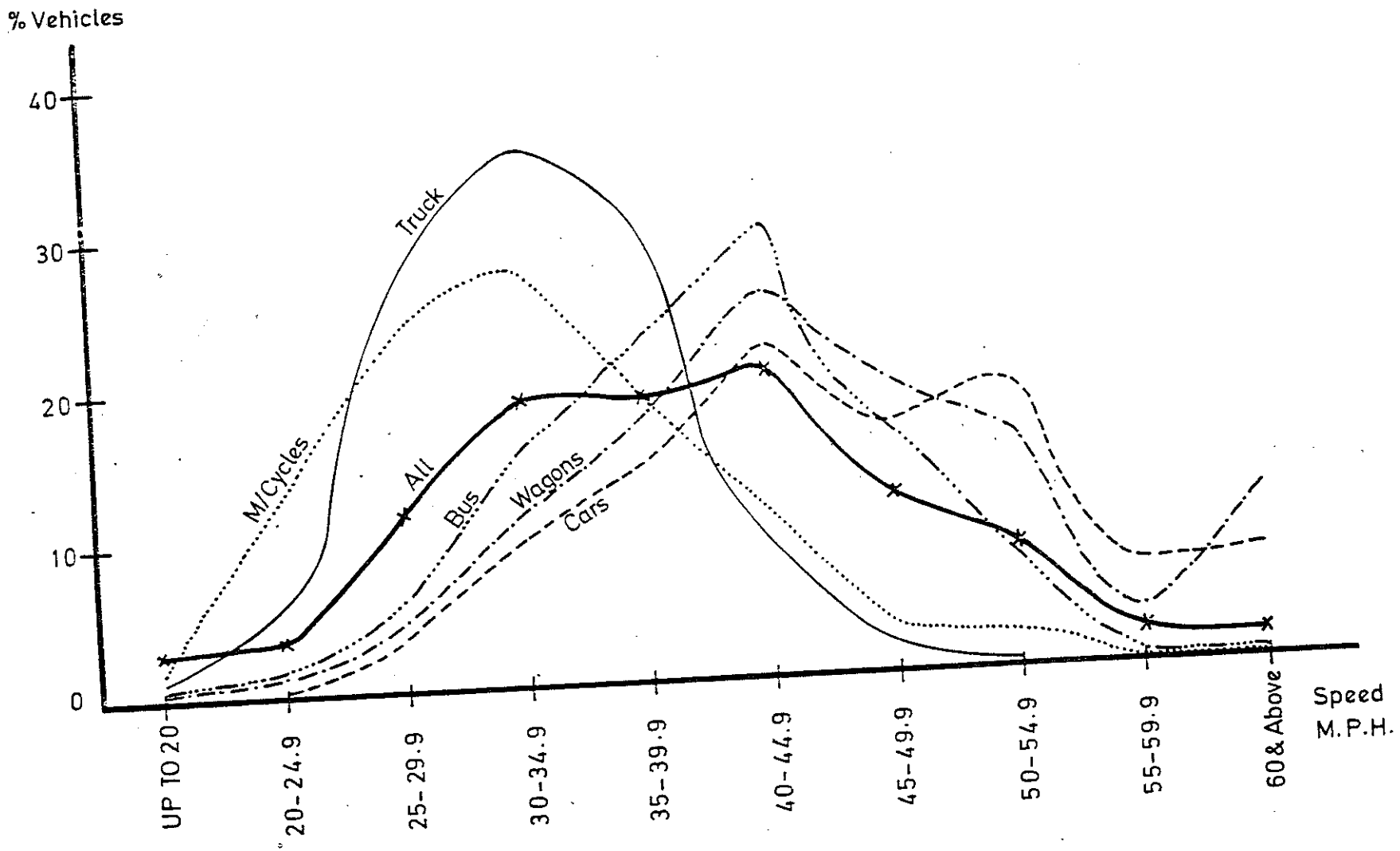
85th Percentile Speeds (MPH)

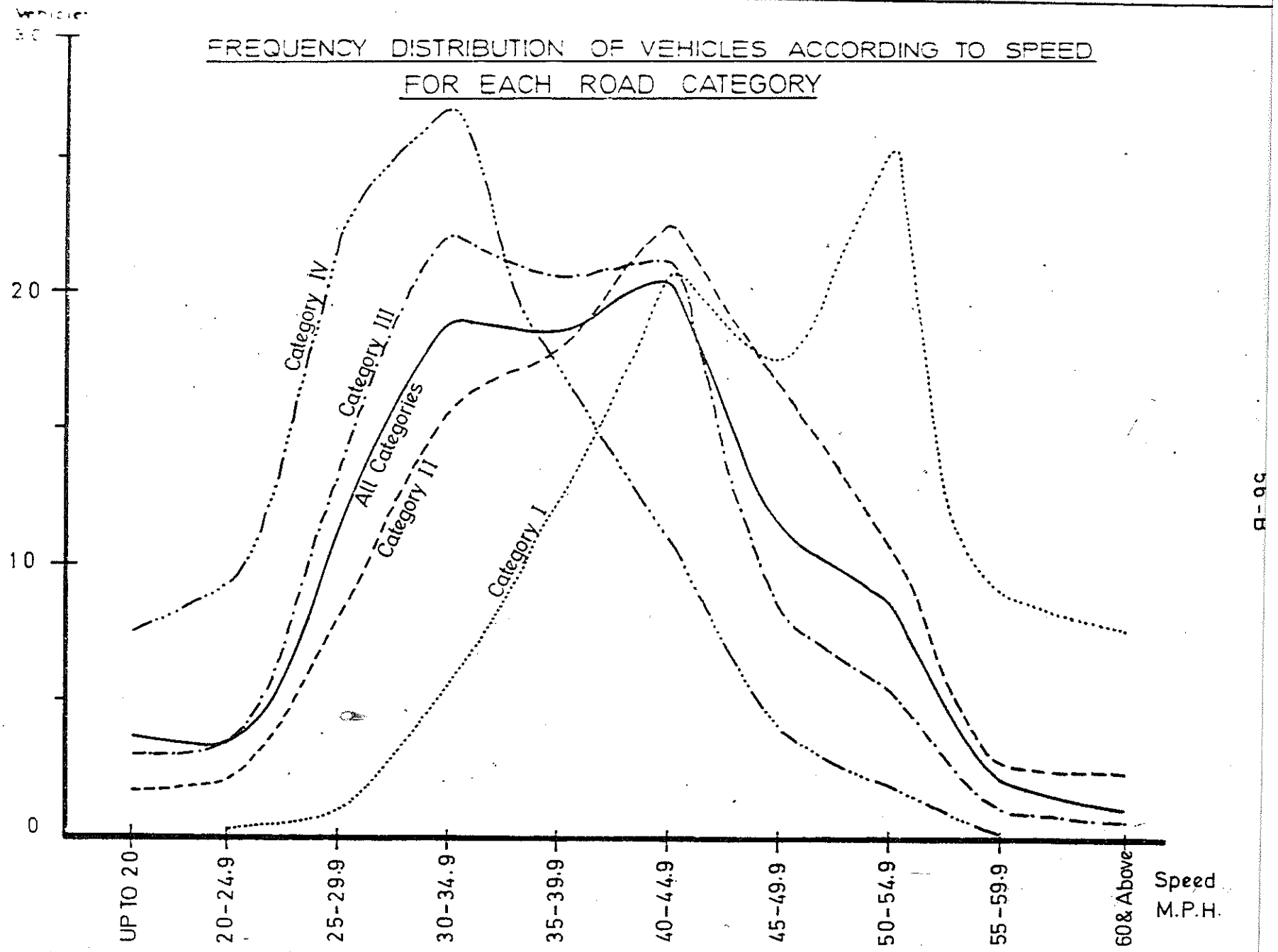
	Category of Road				
Type of Vehicle	I	II	III	IV	All
M/Cycles	52	42	39	37	41
Car	60	56	53	46	55
Wagon	59	50	45	43	52
Bus	53	50	46	41	48
Truck	-	46	38	35	39
Other	-	20	20	19	20
All	56	50	46	41	49

It would be seen that 85th Percentile Speed for all road categories and vehicle types combined is 49 mph. This consists of motor cycles 41 mph, cars 55 mph, wagons 52 mph, Buses 48 mph, trucks 33 mph, and other vehicles about 20 mph. According to types of road, the 85th Percentile speeds are 56 mph for Category I, 50 mph for Category II, 46 mph for Category III, 41 mph for Category IV. If other vehicles which are slow moving are excluded, the above speeds remain the same as the proportion of such vehicles is quite small and their inclusion or exclusion does not effect the percentile speed.

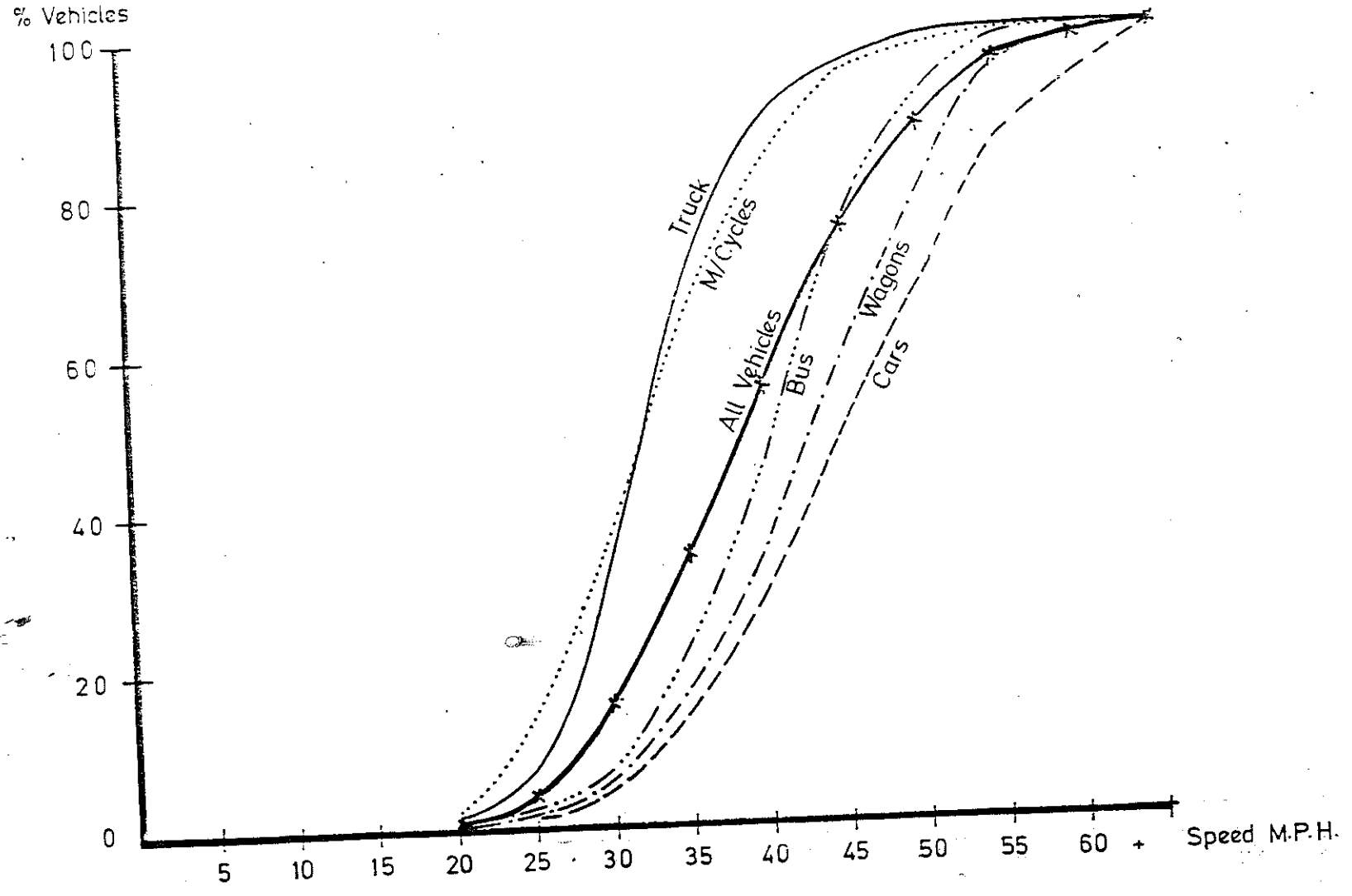
The distribution of vehicles according to speed is also shown in the accompanying grophs. Graph I shows percentage distribution of individual vehicle types for all road categories combined. Graph II shows similar distribution for individual road categories with individual vehicle types combined. Graph II and IV show same distributions cumulatively. These distributions appear quite normal. Curves are bell shaped particularly for vehicle types.

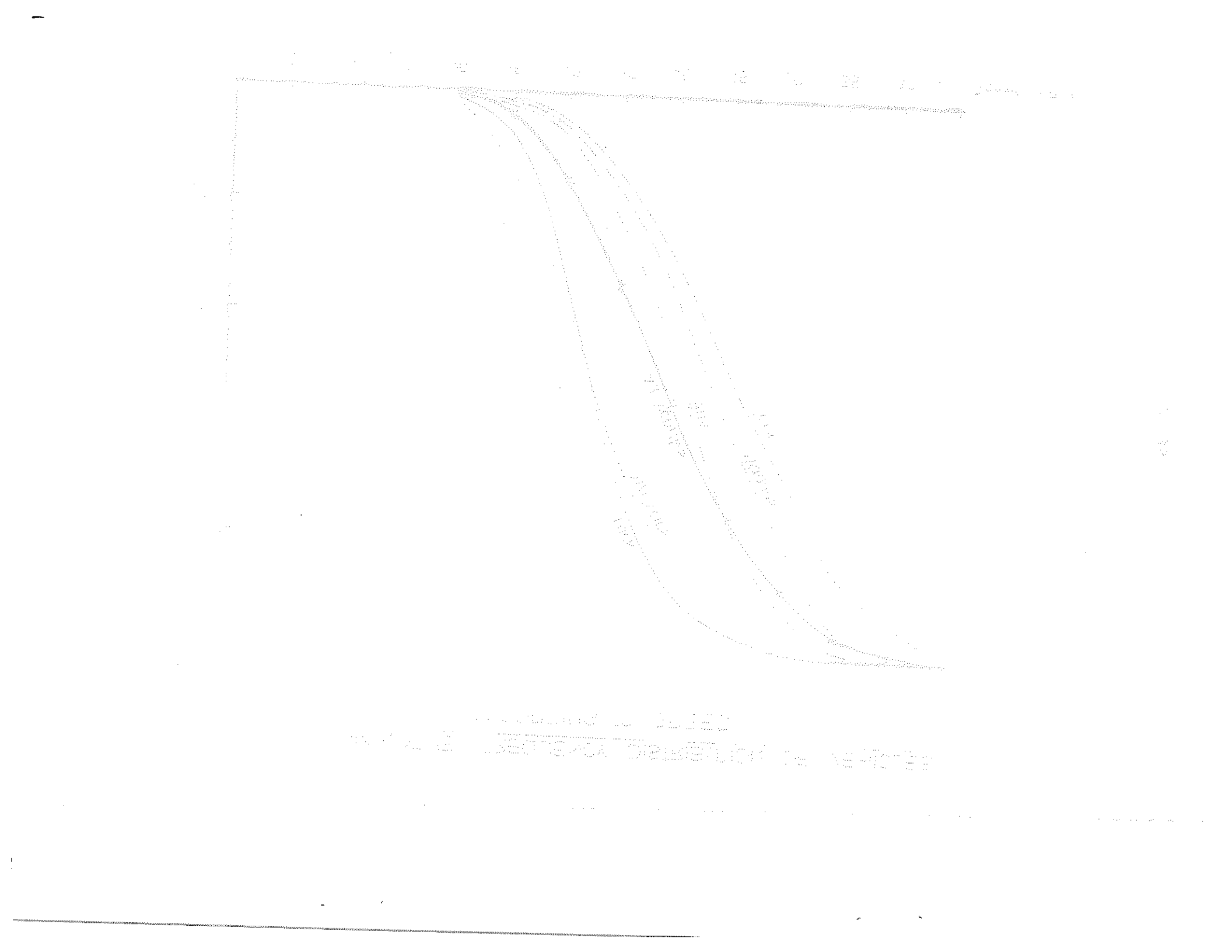
FREQUENCY DISTRIBUTION OF VEHICLES ACCORDING TO SPEED



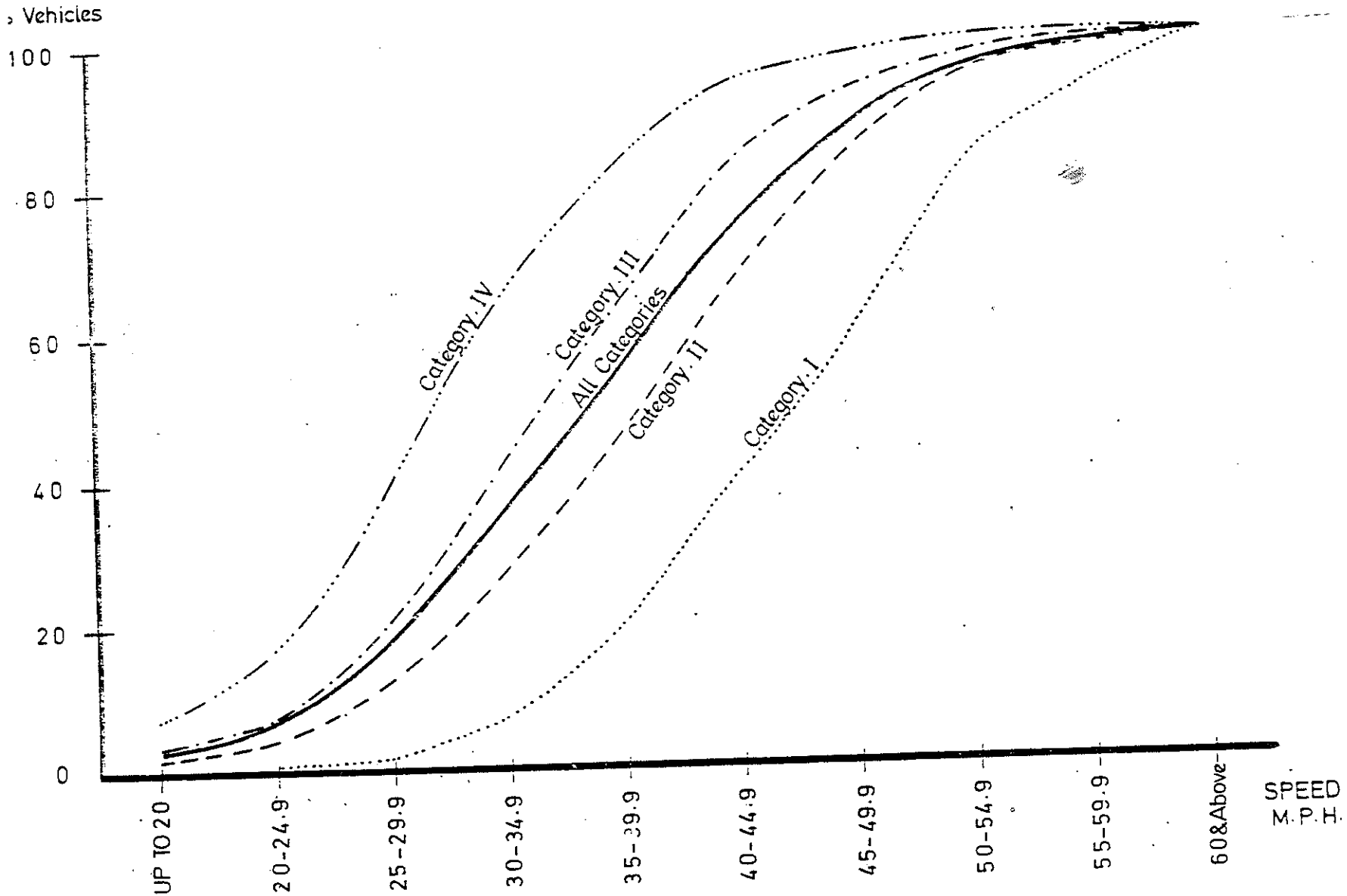

FREQUENCY DISTRIBUTION OF VEHICLES ACCORDING TO SPEED
FOR EACH ROAD CATEGORY
20
10
0
Category IV
Category III
All Categories
Category II
Category I
UP TO 20
20-24.9
25-29.9
30-34.9
35-39.9
40-44.9
45-49.9
50-54.9
55-59.9
60& Above
Speed
M.P.H.

CUMULATIVE FREQUENCY DISTRIBUTION OF VEHICLES ACCORDING TO SPEED





CUMULATIVE DISTRIBUTION OF VEHICLES ACCORDING TO SPEED FOR EACH ROAD CATEGORY



56-D

FIXED LOAD CALIBRATION OF AEROSPACE ACCELEROMETER TO BE USED FOR
FLIGHT STATE DETERMINATION

CHAPTER VII

REGRESSION ANALYSIS

The preceding chapter examined, inter-alia, variations in operating speeds on different categories of road, which ere classified according to width. It was found that speed increases with increase in width of road for all types of vehicles. The increase in certain cases was more than others. Various factors would be respensible for this. The factors which, a priori, appear to determine the operating speeds include width of road, volume and composition of traffic, etc. The precise effects of these factors have been examined in this chapter in mathematical terms by means of Corelation and Regression Analysis.

Variables Considered:

Considered in this Analysis, are 13 variables, 7 dependent relating to average Speed of each type of vehicle and 6 independent including width of road, volume of traffic, including and excluding non-mechanised vehicles, ratio of volume to width and proportion of slow moving traffic. The list of variables giving notations used and range of value contained is given below:

Table VII (1)

List of Variables

Notation		Description	Range of Values
Dependent Variables		Average Speed (MPH)	
Y_1	=	Motor Cycles	... 27.3 - 42.2 MPH
Y_2	=	Cars	... 31.7 - 50.6 "
Y_3	=	Wagons	... 29.7 - 47.2 "
Y_4	=	Buses	... 27.5 - 46.8 "
Y_5	=	Trucks	... 24.8 - 36.8 "
Y_6	=	Other Vehicles	... 11.4 - 23.5 "
Y_7	=	All Vehicles combined	... 27.5 - 47.8 "
Independent Variables:			
X_1	=	Width of road	... 8 ft - 30 ft
X_2	=	Volume of Traffic: Mechanised Vehicles	12 - 490
X_3	=	Volume of Traffic including non-Mechanised Vehicles	17 - 572
X_4	=	Ratio of Volume (Mechanised) to Width X_2/X_1	1.1 - 16.5
X_5	=	Ratio of Volume including non-Mechanised to Width (X_3/X_1)	1.6 - 19.0
X_6	=	Proportion of non-Mechanised Traffic in total volume $X_3 = X_2/X_3$	2.8 - 72.4

The distinction of variables as dependent and independent is for Regression Analysis and not for Correlation Analysis as will be explained in subsequent paragraphs.

The data of above variables was compiled from Table II and III. The average speeds, variables Y_1 to Y_7 are contained in Table III. Variables X_4, X_5 and X_6 are the result of simple calculations on data in Table III. The results of the Analysis are briefly described below.

CORRELATION ANALYSIS:

The Correlation Analysis gives relationships of variables with each other. The degree of Correlation is measured by the Coefficient of Correlation (r). Its value can vary between 0 and $\pm$ 1. If the values of (r) is negative, the relationship is inverse, i.e. as one variable increases, the other decreases. When the value of (r) is positive, both the variables move in the same direction. When the value of Coefficient of Correlation (r) is nearer to 1, it means the variables are closely Correlated. When the value is nearer to zero, the variations between the two factors are not inter related.

MAIN RELATIONSHIPS:

The Zero Order Correlation Matrix which gives Correlation of each of the 13 variables with every other is given in Annexure V attached. The main relationships are briefly described below.

Speed of different types of Vehicles:

Motor Vehicles of different categories move at similar speeds to each other. If the speed of cars is more than buses on one road, it will be the same on the other roads as well. It is, therefore, expected that all vehicles of similar speed capability would move at similar speeds. The Correlations between the speeds of various vehicles should therefore be expected as positive and quite high.

However, there appears to be considerable variation in the Coefficients of Correlations between average speeds of different categories of vehicles. For example, the Coefficient of Correlation (r) between average speeds of Motor Cycles and Cars is .38, wagons .36, Buses .85, Trucks .54, other vehicles .26 and all vehicles combined .58. Similarly, the Coefficient of Correlation between the average speed of cars and wagons is .65, Buses .27 and Trucks .68. The speed of Motor Cycles is more closely related to Buses than Cars and Wagons. The speed of Cars is more correlated to Trucks and Wagons that to motor cycles and buses.

It appears that speeds of different categories of vehicles follow their own pattern which are not very similar to each other as the Coefficients of Correlations between the speeds of different categories of vehicles are neither uniform nor very strong.

It would be seen that the Coefficient of Correlation between the "Other Vehicles" and all other types are negative, although the values are quite small. The category of other vehicles includes mostly tractors which have quite a low speed. Their existance in the traffic stream would reduce the speed of all other vehicle categories. The negative Correlation means that when the speed of all vehicles is high the speed of "Other Vehicles" is slow and vice-versa.

The Coefficient of Correlations between average speeds and other variables like width and volume are more important. These are examined in turn.

Speed and Width:

Width is one of the most important variables affecting speed. It is approxy for the quality of road as well. In the preceeding chapter it was observed that speeds of different categories of vehicles increases with width. However, it would be observed from the correlation matrix that the relationships between average speed and road width are not uniform for all types of vehicles. In certain cases the correlations are higher than other.

The highest Coefficient of Correlation is between width and average speed of all vehicle categories combined (r = .81) Cars have a Coefficient of .78, Trucks .67, Wagons .62, buses .29 and motor cycles .37. The overall speed of all vehicles combined is explained better than individual vehicle categories by the variable width.

The Coefficient of Correlation for "Other Vehicles" category is negative and quite small indicating that speed of these vehicles is inversly related to width. The obvious reason is that on wider roads the volume of traffic is high and the slow moving vehicles have to give way to other vehicles more frequently. Their speed is also inversely related to the speed of all other vehicles.

Speed and Volume:

Theoratically, vehicle speeds are inversely related to volume of traffic. As the volume increases, speeds will decrease. The Correlation between the volume and speed should therefore be negative. This is however, not the case in our analysis. Quite surprisingly, all the Coefficients of Correlations between volumes of traffic both including and excluding non-mechanized vehicles, and average speed are positive and quite significant. The Correlations of speed with both categories of volume are similar. The two categories of traffic volume are themselves highly correlated having a Coefficient of Correlation of .97.

The obvious reason for the wrong sign between speed and volume appears to be the fact that width of road and volume of traffic are themselves Correlated having r = .69. The increase in speed due to increase in width may be more than decrease due to increase in volume.

Secondly, the effect of volume on speed is felt after the volume increases beyond a certain limit. The volume on our roads is not yet so large as to reduce operating speeds.

Width and Volumes:

The width of road and volume of traffic are the two most significant factors affecting speeds of vehicles, however, as these two variables are themselves correlated having r = .69, multiple Correlation between speed and width and volume would not give satisfactory results.

In order to find the combined effect of width and volume on speed, the volume was expressed as a ratio of width. Variables X_4 and X_5 indicate such ratios which have been arrived at as :

$$X_4 = \frac{X_2}{X_1} = \frac{\text{Volume(mechanized)}}{\text{Width(ft)}}$$

$$X_5 = \frac{X_3}{X_1} = \frac{\text{Volume(All Vehicles)}}{\text{Width(ft)}}$$

The above ratios indicate volume per ft. of road width and thus incorporate both the volume and width.

There was no improvement in the Coefficient of Correlations between speed and ratios of volume to width indicated above. Contrary to theoretical expectations, the Coefficients are all positive and significant. The problem of multicolineraity

between volume and width operates here and makes it difficult to isolate the effects of volume of vehicles and width on speed.

Slow Moving Vehicles:

The Correlations between the proportion of slow moving vehicles in total traffic (X_6.) and average speed are negative and significant for all vehicle categories. The values of Coefficients are between (-).26 and (-).29 for Cars, Wagons and Buses, (-) .48 for motor cycles and (-) .09 for trucks. For all vehicles combined the Coefficient is (-) .38. This is in line with theoretical expectations that the slow moving vehicles reduce the speed of other vehicles.

REGRESSION ANALYSIS:

The difference between Correlation and Regression is that the former gives the relationship between the two variables as of X on Y and of Y on X. On the other hand, Regression gives effect of one variable on the other as of X on Y, where Y is dependent variable and X is independent variable. We are more interested to find the effect of various factors on speeds. For this Regression Analysis is more appropriate.

The Model:

Accordingly, simple Regression Analysis has been carried out regression all the X independent variables on each of the Y dependent variables one by one. The model used is of simplistic form like:

$$Y = a + bX$$

where 'Y' = dependent variable representing average speed of Vehicles; and

'X' = independent variable. Such factors as Width, Volume and proportion of slow moving vehicles, etc. were used in different forms.

'a' = Intercept; and

'b' = Coefficient

The values of 'a' and 'b' are determined empirically. Then by putting in different values of 'X' in the equation, the effect of 'X' on 'Y' is estimated.

Types of relationships:

The relationships between speed and other factors can be of sereral forms, viz. linear, exponential, quadratic, logistic and so on. However, simple regressions were carried out in linear and log form. Log to the base 'e' was used.

In linear form, the Coefficient 'b' gives a multiple by which the speed will change as a result of change in 'X'. In log form, 'b' directly gives elasticity and indicates the proportion change with respect to a similar change in 'X'.

The degree of explanation provided by the equation is gives in the Coefficient of Determination (R^2) which is the ratio of variance explained to total variance.

Solution of the equation:

The equation (i) above was solved in linear and log form by method of least squares. Values of 'a' Constant and 'b' Coefficient were obtained for each type of vehicles with all the

six dependent variables as described before. The results are contained in Annexure-VI. The salient features are discussed below:

Data Used:

Two sets of data were used for the Regression Analysis. One set covered 56 road sections as individual observations. In the second data set, the original 56 observations were reduced to 10 by grouping together sections having similar width. The necessity of the second data set was felt due to the fact that variations in width between individual road sections were small. For example, there are 14 road sections having a width of 20 ft., 5 road sections having a width of 19 ft. In such cases, the regression analysis does not work well. For example, all the roads having 20' width were combined together and the average value was taken as one observations. The data in modified form of 10 observations is given at Annexure VII.

There were thus four sets of Regression Analysis, one each in log and linear form with 56 observations and 10 observations respectively. Each set contained regression of 6 independent variables on each of the 7 independent variables. There were thus in all 168 equations contained in Annexure-VI. Only the significant results are described here.

Road Width and Speed:

The first set of equations examines the effect of width on speed with all the four data sets viz. 56 and 10 observations

in linear and log forms. The results with each data set are briefly as follows.

56 Observation - Linear Form.

It would be seen that the Coefficients vary between .09 and .61. The Coefficient for individual vehicle types are .22 for motor cycles, 61 for cars, .51 for wagons, .34 for buses, .41 for trucks, .09 for other vehicles and .59 for all vehicles combined. This means that a 10 ft. increase in the width of a road would increase average speed by about 6 mph.

The R^2 which gives the degree of explanation provided by the equation is highest for the average speed for all vehicle combined (Y_7), (R^2 = .65). This is followed by cars (.61), trucks (.44), wagons (.38). The R^2 for motor cycles is quite low (.13) and still lower than for other vehicles (.01).

't' ratios are significant at 5% level except for Buses and other vehicles.

On the whole, it is evident that the equation explains the variations in the speed of all vehicles combined together better than the speeds of individual categories.

It would also be evident that a large proportion of variation in speed is provided by the term constant, as the value of 'a' is quite high as compared to Coefficient 'b' and Xs. For example, for 20 ft. wide road, X = 20, average speed given by the regression comes to 37.3 miles per hour of which 25.5 miles are contributed by the constant term and the other 12 mph by the coefficent 'b'.

56 Observations, Loge form:

In loge form, the values of Coefficients range between.09 for motor cycles to .7 for other vehicles. However, these are the two extreme figures and abnormal ones as Rs^2 in both case are very small as compared to others. Coefficients in other cases are .24 for cars, .22 for wagons, .17 for buses, .20 for trucks and .26 for all vehicles combined. The Rs^2 in the last case is .61 as compared to .65 in linear form. There is no improvement in R^2s for all vehicle categories except for buses where the R^2 has slightly increased from .08 in linear form to .15 in loge form. In both eases, the R^2 is very low. Besides, 't' ratios for motor cycles, buses and other vehicles are not significant in loge form.

10 Observations - Linear form:

With the number of observations reduced to ten as explained before, the values of constant increased in all cases, the increase for all vehicles combined being more than 20%. The values of Coefficients have, on the other hand, declined. However, the range of variation in this case is much less, between .13 for motor cycle to .31 for trucks. The R^2s have also improved for all vehicle types significantly. The minimum being .47 for motor cycles and highest .90 for trucks. The R^2 for average speed of all vehicles combined increased from .65 with 56 observations .81 with 10 observations. The 't' ratios for buses and other vehicles however remain insignificant.

10 Observations - Log Form:

As in linear form, the value of the term constant is high and the Coefficient 'b' is lower than in the case of 56 observations. The values of Coefficients range between .17 and .20 for cars, wagons, buses, trucks and all vehicles combined with R^2s between .69 and .85. 't' ratios are also significant. The Coefficient for motor cycle is quite small .07. R^2 is also low and 't' ratio insignificant. The Coefficient for other vehicles is 3.26. The sign is correct. The R^2 is not quite low. However, the 't' ratio is insignificant.

As noted earlier, the Coefficient 'b' in log form gives elasticity directly. The Coefficients in Log_e form for most of the vehicle types are similar for 56 and 10 observations. If the values are averaged and rounded off, the Coefficient for cars, wagons, buses and trucks comes to .2. The Coefficient for all vehicles combined with 10 observations is also 0.20 with R^2 = .85. Accordingly, the following equation may be used for estimating purposes.

$$\text{Average Speed} = \log_e Y = 3.0 + .20 \log_e X_1 \text{ (width ft.)} \quad \ldots (ii)$$

By purring in different values of X in the equation (ii) above, the resulting speed of vehicles on a road can be estimated. For example, for 20 ft. wide road the average speed would be $3 + .20 \log 20 = 36.5$ mph.

The equation (ii) above implies that a 100% change in the width of road say from single lane to double lane or from 2 lane to 4 lane, would result in 20% increase in speed of vehicle.

This equation may be used for estimating speed for appraisal of highway project.

Other Variables:

Regression Analysis was also carried out with five other independent variables including volume, ratio of volume to width, two variations of each, one including and the other excluding non-mechanized vehicles, and proportion of slow moving vehicles. In all cases the results are not satisfactory. In the case of volume and ratio of volume to width, the Coefficients are positive, contrary to theoretical expectations. This was due to the problem of multicolinearity between width and volume.

In the case of proportion of slow moving vehicles, the signs of Coefficients are correct. However, R^2 are quite small. 't' ratios in most of the cases are not significant. Therefore, the Regressions of Volume, Ratio of volume to width and ratio of slow moving vehicles may therefore be ignored for the time being. Further research is called for determining the effect of volume and proportion of slow moving vehicles on speed.

Meanwhile other equations particularly those concerning width and speed may be used for estimating speeds for appraisal of highway investment projects and other purposes.

CHAPTER VIII

COMPARISON WITH OTHER SOURCES

Need for Comparison:

It is essential to compare results of any survey with similar other studies to support or contradict the results, to more similarities and differences between different sources and to validate the data. It may also be added here that surveys are intended to estimate population characteristics on sampling basis. The results of one sample can vary considerably from the other sources brings out the range of variation due to sampling and for other reasons. A knowledge of such variations results in better understanding of the problem. With these objectives, a comparison with other sources has been made.

For comparison between the two sources it is necessary that their scope, coverage and methodologies are similar. It is, however, difficult to find identical data from different sources. Variations are likely to arise due to differences in scope and methods as for differences between the time and distance mean speeds. Differences can also arise due to other factors such as vehicle composition, road and traffic conditions, regulations, etc. Such differences should also be kept.

It would not be out of place to add here that very vew general speed surveys have been carried out in the country and abroad. Such surveys which are carried out for various feasibility studies are rarely reported. Nevertheless, some references are available in published and un-published form and accordingly comparison has been made with national and international data available from various sources.

Third Highway Project:

The most recent information for road and traffic conditions comparable to our survey is available in the Third Highway Project Reports which are available in un-published form.

On the basis of speed tests carried out by their contractors, the average speeds laid down by the Project Consultants for preparing feasibility studies are given below:-

Table VIII (i)

Third Highway Project & NTRC Survey

	Average Speed MPH		
	Cars	Buses	Trucks
Third Highway Project*	37.8	31.6	26.3
NTRC Survey	45.0	39.9	32.3

* Source: Louis Berger International Inc. 3rd IBRD Highway Project, Economic Guide Lines for Consultants (No. I(13)/THE/77-315, August, 1977.

It would be seen from the above that Third Highway Project figures are consistently below the figures given by our survey. The difference is of about 16 to 20%. This is due to differences in scope and mehtods. The Third Highway Project figures give average speed for the road sections concerned while our survey gives spot speeds of free moving vehicles on straight level roads. The average speed over a road section is expected to be less than spot speed due to stopping and strarting time, slowing down on the way, curves, rise, fall and other obstructions on the road.

On the other hand, the NTRC Survey figures are an average of four categories of roads including the dual carriageway of the Islamabad Highway, portions of G.T. Road with more than 24 ft. width, other main roads 22 ft.—18 ft.wide, and single lane roads less than 12 ft. wide. The speed survey thus represents a sample of existing roads. As compared to this, the Third Highway Project included road sections needing improvements. Obviously, these would be the roads which are not in good condition. The speed on such roads would be less than on other roads.

Keeping in view the above factors, higher speeds given by our survey appear in order.

Transport and Road Research Laboratory,U.K. (TRRL):

The Transport and Road Research Laboratory of U.K. Report on Research on Road Traffic gives results of a number of speed studies. The distribution of speeds on different types of roads indicated in this Report and by our survey are

given below. The U.K. figures relate to cars only which constitute a major proportion of traffic there. The comparison has therefore been made between the speeds of cars only.

Table VIII (ii)

U.K. Roads and NTRC Survey
(Cars only)

Type of Road	Mean Speed MPH	Standard Deviation
TRRL (U.K.)		
Outer Sub-urban roads (1958)	35.2	6.0
Rural Roads (1958)	45.6	8.4
Motor Ways (1960)	59.2	13.2
NTRC Survey		
Dual Carriageway	50.5	8.8
Two Lane	44.7	8.9
Single Lane Roads	32.1	7.8
Average all roads	45.0	9.4

Source: TRRL, "Research on Road Traffic", 1965 Ch.3.

In the above data, the Rural Roads of U.K. are comparable to our intercity roads. The sub-urban roads, both inner and outer, do not have an equivalance in our survey. Similarly, single lane roads in our survey would have no equivalance in the U.K. data. These two categories i.e. sub-urban roads of U.K. and Single Lane roads of Pakistan may, therefore, be ignored. The comparison may be between the remaining categories viz between motorways and dual carriageway of Islamabad Highway and Rural Roads of U.K. and Two Lane roads in our survey.

Rural Roads:

It would be seen that the mean speed and standard deviations on U.K. rural roads and two lane roads in our survey are quite close to each other.

It may however be added that the U.K. data relates to 1958 while our figures relate to 1978. Thus there is a difference of 20 years. Speeds have been found to be increasing historically. Possible reasons are improvements in vehicle design, better driving skill, accumulation of experience, etc. Matson and others indicate an increase of one mile per hour per year from 1910 to 1941#. The Transport and Road Research Lab. of U.K.* have also found similar trends between the period 1947 and 1955. However, as indicated by Matson and others, the growth will level off under normal conditions and any large increase will be found on wider roads of higher speed design.

In the case of above comparison, it seems that speeds on our roads are the same as were 20 years before on the U.K. roads. Speed on U.K. roads should now be higher than on Pakistan roads as the U.K. roads are of much better standards. Besides, the vehicle composition on U.K. roads includes a large proportion of cars which operate at higher speeds than other vehicles.

In the above table, motorway speed of 59.2 MPH is higher than the Dual Carriageway of Islamabad Highway (50.5 MPH). As will be shown in the next paragraph, the motorway speed is also higher.

#Matson, Smith and Hurd, "Traffic Engineering" New York, 1955 Chapter 4.

*TRRL, "Research on Road Traffic" Chapter 3, Table 3.2

than speeds on other European Motorways. Therefore, a comparison of speeds on Dual Carriageway with other European Motorways has been made.

Motorway Speeds:

The following table compares speeds on European Motorways with the Dual Carriageway of Islamabad Highway:

Table VIII (iii)

European Motorways & Islamabad Highway

Mean Speed (M.P.H.)		Class of Vehicle			
		Cars	Light Comm.	Medium Comm.	Heavy Comm.
U.K.	2x3 lane (1960)	58	49	41	37
	2x2 lane (1959)	53	46	37	388
Germany	2x2 lane (1957)	54	46	40	38
Netherland	2x2 lane (1957)	53	45	41	40
Belgium	2x2 lane (1957)	52	40	38	35
France	2x2 lane (1957)	52	43	36	35
Pak.	2x2 lane (1978)	50	47	45	-

Source: "Research on Road Traffic" 1965, p.110 Table 3.1.

It would be seen that speed on the U.K. Motorway of 2x3 lanes is higher than on the other European Motorways of 2x2 lane. The Islamabad Highway is 2x2 lane. Speeds here are quite close to 2x2 lane European Motorways where speeds of cars vary between 52-54 MPH as compared to 50 MPH on the Islamabad Highway, more exactly 50.5 MPH. In the case of light commercial vehicles, the average speed on the European Motorways are between 40-46 MPH as against 47 MPH on

Islamabad Highway. Probably, the motorways include several types of vehicles in this category whereas our survey includes only wagons which are capable of operating at relatively higher speeds. In the Medium Commercial Vehicles Class, the European data includes goods vehicles as well, whereas our survey contains buses only the speed of which is higher than goods vehicles. The heavy commercial vehicles which on European Motorways include mostly multi-axle trucks, are not found on our roads and on the Islamabad Highway trucks are not allowed. Thus comparable vehicles in this class are not available.

It may be restated here that there is a difference of 20 years between the European motorways figures and our data. The historical increase over time may have made up the difference due to quality of roads in Pakistan.

Kenya Study:

The Kenya Study carried out by the Transport and Road Research Laboratory of U.K. in collaboration with the World Bank, also included, among other things, speed measurements. These were taken over 95 test sections of one kilometer length, at intervals of one month for unpaved and of two months for paved surfaces, for a period of two years. During this time 130,000 individual measurements were taken[(i)]. As compared to this, our survey covered about 25,980 measurements of spot speeds over 56 road sections.

(i) H.Hide,"An improved Data Base for Estimating Vehicle operating costs in developing countries" Transport and Road Research Laboratory Supplementary Report 223 UK, Crowthane 1976.

The road classification used in the Kenya Study include Asphalt Concrete Surface Roads, New Surface Dressed Roads and Graved Roads. In our survey, Category-I was asphalt concrete surface while other categories are surface dressed of different widths. Our survey does not include any gravel road. Therefore, comparison has been made between the three categories of roads in Kenya Study and average speed in our survey for all categories of roads.

The vehicle classifications used in the two studies differ in nominclature and possibly in composition as well. The vehicles classified as "Medium goods" in the Kenya Study are described as wagons in our survey. In both cases, the vehicles include mini-buses and light commercial vehicles. However, in our survey the number of wagons is dominent. In comparison to Medium and Heavy Goods Vehicles in the Kenya Study our survey includes Trucks only which are mostly of 10 ton capacity. It is thus possible that some Medium goods vehicles are included in the category of Medium and Heavy Goods Vehicles in the Kenya Study and are classified as wagons in our survey. However, any such overlapping is likely to be small. The classifications are broadly comparable.

The following table provides a comparison of average speeds and standard deviations (within brackets) between the Kenya Study and our survey. For the three categories of roads in the Kenya Study, an un-weighted average speed has also been calculated for ease of comparison with average speed of our survey.

Table VIII (iv)

Average Speed (MPH) and Standard Deviations

(within brackets)

Kenya Study*	Cars	Light Goods	Medium & Heavy Goods	Buses
1. Asphalt concrete surface on crushed stone base.	55.1 (8.6) (8.6)	46.4 (9.0)	36.3 (8.8)	36.4 (11.1)
2. New surface dressed road with Cement Stabalised base.	50.0 (7.7)	44.8 (7.4)	36.2 (8.1)	35.0 (9.9)
3. Old surface dressed road with Cement Stabalized base.	52.5 (9.4)	45.1 (8.3)	34.8 (8.8)	30.0 (11.1)
4. Average for 1-3 above.	52.5	45.4	35.7	35.8
NTRC Survey:				
1. Asphalt Concrete pre-mix(Category I)	50.0 (8.8)	47.1 (6.3)	- -	45.6 (5.0)
2. Surface Treated 2 lane (Category II, III and IV)	44.7 (8.9)	41.2 (6.8)	32.7 (6.5)	40.5 (6.3)

*Source: "The Kenya Road Transport Cost Study: Research on Vehicle Operating Costs". TRRL Report, 672 Table II.

As will be seen from the above, the speed of cars is higher in Kenya Study than our survey for all road categories, the average difference being 6.6 miles per hour. In the case of light goods vehicles, the speed on our Category I Roads is higher than Category I of Kenya Study. However, the speed on Category 2 and 3 of Kenya Study is higher than our surface treated two lane roads. The average difference being 2 MPH. In the case of Medium and Heavy Goods vehicles, the speeds for Kenya Study are higher than the speed of trucks on our roads. The difference is of 3 MPH. In the case of buses the speed indicated by our survey is higher than all road categories of Kenya, the difference being of 4.7 MPH on the average.

It would also be evident from the above that the largest difference is between the speeds of cars. This may be due to different composition of car fleets in the two countries. In Pakistan, small cars dominate. In kenya, cars may be of relatively larger size capable of running at higher speeds. The difference in the speed of other vehicles may also be due to composition of vehicle fleets, differences in quality of roads, driving habits and local regulations, etc.

Looking at standard deviations which indicate spread of values around the Mean, it would be seen that values for cars are more or less similar in both the Kenya Study and our survey. However, in the case of other road categories, values in the Kenya Study are large than our survey. This implies that speeds of vehicles are more consistent and have less spread around the mean on our roads as compared to Kenya. One of the reasons may be that Buses, Trucks and Wagons in Pakistan are mostly of the same make and type and their speed capabilities are not much different. Hence lower standard deviations.

It may also be indicated here that the Kenya observations were made over a length of one km. while our observations were made for 352 ft distance. Obviously, the speed over larger distance is likely to be less than over short distance. The difference in speeds between the Kenya Study and our survey would have been larger if the length of distance used for measurements were similar.

The obvious conclusion to be drawn is that average speeds in Kenya Study are somewhat higher than our survey.

The pattern of results is however the same.

U.S.A.

A comparison with somewhat different road and traffic conditions would also be interesting. Such a comparison would be provided by U.S. roads. However, the data for USA is available in the form of text book references which are quite old. Nevertheless, these provide some useful comparison.

The following table shows average spot speeds indicated by the Connecticut Highway Speed Study, 1953 alongwith speed indicated by our survey:

Table VIII (v)

Connecticut (USA) Study and NTRC Survey

	Spot Speed MPH	
	USA (1953)	NTRC Survey (1978)
Passenger Cars	48.1	44.7 Car
Light Truck	44.5	41.2 Wagon
Heavy Truck	44.0	32.3 Truck
Bus	50.0	40.5 Bus

Source: Matson, Smith and Hurd, Traffic Engineering New York, 1955, Table 4.4 Page 58.

It would be appropriate to indicate here that road conditions and vehicle composition in the United States are quite different from those in Europe and superior than this part of the world. Motor vehicles in the states are of larger size and capable of running aa higher speeds. Roads are also of better quality. The speeds in the United States are therefore expected to be higher than elsewhere.

It will be seen from the above table that inspite of the fact that time interval between the two sets of data is of more than 25 years during which vehicle design, quality of roads and driving skills have improved, speeds in USA are higher than in Pakistan for all categories of vehicles. The difference is largest for heavy trucks for which the speeds in USA are 44 MPH as compared to 32 MPH in our survey, a difference of 12 MPH. This is followed by buses where the difference is of 10 MPH. In the case of passenger cars and light goods vehicles, the difference is of 3.3 and 3.4 MPH only.

The above differences are, as indicated before, due to better road conditions, vehicle fleets capable of running at higher speeds and better overall environment. The differences in speed may not have increased much now due to present restrictions on maximum speed limits for energy savings, which on Inter State Highways is 55 MPH.

Conclusion of Comparisons:

The foregoing analysis has indicated that results of our survey are consistent and comparable with other national and international sources. Small variations are due to differences in scope, methodology and the environment. The reasons for other differences, where-ever existing, have been provided in the text. What was needed is that the data should be broadly comparable and the above comparisons have indicated that it is so undoubtedly. The results of our survey are thus strengthened and validated.

ANNEXURE - I

LIST OF ROADS COVERED IN THE SURVEY

S. No.	Code	Name of Road	Location of Obs. Point	Width of Surface (ft)	Date of Obs.	Time From	Time To
		Cat.I					
1	101	Islamabad Highway (Rawalpindi Islamabad direction)	(1.5 Km from Zero Point)	30'-0"	22.4.78	0700	1600
2	102	Islamabad Highway (Islamabad Rawalpindi direction)	(1.5 Km from Zero Point)	30'-0"	22.4.78	0800	1700
		Cat.II					
3	201	Faisalabad-Sheikhupura Road	(12 Km from Faisalabad)	30'-0"	11.5.78	0930	1830
4	202	Turnol-Taxila Road	(2 Km from Turnol)	23'-8"	19.4.78	1040	1555
5	203	Turnol-Taxila Road	(5 Km from Turnol)	28'-8"	19.4.78	1130	1900
6	204	Lahore Gujranwala Road	(5 Km from Muridka)	25'-0"	10.5.78	0930	1830
7	205	Sehala Rawat Road	(1.5 Km from Sehala Turn)	24'-6"	24.4.78	1000	1600
8	206	Sargodha Khushab Road	(13 Km from Sargodha)	24'-6"	25.5.78	0830	1730
9	207	Rawat Mandra Road	(3 Km from Mandra)	24'-0"	18.4.78	1200	1830
10	208	Sheikhupura Pindi Bhattian Road	(4 Km from Sheikhupura)	24'-0"	9.5.78	0900	1800
11	209	Sahiwal Okara Road	(8 Km from Sahiwal)	22'-6"	20.5.78	0800	1880
12	210	Dena Mangla Road	(8 Km from Dena)	22'-0"	3.5.78	0900	1800
13	211	Sheikhupura-Faisalabad Road	(10 Km from Sheikhupura)	22'-0"	9.5.78	0815	1815
14		**Cat.III**					
14	301	Sahiwal-Chichawatni Road	(9 Km from Sahiwal)	21'-0"	20.5.78	0730	1800
15	302	Jhang Faisalabad Road	(13 Km from Jhang)	20'-8"	12.5.78	0830	1830
16	303	Fatehjang Khour Road	(3 Km from Fatehjang)	20'-6"	29.4.79	1000	1800
17	304	Turnol Fatehjang Road	(3 Km from Turnol)	20'-0"	19.4.78	1233	1833
18	305	Fatehjang Turnol Road	(2 Km from Fatehjang)	20'-0"	30.4.78	0830	1800
19	306	Gujrat Mandi Bahuddin Road	(14 Km from Gujrat)	20'-0"	4.5.78	0800	1800
20	307	Gujrat Jalalpur Jattan Road	(9 Km from Gujrat)	20'-0"	4.5.78	1000	1900
21	308	Gujranwala Faizabad Road	(7 Km from Gujranwala)	20'-0"	8.5.78	0900	1800
22	309	Rajana Sammundri Road	(2 Km from Rajana)	20'-0"	15.5.78	0900	1800
23	310	Rajana Toba Tak Singh Road	(4 Km from Rajana)	20'-0"	16.5.78	0830	1830
24	311	Chichawatni Sahiwal Road	(6 Km from Chichawatni)	20'-0"	17.5.78	0920	1820
25	312	Sahiwal Pakpattan Road	(6 Km from Sahiwal)	20'-0"	18.5.78	0800	1800

S. No.	Code	Name of Road and	Location of Obs. Point	Width of Surface(ft)	Date of Obs.	Time From	Time To
26	313	Okara Sammundri Road	(10 Km from Okara)	20'-0"	21.5.78	0915	1815
27	314	Jhang 18 Hazari Road	(7 Km from Jhang)	20'-0"	24.1.78	0300	1700
28	315	Sargodha Jhang Road	(11 Km from Sargodha)	20'-0"	25.5.78	0300	1700
29	316	Sargodha Bhalwal Road	(17 Km from Sargodha)	20'-0"	27.5.78	0800	1800
30	317	Sargodha Lallian Road	(30 Km from Sargodha)	20'-0"	27.5.78	0900	1830
31	401	Faisalabad Chiniot Road	(13 Km from Faisalabad)	19'-6"	13.5.78	0715	1715
32	402	Faisalabad Samundri Road	(10 Km from Faisalabad)	19'-6"	14.5.78	0815	1715
33	403	Lawalpindi 17 Mile	(3 Km from Barakou towards Murree)	19'-0"	20.4.78	1000	1900
34	404	Wazirabad Sialkot Road	(5 Km from Wazirabad)	19'-0"	5.5.78	1030	1900
35	405	Sheikhupura Gujranwala Road	(10 Km from Sheikhupura)	19'-0"	10.5.78	0830	1800
36	406	Faisalalad Jhang Road	(18 Km from Faisalabad)	19'-0"	13.5.78	0900	1800
37	407	Chichawatni Burewala Road	(6 Km from Chichawatni)	19'-0"	17.5.78	0840	1735
38	408	Gujranwala Daska Road	(7 Km from Gujranwala)	18'-0"	6.5.78	0880	1830
39	409	Gujranwala Sheikhupura Road	(7 Km from Gujranwala)	18'-0"	8.5.78	0830	1830
40	410	Faisalalad Jararwala Road	(8 Km from Faisalabad)	18'-0"	11.5.78	1100	1800
41	411	Sahiwal Arifwala Road	(12 Km from Sahiwal)	17'-6"	18.5.78	0900	1800
42	412	Rajana Kamalia Road	(2 Km from Rajana)	16'-0"	15.5.78	0830	1830
43	Cat.IV						
43	501	Gujrat Dinber Road	(5 Km from Gujrat)	13'-0"	5.5.78	0900	1800
44	502	Mandra Chakwal Road	(5 Km from Mandara)	12'-0"	18.4.78	1500	1900
45	503	Jhang Sargodha Road	(8 Km from Jhang)	12'-0"	24.5.78	0830	1730
46	504	Okara Dibalpur Road	(13 Km from Okara)	11'-6"	21.5.78	0845	1800
47	505	Gujranwala Pasrur Road	(4.5 Km from Gujranwala)	11'-3"	6.5.78	0930	1900
48	506	Rawalpindi Lehtrar Road	(13 Km from Rawalpindi)	11'-0"	20.4.78	1100	1900
49	507	Kharian Rasul Road	(9 Km from Kharian)	10'-6"	3.5.78	1030	1900
50	508	Jhang Gojra Road	(13 Km from Jhang)	10'-6"	22.5.78	0930	1800
51	509	Jhang Chiniot Road	(11 Km from Jhang)	10'-6"	23.5.78	0900	1800
52	510	Jhang Toba Tak Singh Road	(12 Km from Jhang)	10'-4"	22.5.78	0830	1830
53	511	Rajana Pirmahal Road	(7 Km from Rajana)	10'-0"	16.5.78	0800	1800
54	512	Fatehjang Attock Road	(5 Km from Fatehjang)	9'-6"	29.4.78	0930	1800
55	513	Fatehjang Kohat Road	(2.5 Km from Fatehjang)	8'-6"	30.4.78	0900	1800
56	514	Fatehjang Attock Road	(1 Km from Fatehjang)	8'-0"	29.4.78	1200	1800

VOLUME OF TRAFFIC AND SPEED OBSERVATIONS

S. No.	ROAD CAT./ CODE	NAME OF ROAD	WIDTH Ft.In.	Dist.	M/Cy.	Car	Wagon	Bus	Truck	Other	All
1.	1.01	ISLAMABAD HIGHWAY	30.00	Vol.	876	2265	1005	291	26	-	4463
				Sp.Obs.	208	472	334	164	2	-	1180
2.	1.02	ISLAMABAD HIGHWAY	30.00	Vol.	864	2369	914	259	54	3	4463
				Sp.Obs.	164	674	374	145	25	-	1382
		CATEGORY-I		Vol.	1740	4634	1919	550	80	3	8926
				Sp.Obs.	372	1146	708	309	27	-	2562
3.	2.01	FAISALABAD-SHEIKHUPURA ROAD	30.00	Vol.	117	273	33	517	206	21	1167
				Sp.Obs.	59	154	27	290	133	13	676
4.	2.02	TURNOL TO TAXILA ROAD	28.08	Vol.	138	1187	476	640	1176	28	3645
				Sp.Obs.	57	205	122	265	275	12	936
5.	2.03	TURNOL-TAXILA ROAD	28.08	Vol.	134	1078	416	586	1033	23	3320
				Sp.Obs.	34	219	145	236	365	11	1012
6.	2.04	LAHORE-GUJRANWALA ROAD	25.00	Vol.	75	813	192	643	363	17	2189
				Sp.Obs.	38	336	104	337	179	12	1006
7.	2.05	SEHALA-RAWAT ROAD	24.06	Vol.	13	143	36	275	157	4	615
				Sp.Obs.	8	87	26	178	101	1	401
8.	2.06	SARGODHA-KHUSHAB ROAD	24.06	Vol.	30	194	4	333	177	24	762
				Sp.Obs.	22	146	1	287	140	12	608
9.	2.07	RAWAT-MANDRA ROAD	24.00	Vol.	53	508	144	384	425	5	1519
				Sp.Obs.	31	170	69	185	171	2	628
10.	2.08	SHEIKHUPURA-PINDI BHATTIAN ROAD	24.00	Vol.	112	204	31	237	236	21	841
				Sp.Obs.	63	125	19	199	167	10	583

S. No.	ROAD CAT./ CODE	NAME OF ROAD	WIDTH Ft.In.	Dist.	M/Cy	Car	Wagon	Bus	Truck	Other	All
11.	2.09	SAHIWAL-OKARA ROAD	22-06	Vol.	83	216	20	340	344	39	1042
				Sp.Obs.	58	164	18	301	261	26	823
12.	2.10	DENA-MANDRA ROAD	22-00	Vol.	104	285	143	115	169	1	817
				Sp.Obs.	66	205	101	93	114	1	580
13.	2.11	SHEIKHUPURA-LYALLPUR ROAD	22-00	Vol.	62	273	35	464	332	37	1203
				Sp.Obs.	31	157	27	279	204	25	723
		C.TEGORY-II		Vol.	921	5174	1530	4534	4668	220	17047
				Sp.Obs.	467	1968	654	2652	2110	125	7976
14.	3.01	SAHIWAL-CHICHA WATNI ROAD.	21-00	Vol.	72	121	19	384	260	16	872
				Sp.Obs.	45	104	11	285	172	12	629
15.	3.02	JHANG-FAISALABAD ROAD	20-08	Vol.	25	89	8	188	159	10	479
				Sp.Obs.	19	80	7	154	134	8	402
16.	3.03	FATEH JANG-KHOUR ROAD	20-06	Vol.	2	63	36	71	100	2	272
				Sp.Obs.	2	52	30	57	84	2	227
17.	3.04	TURNOL-FATEH JANG ROAD	20-00	Vol.	11	106	18	104	115	5	359
				Sp.Obs.	8	79	15	87	84	4	277
18.	3.05	FATEI JANG-TURNOL ROAD	21-00	Vol.	23	141	53	196	157	8	578
				Sp.Obs.	16	117	39	171	124	5	472
19.	3.06	GUJRAT-MANDI BHAUIDIN ROAD	20-08	Vol.	37	56	5	183	93	7	381
				Sp.Obs.	33	50	4	139	85	6	317
20.	3.07	GUJRAT-JALALPUR JATTAN ROAD		Vol.	90	95	17	217	27	7	453
				Sp.Obs.	70	71	13	170	22	6	352
21.	3.08	GUJRANWALA-HAFIZABAD ROAD.	20-00	Vol.	93	64	118	124	85	65	549
				Sp.Obs.	60	64	79	106	66	36	411
22.	3.09	RAJANA-SAMMUNDRI ROAD	20-00	Vol.	49	44	7	218	81	26	425
				Sp.Obs.	32	39	4	192	64	13	344

S. No.	ROAD CAT./ CODE	NAME OF ROAD	WIDTH Ft.In.	Dist.	M/Cy.	Car	Wagon	Bus	Truck	Other	All
23	3.10	RAJANA-TOBA TAKE SINGH ROAD	20-00	Vol.	65	64	32	112	59	48	380
				Sp.Obs.	51	53	26	92	52	23	297
24.	3.11	CHICHA WATNI-SAHIWAL ROAD	20-00	Vol.	45	109	9	268	229	27	687
				Sp.Obs.	32	88	8	205	154	16	503
25.	3.12	SAHIWAL-PAKPATTAN ROAD	20-00	Vol.	48	63	5	130	59	32	337
				Sp.Obs.	40	59	2	116	49	27	293
26.	3.13	OKARA-SAMMUNIDRI ROAD (ATHARAN)	20-00	Vol.	34	26	1	110	16	25	212
				Sp.Obs.	29	24	1	104	15	21	194
27.	3.14	JHANG-18/HAZARI ROAD	20-00	Vol.	37	88	9	301	227	29	691
				Sp.Obs.	25	72	7	216	153	26	499
28.	3.15	SAHGODHA-JHANG ROAD	20-00	Vol.	33	69	6	123	70	15	316
				Sp.Obs.	26	63	6	107	55	13	270
29.	3.16	SARGODHA-BHALWAL ROAD	20-00	Vol.	16	76	11	211	54	15	383
				Sp.Obs.	13	56	11	107	45	11	325
30.	3.17	SARGODHA-LALLIAN ROAD	20-00	Vol.	65	229	8	366	470	17	1155
				Sp.Obs.	34	162	5	305	291	11	808
31.	4.01	LYALLPUR-CHINIOT ROAD	19-06	Vol.	143	207	15	301	403	21	1090
				Sp.Obs.	72	135	9	237	254	8	715
32.	4.02	LYALLPUR-SAMMUNDRI ROAD	19-06	Vol.	150	139	14	512	252	31	1098
				Sp.Obs.	69	88	13	294	159	20	643
33.	4.03	RAWALPINDI-SATRA MILE ROAD	19-00	Vol.	60	447	120	180	129	2	878
				Sp.Obs.	30	256	93	133	87	2	601

S. No.	ROAD CAT./ CODE	NAME OF ROAD	Width Ft.In	Dist	M/Cy.	Car	Wagon	Bus	Truck	Other	All
34	4.04	WAZIRABAD-SIALKOT ROAD	19-00	Vol.	110	157	21	130	57	9	484
				Sp.Obs.	69	112	15	105	51	7	359
35.	4.05	SHEIKHUPURA-GUJRANWALA ROAD	19-00	Vol.	27	91	16	201	219	29	583
				Sp.Obs.	16	66	9	169	154	11	425
36.	4.06	LYALLPUR-JHANG ROAD	19-00	Vol.	60	92	13	279	170	22	805
				Sp.Obs.	36	68	13	212	136	15	480
37.	4.07	CHICHA WATNI-BUREWALA ROAD	19-00	Vol.	52	15	3	131	66	37	304
				Sp.Obs.	44	15	3	107	55	20	244
38.	4.08	GUJRANWALA-DASKI ROAD	18-00	Vol.	211	256	80	350	143	34	1074
				Sp.Obs.	117	178	55	225	104	28	708
39.	4.09	GUJRANWALA-SHEIKHUPURA ROAD	18-00	Vol.	125	145	19	282	273	23	877
				Sp.Obs.	67	106	11	184	178	20	566
40.	4.10	LYALLPUR-JARANWALA ROAD	18-00	Vol.	161	129	26	254	102	46	718
				Sp.Obs.	100	98	17	214	83	18	530
41.	4.11	SAHIWAL-ARIF WALA ROAD	17-06	Vol.	28	62	3	140	91	11	335
				Sp.Obs.	22	54	3	121	79	6	285
42.	4.12	PAJANA-KAMALLA ROAD	16-00	Vol.	36	44	8	264	81	45	528
				Sp.Obs.	44	30	6	200	58	25	363
		CATEGORY - III		Vol.	1958	3287	722	6339	4247	664	17186
				Sp.Obs.	1213	2439	515	4395	3047	420	12539
43.	5.01	GUJRAT-BHIMBER ROAD	13-00	Vol.	51	31	7	90	42	3	224
				Sp.Obs.	40	30	4	81	41	2	198
44.	5.02	MANDRA-CHAKWAL ROAD	12-00	Vol.	10	70	28	60	44	30	215
				Sp.Obs.	10	66	25	58	43	3	205
45.	5.03	JHANG-SARGODHA ROAD	12-00	Vol.	28	69	44	98	31	17	287
				Sp.Obs.	21	52	34	88	27	11	233

S. No.	ROAD CAT./ CODE	NAME OF ROAD	Width Ft.In.	Dist.	M/Cy.	Car	Wagon	Bus	Truck	Other	All
46.	5.04	OKARA-DIBALPUR ROAD	11-06	Vol.	45	74	3	152	160	28	462
				Sp.Obs	28	48	3	104	98	20	301
47	5.05	GUJRANWALA-PASRUR ROAD	11-03	Vol.	157	55	53	73	25	74	437
				Sp.Obs.	83	40	48	62	17	43	293
48.	5.06	RAWALPINDI-LEHTRAR	11-00	Vol.	81	188	54	67	48	2	440
				Sp.Obs.	51	123	43	61	44	1	326
49.	5.07	KHARIAN-RASUL ROAD	10-06	Vol.	43	62	20	111	93	13	342
				Sp.Obs.	34	54	11	94	71	10	274
50.	5.08	JHANG-GOJRA ROAD	10-06	Vol.	21	9	2	50	15	5	102
				Sp.Obs.	20	9	1	50	15	5	100
51.	5.09	JHANG-CHINIOT ROAD	10-06	Vol.	9	23	10	89	98	19	248
				Sp.Obs.	9	21	10	83	85	13	221
52.	5.10	JHANG-TOBA TAKE SINGH ROAD	10-04	Vol.	17	25	2	102	22	14	182
				Sp.Obs.	15	24	2	97	22	13	173
53.	5.11	RAJANA-PIR MAHAL ROAD	10-00	Vol.	35	23	15	103	46	9	281
				Sp.Obs.	33	23	3	100	40	9	288
54.	5.12	FATEH JANG-ATTOCK ROAD	09-06	Vol.	1	24	3	41	49	-	118
				Sp.Obs.	1	24	2	4	44	-	112
55.	5.13	FATEH JANG-KOHAT ROAD	08-06	Vol.	8	60	31	76	47	6	228
				Sp.Obs.	7	44	26	67	38	6	188
56.	5.14	FATEH JANG-ATTOCK ROAD	08-00	Vol.	1	18	2	20	32	-	73
				Sp.Obs.	1	17	2	20	31	-	71
		CATEGORY-5		Vol.	507	731	274	1132	752	193	3589
				Sp.Obs.	356	575	214	1006	616	136	2903
		ALL CATEGORIES COMBINED		Vol.	5126	13826	4423	12546	9747	1080	46748
				Sp.Obs.	2418	6128	2091	8862	5800	681	25980

ANNEXURE-III

AVERAGE SPEED OF VEHICLES (MPH)
(Standard Deviations within Brackets)

S. No.	CODE	NAME OF ROAD	Width Ft.In.	M/Cy.	CAR	WAGON	BUS	TURCK	OTHER	ALL
1	101	ISLAMABAD HIGHWAY	30'-00"	38.6 (6.7)	50.3 (9.4)	46.9 (6.6)	44.7 (4.7)	- -	- -	46.5 (8.7)
2	102	ISLAMABAD HIGHWAY	30'-00"	38.8 (7.4)	50.6 (8.5)	47.2 (6.2)	46.8 (5.1)	-	-	47.8 (8.4)
		CATEGORY - I		38.7 (7.0)	50.5 (8.9)	47.0 (6.4)	45.6 (5.0)	-	-	47.2 (8.6)
3.	201	LYALLPUR-SHEIKHUPURA ROAD	30'-00"	29.2 (6.6)	48.1 (8.3)	43.0 (6.1)	42.6 (5.4)	31.2 (5.3)	15.1 (1.9)	39.9 (9.7)
4.	202	TURNOL-TAXILA ROAD	28'-08"	37.2 (5.0)	46.6 (8.2)	44.0 (6.0)	41.2 (5.9)	35.0 (5.8)	20.1 (7.2)	40.4 (8.1)
5.	203	TURNOL-TAXILA ROAD	28'-08"	37.4 (7.5)	47.7 (8.6)	45.3 (5.0)	43.4 (6.7)	36.8 (5.7)	16.9 (5.4)	41.7 (8.4)
6.	204	LAHORE-GUJRANWALA ROAD	25'-00"	33.8 (6.5)	46.6 (8.9)	44.0 (4.7)	43.9 (4.3)	31.5 (4.7)	15.6 (2.3)	41.9 (8.9)
7.	205	SEHALA-RAWAT ROAD	24'-06"	33.7 (5.2)	45.6 (9.7)	43.3 (6.3)	43.5 (8.0)	30.0 (7.2)	11.4	40.3 (10.3)
8.	206	SARGODHA-KHUSHAB ROAD	24'-06"	33.8 (6.3)	42.3 (8.9)	40.0	41.6 (5.3)	33.7 (5.4)	13.2 (3.1)	39.1 (8.2)
9.	207	RAWAT-TANDPA ROAD	24'-00"	35.4 (8.3)	50.2 (9.3)	43.3 (5.3)	44.1 (7.8)	34.2 (5.8)	15.8 (1.3)	42.6 (9.6)
10.	208	SHEIKHUPURA-PINDI BHATTIAN ROAD	24'-00"	30.7 (5.4)	45.2 (8.7)	38.3 (6.7)	38.6 (5.8)	32.4 (5.3)	18.0 (7.7)	37.0 (8.6)
11.	209	SAHIWAL-OKARA ROAD	22'-06"	31.1 (6.0)	48.1 (8.7)	49.0 (7.0)	42.6 (6.1)	33.0 (5.6)	16.0 (2.2)	39.1 (9.9)

S. No.	Code	Name of Road	Width Ft.In.	M/Cy.	Car	Wagon	Bus	Truck	Other	All
12.	210	DENA-MANGLA ROAD	22'-00"	36.2 (7.4)	44.9 (7.8)	40.5 (6.5)	38.6 (4.5)	34.9 (4.7)	23.5	40.1 (7.7)
13.	211	SHEIKHUPURA-LYALPUR ROAD	22'-00"	32.2 (6.9)	49.9 (9.1)	42.7 (6.2)	45.5 (4.6)	33.8 (5.0)	14.5 (1.7)	41.4 (10.1)
		CATEGORY - II		33.8 (7.3)	46.9 (8.9)	43.5 (6.0)	42.6 (6.1)	33.8 (5.8)	16.0 (4.4)	40.5 (4.0)
14.	301	SAHIWAL-CHICHA WATNI ROAD	21'-00"	30.5 (6.7)	49.2 (9.8)	42.9 (7.3)	41.5 (6.0)	32.3 (4.5)	18.3 (8.3)	39.0 (9.4)
15.	302	JAHNG-FAISALABAD ROAD	20'-08"	33.3 (7.5)	45.9 (8.9)	40.5 (8.9)	43.1 (5.3)	33.0 (5.7)	15.4 (1.4)	39.2 (9.0)
16.	303	FATEH JANG-KHOUR ROAD	20'-06"	41.2 (8.8)	44.7 (8.7)	35.8 (7.0)	40.3 (6.0)	33.2 (6.0)	15.6 .3	37.9 (8.5)
17.	304	TURNOL-FATEHJANG ROAD	20'-00"	37.9 (10.5)	39.7 (7.9)	38.3 (6.4)	33.9 (3.4)	29.4 (4.4)	14.2 (1.2)	34.3 (7.4)
18.	305	FATEHJANG-TURNOL ROAD	20'-00"	32.2 (7.0)	44.1 (8.7)	39.2 (7.9)	39.8 (4.6)	34.3 (4.2)	14.7 (2.1)	38.9 (7.6)
19.	306	GUJRAT-MANDI BHAUDDIN ROAD	20'-00"	37.4 (7.8)	47.6 (6.8)	42.8 (4.2)	40.7 (6.9)	35.8 (5.8)	14.6 (1.1)	39.7 (8.4)
20.	307	GUJRAT-JALALPUR JATTAN ROAD	20'-00"	31.7 (7.1)	43.3 (7.6)	35.6 (6.0)	34.3 (4.6)	35.1 (4.7)	15.4 (3.2)	35.4 (7.6)
21.	308	GUJRANWALA-HAFIZABAD ROAD	20'-00"	31.1 (6.2)	41.8 (7.9)	36.3 (5.4)	38.8 (5.1)	34.2 (5.8)	16.1 (1.8)	34.9 (8.8)
22.	309	RAJANA-SAMUNDRI ROAD	20'-00"	30.1 (5.0)	42.1 (7.3)	42.4 (7.0)	43.9 (5.7)	33.2 (5.2)	17.3 (2.8)	39.4 (8.8)
23.	310	RAJANA-JHANG TAKE SINGH ROAD.	20'-00"	31.4 (5.0)	40.5 (8.7)	35.4 (7.5)	35.3 (5.8)	33.1 (6.2)	15.1 (2.6)	33.6 (8.8)

S. No.	CODE	NAME OF ROAD	WIDTH Ft.In.	M/Cy	CAR	WAGON	BUS	TRUCK	OTHER	ALL
24.	311	CHICHA WATNI-SAHIWAL ROAD	20'-00"	28.8 (5.6)	45.6 (7.1)	40.1 (6.3)	41.1 (5.1)	81.5 (5.2)	14.8 (2.2)	37.3 (8.9)
25.	312	SAHIWAL-PAKPATTAN ROAD	20'-00"	32.8 (5.8)	43.4 (7.0)	46.4 (3.6)	39.6 (5.6)	33.7 (5.9)	16.5 (2.4)	36.4 (9.3)
26.	313	OKARA-SAMMUNDARI ROAD	20'-00"	28.8 (6.1)	38.8 (6.4)	46.1 (	35.8 (5.8)	33.0 (5.7)	15.8 (2.2)	32.8 (8.7)
27.	314	JHANG-18 HAZARI ROAD	20'-00"	29.1 (5.2)	42.9 (8.1)	41.2 (2.8)	41.3 (5.9)	82.0 (4.0)	15.1 (3.8)	36.7 (9.0)
28.	315	SARGODHA-JHANG ROAD	20'-00"	31.3 (5.7)	45.2 (8.7)	35.5 (2.4)	39.7 (6.2)	31.9 (4.5)	14.4 (1.7)	37.3 (9.6)
29.	316	SARGODHA-BHALAWAL ROAD	20'-00'	30.5 (4.8)	41.4 (7.5)	41.8 (7.5)	40.8 (5.0)	33.9 (5.6)	14.5 (3.0)	38.6 (7.9)
30.	317	SARGODHA-LALLIAN ROAD	20'-00'	30.0 (6.6)	43.6 (8.0)	40.3 (5.0)	40.6 (5.7)	32.7 (4.8)	40.9 (1.6)	37.6 (8.0)
31.	401	LYALLPUR-CHINIOT ROAD	19'-6"	29.8 (6.3)	43.7 (7.6)	38.0 (7.5)	37.0 (5.7)	29.8 (4.4)	16.9 (3.0)	34.8 (8.1)
32.	402	LYALLPUR-SAMMUNDRI ROAD	19'-6"	30.7 (5.9)	38.6 (7.1)	32.6 (4.6)	37.8 (4.7)	30.3 (4.2)	15.3 (2.1)	34.5 (7.1)
33.	403	RAWALPINDI-SATRA MILE ROAD	19'-0"	32.1 (6.3)	37.5 (5.4)	37.5 (4.7)	31.0 (5.6)	26.4 (7.5)	30.1 (2.3)	34.2 (7.1)
34.	404	WAZIRABAD-SIALKOT ROAD	19'-0"	31.9 (6.4)	46.3 (8.9)	41.8 (5.7)	40.8 (5.4)	33.0 (4.9)	14.1 (2.9)	39.2 (9.5)
35.	405	SHEIKHUPURA-GUJRANWALA ROAD.	19'-0"	31.1 (5.2)	44.5 (7.8)	39.2 (4.8)	38.3 (6.3)	30.7 (4.6)	14.9 (2.4)	35.9 (8.5)
36.	406	LYALLPUR-JHANG ROAD	19'-00"	29.6 (3.8)	41.1 (9.0)	33.9 (9.5)	36.9 (5.7)	29.7 (3.7)	14.4 (1.9)	34.1 (7.9)

S. No.	Code	Name of Road	Width Ft.In	M/Cy.	CAR	WAGON	BUS	TRUCK	OTHER	ALL
37.	407	CHICHA WATNI-BUREWALA ROAD	19'-00"	29.1 (5.8)	41.3 (7.7)	39.0 (1.8)	37.7 (6.4)	30.9 (4.4)	15.4 (2.4)	33.0 (8.7)
38.	408	GUJRANWALA-DASKA ROAD	18'-00"	33.2 (6.8)	42.8 (7.6)	42.0 (6.5)	39.5 (6.2)	33.5 (5.1)	13.7 (1.5)	37.6 (8.9)
39.	409	GUJRANWALA-SHEIKHUPURA ROAD	18'-00"	28.8 (4.8)	45.9 (9.0)	42.2 (4.6)	40.6 (7.3)	32.1 (5.0)	16.2 (2.7)	36.7 (9.7)
40.	410	LYALLPUR-JARANWALA ROAD	18'-00"	30.9 (6.2)	39.3 (8.9)	39.4 (6.4)	39.4 (5.5)	32.5 (5.1)	16.8 (2.2)	35.9 (8.1)
41.	411	SAHIWAL-ARIF WALA ROAD	17'-06"	30.9 (6.6)	44.7 (8.6)	41.5 (6.5)	40.4 (5.7)	33.1 (5.2)	16.4 (5.5)	38.0 (8.5)
42.	412	RAJANA-KAMALIA ROAD	16'-00"	32.2 (6.9)	41.1 (8.3)	36.4 (8.3)	43.1 (4.8)	31.4 (4.9)	15.1 (2.8)	37.7 (9.6)
		CATEGORY - III		31.2 (6.5)	42.9 (8.5)	38.4 (6.7)	39.4 (6.2)	32.0 (5.3)	15.6 (3.2)	36.7 (8.7)
43.	501	GUJRAT-BHIMBER ROAD	13'-00"	28.7 (6.5)	41.7 (6.4)	32.1 (4.6)	82.0 (6.1)	31.2 (5.6)	12.51 (.4)	32.4 (7.5)
44.	502	MANDRA-CHAKWAL ROAD	12'-00"	37.1 (2.6)	37.1 (6.9)	38.9 (6.1)	39.5 (5.6)	34.6 (5.1)	12.3 (2.7)	37.3 (6.8)
45.	503	JHANG-SARGODHA ROAD	12'-00"	29.4 (4.2)	36.3 (7.3)	33.8 (6.3)	36.2 (6.4)	29.3 (4.0)	14.3 (2.9)	33.4 (7.9)
46.	504	OKARA-DIPALPUR ROAD	11'-06"	31.5 (7.4)	42.0 (8.0)	31.7 (8.5)	32.2 (5.5)	28.3 (7.0)	15.6 (2.4)	30.8 (8.8)
47.	505	GUJRANWALA-PASRUR ROAD	11'-03"	28.3 (5.3)	38.2 (8.0)	28.0 (7.1)	28.7 (5.2)	26.1 (4.2)	14.4 (3.0)	27.5 (8.6)

S. No.	CODE	NAME OF ROAD	WIDTH FT.IN.	M/CY	CAR	WAGON	BUS	TRUCK	OTHER	ALL
48.	506	RAWALPINDI-LEHTRAR ROAD	11'-00"	31.3 (6.3)	33.6 (6.8)	33.2 (4.3)	30.3 (6.2)	23.5 (5.8)	11.4	31.8 (6.7)
49.	507	FTARIAN-BASUR ROAD	10'-06"	27.3 (4.4)	33.6 (7.7)	32.1 (6.3)	27.5 (5.9)	25.1 (5.4)	16.0 (6.6)	28.1 (7.0)
50.	508	JHANG-GOJRA ROAD	10'-06"	30.0 (6.7)	36.9 (6.4)	44.4	31.7 (4.8)	32.0 (5.5)	14.4 (.9)	31.1 (6.9)
51.	509	JHANG-CHINIOT ROAD	10'-06"	27.8 (7.4)	37.0 (4.8)	35.9 (7.6)	33.5 (7.6)	25.6 (5.9)	14.5 (2.9)	29.9 (8.5)
52.	510	JHANG-TOBA TAKE SINGH ROAD	10'-04"	28.4 (5.6)	41.6 (5.5)	48.0 (1.9)	37.2 (5.0)	31.5 (5.3)	14.3 (1.1)	34.6 (8.5)
53.	511	RAJANA-PIR MAHAL ROAD	10'-00"	30.2 (6.4)	38.3 (6.2)	34.2 (5.1)	34.3 (4.7)	23.7 (5.3)	14.1 (1.4)	32.3 (7.0)
54.	512	FATEH JANG-ATTOCK ROAD	09'-06"	37.5	37.4 (5.6)	42.9 (1.5)	33.9 (4.2)	31.2 (4.1)		33.8 (5.2)
55.	513	FATEH JANG-KOHAT ROAD	08'-06"	36.7 (7.0)	42.3 (9.2)	37.3 (5.7)	37.2 (5.1)	29.7 (3.4)	12.8 (2.9)	36.2 (8.9)
56.	514	FATEH JANG-ATTOCK ROAD	08'-00"	31.5	31.7 (6.8)	29.7 (1.8)	29.3 (2.6)	24.8 (3.7)		27.9 (5.2)
		CATEGORY-IV		29.7 (6.3)	37.1 (7.8)	33.7 (7.3)	33.2 (6.6)	28.8 (6.0)	14.5 (3.1)	31.8 (8.2)
		ALL CATEGORIES		32.6 (7.3)	45.0 (9.4)	42.4 (7.8)	38.9 (6.9)	32.3 (5.8)	15.4 (3.4)	38.3 (9.6)

Table IV

Distribution of Vehicles According to Speed

Road Category	Speed Class MPH	M/Cy.	Cars	Wagon	Bus	Truck	Other	Total
I	Upto 20	1	-	-	-	-	-	1
	20- 24.9	4	-	-	-	-	-	4
	25- 29.9	21	3	1	-	1	-	6
	30- 34.9	86	31	19	6	2	-	144
	35- 39.9	116	87	72	39	5	-	319
	40- 44.9	76	190	178	82	6	-	532
	45- 49.9	31	186	148	88	1	-	454
	50- 54.9	32	313	210	89	9	-	653
	55- 59.9	1	160	61	5	3	-	230
	60 +over	4	176	19	-	-	-	119
	Total	372	1146	708	809	27	-	2562
II	Upto 20	5	-	-	-	14	116	135
	20- 24.9	44	17	1	6	94	5	157
	25- 29.9	102	35	10	57	430	1	635
	30- 34.9	123	136	39	234	714	1	1247
	35- 39.9	85	233	123	489	506	-	1436
	40- 44.9	76	390	184	878	273	2	1803
	45- 49.9	20	394	90	652	59	-	1315
	50- 54.9	10	432	93	292	20	-	847
	55- 59.9	2	159	11	35	-	-	207
	60 +over	-	182	3	9	-	-	194
	Total	467	1968	654	2652	2110	125	7976

Contd.....

(from pre-page)

Road Category	Speed Class MPH	M/Cy.	Cars	Wagon	Bus	Truck	Other	Total
III	Upto 20	21	1	-	6	25	395	450
	20- 24.9	169	23	10	47	145	20	414
	25- 29.9	348	103	37	262	920	2	1672
	30- 34.9	353	297	122	850	1139	2	2763
	35- 39.9	202	449	131	1245	550	-	2577
	40- 44.9	94	637	133	1569	222	1	2656
	45- 49.9	20	373	52	639	37	-	1121
	50- 54.9	13	371	25	264	8	-	681
	55- 59.9	-	95	3	11	1	-	110
	60 +over	1	90	2	2	-	-	95
	Total	1223	2439	515	4895	3047	420	12539
VI	Upto 20	15	4	7	24	36	132	218
	20- 24.9	66	27	15	64	98	1	271
	25- 29.9	108	74	44	213	211	2	652
	30- 34.9	93	138	56	312	184	1	784
	35- 39.9	50	117	42	220	58	-	496
	40- 44.9	20	118	35	116	25	-	314
	45- 49.9	4	48	12	41	4	-	109
	50- 54.9	-	45	3	7	-	-	55
	55- 59.9	-	4	-	-	-	-	4
	60-+over	-	-	-	-	-	-	-
	Total	356	575	214	1006	616	136	2903
ALL	Upto 20	44	5	7	30	75	643	804
	20- 24.9	283	57	26	117	337	26	846
	25- 29.9	579	215	92	532	1562	5	2985
	30- 34.9	655	602	236	1402	2039	4	4938
	35- 39.9	458	886	368	2002	1119	-	4828
	40- 44.9	266	1335	530	2645	526	3	5305
	45- 49.9	75	1001	402	1420	101	-	2999
	50- 54.9	56	1161	331	652	37	-	2236
	55- 59.9	3	418	75	51	4	-	551
	60 +over	5	448	24	11	-	-	488
	Total	2418	6128	2091	8262	5800	681	25980

ANNEXURE - V

ZERO ORDER CORRELATION MATRIX

		Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	X_1	X_2	X_3	X_4	X_5	X_6
Av. Speed M/Cy	Y_1	1.00												
Car	Y_2	.38	1.00											
Wagon	Y_3	.36	.65	1.00										
Bus	Y_4	.85	.27	.29	1.00									
Truck	Y_5	.54	.68	.66	.28	1.00								
Other	Y_6	-.26	.05	-.04	-.02	-.27	1.00							
All Veh.	Y_7	.58	.86	.74	.34	.82	-.08	1.00						
Width	X_1	.37	.78	.62	.29	.67	-.11	.81	1.00					
Vol.Mech.	X_2	.50	.55	.47	.26	.63	-.18	.66	.69	1.00				
Vol. All	X_3	.44	.52	.43	.23	.65	-.22	.63	.68	.97	1.00			
X_2/X_1	X_4	.46	.47	.37	.25	.52	-.13	.58	.59	.98	.95	1.00		
X_3/X_1	X_5	.31	.34	.21	.13	.46	-.18	.42	.47	.86	.93	.90	1.00	
X_3-X_2/X_3	X_6	-.48	-.29	-.26	-.27	-.09	-.78	-.38	-.23	-.33	-.14	-.32	.04	1.00

ANNEXURE-VI

RESULTS OF REGRESSION ANALYSIS

Y (Average Speed) = a + bx (Width)

Average Speed		a. Const. (t ratio)	b. Coefficient (t ratio)	R^2 (F ratio)
56 Observations - Linear Form				
M/Cy.	Y_1 =	28.14 + (1.4)	.220 X_1 (.07)	.135 (8.5)
Car	Y_2 =	31.25 + (24)	.610 X_1 (9.2)	.612 (85)
Wagon	Y_3 =	29.81 + (17)	.512 X_1 (5.8)	.386 (34)
Bus	Y_4 =	33.06 + (10.9)	.340 X_1 # (2.2)	.082 # (4.8)
Truck	Y_5 =	24.40 + (20)	.413 X_1 (6.6)	.447 (43)
Other	Y_6 =	12.67 + (5.5)	.094 X_1 # (0.8)	.012 # (.66)
All Veh.	Y_7 =	25.49 + (22)	.589 X_1 (10)	.652 (101)
56 Observations — Log_e Form				
M/Cy.	Y_{14} =	3.19 + (28)	.094 X_1 # (2.4)	.099 # (5.9)
Car	Y_{15} =	3.04 + (39)	.243 X_1 (9.0)	.601 (81)
Wagon	Y_{16} =	3.03 + (26.7)	.218 X_1 (5.5)	.364 (31)
Bus	Y_{17} =	3.16 + (19)	.172 X_1 # (3.1)	.153 # (9.8)
Truck	Y_{18} =	2.87 + (31)	.204 X_1 (6.3)	.429 (40)
Other	Y_{19} =	.017 + (.005)	.704 X_1 # (.07)	.009 # (.49)
All Veh.	Y_{20} =	2.82 + (34)	.265 X_1 (9.2)	.613 (85)

Not Significant

(from pre-page)

No. of Obs. =10

10 Observations — Linear Form

Average Speed		Const.		Coefficient		R^2
$Y = a + bx$						
M/Cy.	Y_1 =	30	+	.13 (2.6)	X_1	.47 (7.0)
Car	Y_2 =	38 (21)	+	.26 (3.8)	X_1	.64 (14)
Wagon	Y_3 =	34 (19)	+	.25 (3.7)	X_1	.64 (14)
Bus	Y_4 =	35 (16)	+	.23 (2.9)	X_1 #	.52 # (8.6)
Truck	Y_5 =	26 (27)	+	.31 (8.5)	X_1	.90 (73)
Other	Y_6 =	19 (10)	-	.26 -(3.5)	X_1 #	.61 (12) #
All Veh.	Y_7 =	31 (24)	+	.29 (5.8)	X_1	.81 (34)

10 Observations Log_e Form

M/Cy.	Y_1 =	3.27 (24)	+	.074 (1.7)	X_1 #	.265 # (2.8)
Car	Y_2 =	3.27 (34)	+	.168 (5.2)	X_1	.709 (27)
Wagon	Y_3 =	3.17 (26)	+	.171 (4.2)	X_1	.691 (17)
Bus	Y_4 =	3.15 (25)	+	.175 (4.3)	X_1	.700 (18)
Truck	Y_5 =	2.87 (24)	+	.206 (5.3)	X_1	.782 (28)
Other	Y_6 =	1.25 (3.8)	-	3.26 -(2.6)	X_1 #	.476 # (7.2)
All Veh.	Y_7 =	3.03 (33)	+	.200 (6.7)	X_1	.848 (44)

Not Significant

Y (Average Speed) = a + bx_2 (Volume Mechanical)

Average Speed		a. Const. (t ratio)		b. Coefficient (t ratio)		R^2 (F ratio)
56 Observations — Linear Form						
M/Cy.	Y_1 =	30.81 (5.8)	+	.015 (4.2)	X_2	.249 (18.0)
Car	Y_2 =	40.57 (61)	+	.022 (4.8)	X_2	.303 (23)
Wagon	Y_3 =	37.50 (51)	+	.020 (3.9)	X_2	.222 (15)
Bus	Y_4 =	37.93 (32)	+	.016 (1.9)	X_2 #	.067 # (3.9)
Truck	Y_5 =	30.23 (62)	+	.020 (5.9)	X_2	.399 (35)
Other	Y_6 =	15.20 (17)	+	.008 -(1.3)	X_2 #	.032 # (1.8)
All Veh.	Y_7 =	34.17 (61)	+	.025 (6.4)	X_2	.438 (42)
56 Observations — Log_e Form						
M/Cy.	Y_{14}	3.28 (5.2)	+	.045 (3.0)	X_2	.147 (9.3)
Car	Y_{15}	3.42 (61)	+	.079 (6.0)	X_2	.403 (36)
Wagon	Y_{16}	3.41 (45)	+	.061 (3.5)	X_2	.184 (12.2)
Bus	Y_{17}	3.38 (36)	+	.068 (3.1)	X_2	.152 (9.7)
Truck	Y_{18}	3.19 (52)	+	.064 (4.5)	X_2	.273 (20)
Other	Y_{19}	2.65 (1.5) #	-	.147 -(.03)	X_2 #	.002 (.13) #
All Veh.	Y_{20}	3.20 (57)	+	.094 (7.1)	X_2	.485 (50)

Not Significant

10 Observations — Linear Form

Average Speed		a. Constant (t)	b. Coefficient (t)	R^2 (F ratio)
M/Cy.	Y_1 =	31 (32) +	.01 (2.6) X_2	.47 (7.9)
Car	Y_2 =	40 (28) +	.02 (3.4) X_2	.59 (11)
Wagon	Y_3 =	36 (29) +	.03 (4.0) X_2	.67 (16)
Bus	Y_4 =	37 (22) +	.02 (2.4) X_2	.43 (5.9)
Truck	Y_5 =	29 (27) +	.03 (5.4) X_2	.79 (29)
Other	Y_6 =	16 (91) +	.02 -(2.2) X_2#	.39 (5.1)#
All Veh.	Y_7 =	34 (28) +	.03 (4.4) X_2	.71 (19)

10 Observations - Log_e Form

M.Cy.	Y_1 =	3.32 (28) +	.038 (1.5) X_2#	.220 (2.2)#
Car	Y_2 =	3.36 (36) +	.090 (44) X_2	.709 (19)
Wagon	Y_3 =	3.25 (31) +	.095 (4.1) X_2	.682 (17)
Bus	Y_4 =	3.26 (27) +	.092 (35) X_2	.613 (12)
Truck	Y_5 =	3.02 (24) +	.105 (3.8) X_2	.646 (14)
Other	Y_6 =	9.16 (2.3) +	1.68 -(119) X_2#	.318 (3.7)#
All Veh.	Y_7 =	3.16 (32) +	.105 (4.8) X_2	.745 (23)

Not Significant

Y (Average Speed) = a + bx_3 (Volume All Vehicle)

56 Observations — Linear Form

Average Speed			a Constant (t)		b Coefficient (t)		R^2 (F ratio)
M/Cy.	Y_1	=	30.79 (53)	+	.012 (3.5)	X_3	.190 (12)
Car	Y_2	=	40.37 (56)	+	.019 (4.5)	X_3	.275 (20)
Wagon	Y_3	=	37.42 (46)	+	.016 (3.4)	X_3	.182 (12)
Bus	Y_4	=	37.34 (30)	+	.012 (1.7)	X_3 #	.050 # (2.8)
Truck	Y_5	=	29.86 (59)	+	.018 (6.3)	X_3	.428 (48)
Other	Y_6	=	15.53 (17)	+	.009 -(1.6)	X_3 #	.050 # (2.8)
All Veh.	Y_7	=	33.93 (55)	+	.021 (6.0)	X_3	.400 (36)

56 Observations — Linear Form

M/Cy.	Y_{14}	=	3.32 (45)	+	.032 (1.9)	X_3	.066 (3.8)
Car	Y_{15}	=	3.41 (51)	+	.073 (5.1)	X_3	.326 (26)
Wagon	Y_{16}	=	3.43 (39)	+	.052 (2.7)	X_3	.123 (7.6)
Bus	Y_{17}	=	3.42 (31)	+	.054 (2.2)	X_3	.088 (5.2)
Truck	Y_{18}	=	3.17 (46)	+	.065 (4.3)	X_3	.255 (18)
Other	Y_{19}	=	2.42 (1.2)	+	.085 -(.02)	X_3	.000 # (.04)
All Veh.	Y_{20}	=	3.21 (46)	+	.084 (5.4)	X_3	.357 (30)

Not Significant

10 Observations — Linear Form

Average Speed			a Constant (t)		b Coefficient (t)		R^2 (F Ratio)
M/Cy.	Y_1	=	31 (31)	+	.01 (2.6)	X_3	.47 (7.0)
Car	Y_2	=	40 (27)	+	.02 (3.3)	X_3	.59 (11)
Wagon	Y_3	=	36 (27)	+	.02 (3.7)	X_3	.64 (14)
Bus	Y_4	=	37 (21)	+	.02 (2.4)	X_3	.48 (6.0)
Truck	Y_5	=	29 (31)	+	.03 (6.5)	X_3	.84 (43)
Other	Y_6	=	17 (99)	+	.002 -(2.7)	X_3	.49 (7.5)
All Veh.	Y_7	=	34 (27)	+	.02 (4.5)	X_3	.45 (20)

10 Observations — Log_e Form

M/Cy.	Y_1	=	3.33 (24)	+	.034 (1.2)	X_3#	.155 (1.4)#
Car	Y_2	=	3.33 (28)	+	.92 (3.7)	X_3	.634 (13)
Wagon	Y_3	=	3.22 (23)	+	.095 (3.4)	X_3	.591 (11)
Bus	Y_4	=	3.22 (22)	+	.095 (3.2)	X_3	.569 (10)
Truck	Y_5	=	2.95 (20)	+	.112 (3.7)	X_3	.638 (14)
Other	Y_6	=	10.57 (2.3)	-	1.87 -(2.0)	Y_3#	.341 (4.5)#
All Veh.	Y_7	=	3.11 (24)	+	.108 (4.0)	X_3	.676 (16)

Not Significant.

Y(Average Speed) = a + b^{X_4} (Ratio of Vol.(Mech) to Width)

56 Observations — Linear Form

Average Speed			a Constant (t)		b Coefficient (t)		R^2 (F ratio)
M.Cy.	Y_1	=	30.30 (46)	+	.450 (3.8)	X_4	.213 (14)
Car	Y_2	=	40.07 (47)	+	.596 (3.8)	X_4	.219 (15)
Wagon	Y_3	=	37.22 (39)	+	.500 (2.9)	X_4	.138 (8.6)
Bus	Y_4	=	37.36 (26)	+	.479 (1.8)	$X_4^{\#}$	.061 (3.5)
Truck	Y_5	=	29.84 (45)	+	.526 (4.5)	X_4	.272 (20)
Other	Y_6	=	15.26 (14)	+	.187 -(.09)	$X_4^{\#}$	.017# (.9)
All Veh.	Y_7	=	33.54 (45)	+	.687 (5.1)	X_4	.332 (26)

56 Observations — Linear Form

M.Cy.	Y_1	=	3.40 (11)	+	.054 (2.6)	X_4	.116 (7.1)
Car	Y_2	=	3.65 (126)	+	.072 (3.5)	X_4	.186 (12)
Wagon	Y_3	=	3.60 (100)	+	.047 (1.8)	$X_4^{\#}$	.059# (3.4)
Bus	Y_4	=	3.57 (83)	+	.071 (2.3)	X_4	.093 (5.5)
Truck	Y_5	=	3.93 (113)	+	.056 (2.6)	$X_4^{\#}$	.114# (6.9)
Other	Y_6	=	2.61 (3.4)	+	.454 (.08)	$X_4^{\#}$	.013# (.71)
All Veh.	Y_7	=	3.47 (16)	+	.091 (4.2)	X_4	.254 (18)

#Not Significant

10 Observations — Linear Form

Average Speed			a Constant (t)		b Coefficient (t)		R^2 (F ratio)
M/Cy.	Y_1	=	31 (25)	+	.41 (2.3)	X_4	.40 (5.3)
Car	Y_2	=	40 (20)	+	.70 (2.4)	X_4	.42 (5.9)
Wagon	Y_3	=	36 (20)	+	.78 (3.0)	X_4	.54 (93)
Bus	Y_4	=	37 (16)	+	.57 (1.7)	X_4 #	.28 # (3.1)
Truck	Y_5	=	28 (21)	+	.96 (4.9)	X_4	.75 (24)
Others	Y_6	=	17 (85)	+	.73 -(2.3)	X_4	.42 (5.7)
All Veh.	Y_7	=	33 (19)	+	.82 (3.1)	X_4	.56 (10)

10 Observations — Log Form

M/Cy.	Y_1	=	3.40 (54)	+	.062 (1.5)	X_4 #	.236 (2.4)
Car	Y_2	=	3.6 (49)	+	.104 (2.2)	X_4	.384 (5.0)
Wagon	Y_3	=	3.49 (47)	+	.125 (2.7)	X_4	.477 (7.3)
Bus	Y_4	=	3.53 (40)	+	.096 (1.7)	X_4 #	.269 (2.9)
Truck	Y_5	=	2.25 (46)	+	.162 (3.6)	X_4	.619 (13)
Other	Y_6	=	6.27 (3.2)	+	3.13 -(2.5)	X_4	.447 (6.4)
All Veh.	Y_7	=	3.43 (44)	+	.133 (2.7)	X_4	.480 (7.0)

Not Significant

Y(Average Speed)= A + b^{X_5} (Ratio of Vol. all Veh. to Width)

56 Observations — Linear Form

Average Speed			a Constant (t)		b Coefficient (t)		R^2 (F ratio)
M/Cy.	Y_1	=	30.79 (41)	+	.252 (2.4)	X_5	.097 (5.8)
Car	Y_2	=	40.57 (42)	+	.359 (2.6)	X_5 #	.115 # (7.0)
Wagon	Y_3	=	38.02 (35)	+	.236 (1.8)	X_5 #	.044 (2.5) #
Bus	Y_4	=	38.21 (2.4)	+	.210 (9.7)	X_5 #	.017# (.94)
Truck	Y_5	=	29.88 (41)	+	.385 (3.8)	X_5	.211 (14)
Other	Y_6	=	15.69 (12)	-	.213 -(1.3)	X_5 #	.033# (1.8)
All Veh.	Y_7	=	34.08 (39)	+	.419 (3.4)	X_5	.179 (11)

56 Observations — Loge Form

M/Cy.	Y_{14}	=	3.42 (92)	+	.027 (1.2)	X_5 #	.028 # (1.5)
Car	Y_{15}	=	3.66 (97)	+	.055 (2.4)	X_5	.103 (6.2)
Wagon	Y_{16}	=	3.62 (80)	+	.025 (.95)	X_5 #	.016 # (.90)
Bus	Y_{17}	=	3.59 (65)	+	.041 (1.2)	X_5 #	.029 # (1.6)
Truck	Y_{18}	=	3.38 (90)	+	.052 (2.3)	X_5	.092 (5.5)
Other	Y_{19}	=	2.62 (2.8) #	+	.374 -(.06)	X_5 #	.008 # (.45)
All Veh.	Y_{20}	=	3.48 (87)	+	.065 (2.7)	X_5	.124 (7.6)

Not Significant.

10 Observations — Linear Form

Average Speed			Constant (t)		Coefficient (t)		R^2 (F ratio)
M/Cy.	Y_1	=	31 (22)	+	.33 (2.0)	X_5	.35 (4.2)
Car	Y_2	=	40 (17)	+	.56 (2.1)	$X_5^{\#}$	.36# (46)
Wagon	Y_3	=	35 (17)	+	.63 (2.6)	X_5	.47 (7.0)
Bus	Y_4	=	36 (14)	+	.47 (1.6)	$X_5^{\#}$	.25 (2.6)#
Truck	Y_5	=	27 (19)	+	.83 (4.9)	X_5	.75 (24)
Other	Y_6	=	18 (89)	-	.69 -(2.8)	X_5	.50 (8.2)
All	Y_7	=	33 (16)	+	.68 (2.9)	X_5	.52 (8.6)

10 Observations — Linear Form

M/Cy.	Y_1	=	3.41 (40)	+	.048 (1.0)	$X_5^{\#}$	.123# (1.1)
Car	Y_2	=	3.60 (35)	+	.095 (17)	$X_5^{\#}$	.277# (3.0)
Wagon	Y_3	=	3.47 (33)	+	.133 (1.4)	$X_5^{\#}$	.342# (2.0)
Bus	Y_4	=	3.51 (30)	+	.088 (1.4)	X_5	.200 (2.0)
Truck	Y_5	=	3.2 (32)	+	.162 (3.0)	X_5	.541 (9.4)
Other	Y_6	=	7.67 (3.1)	-	3.36 -(2.5)	X_5	.451 (6.5)
All Veh.	Y_7	=	3.40 (31)	+	1.24 (2.1)	$X_5^{\#}$	.367# (4.6)

#Not Significant.

ANNEXURE-VII

DATA FOR REGRESSION ANALYSIS
(10 OBSERVATIONS)

DEPENDENT VARIABLES							INDEPENDENT VARIABLES					
M/Cy Y1	Car Y2	Wagon Y3	Bus Y4	Truck Y5	Other Y6	All Y7	Width X1	Vol.Mech. X2	All X3	X2/X1 X4	X3/X1 X5	X3-X2/X2 X6
38.7	50.55	47.1	45.7	45.0	-	47.2	60.0	448.0	568.0	15.0	19.0	21.1
34.1	47.4	44.6	42.4	35.9	17.3	40.8	29.0	338.0	359.0	11.6	12.4	5.8
33.7	46.4	43.2	43.2	30.9	14.6	40.5	24.0	148.0	166.0	4.7	6.2	10.8
33.5	48.3	41.0	46.8	35.7	15.5	41.2	22.0	103.0	137.0	2.7	3.7	24.8
31.5	44.0	37.0	40.0	32.9	15.7	37.7	20.0	54.0	74.0	2.7	3.7	27.0
30.6	41.0	37.4	37.2	30.0	15.6	35.0	19.0	78.0	108.0	4.1	5.7	27.7
31.5	42.0	41.3	40.6	32.6	15.4	37.1	18.0	71.0	115.0	4.0	6.6	38.2
31.5	38.1	35.7	35.6	32.1	13.7	34.4	12.0	73.0	51.0	3.0	4.1	27.4
29.5	36.1	31.6	32.1	27.0	14.8	30.5	10.0	34.0	63.0	3.2	5.0	46.0
36.3	38.0	37.8	34.0	30.0	12.8	33.0	8.0	17.0	21.0	2.0	2.4	13.0

SPECIMENS OF SURVEY FORMS

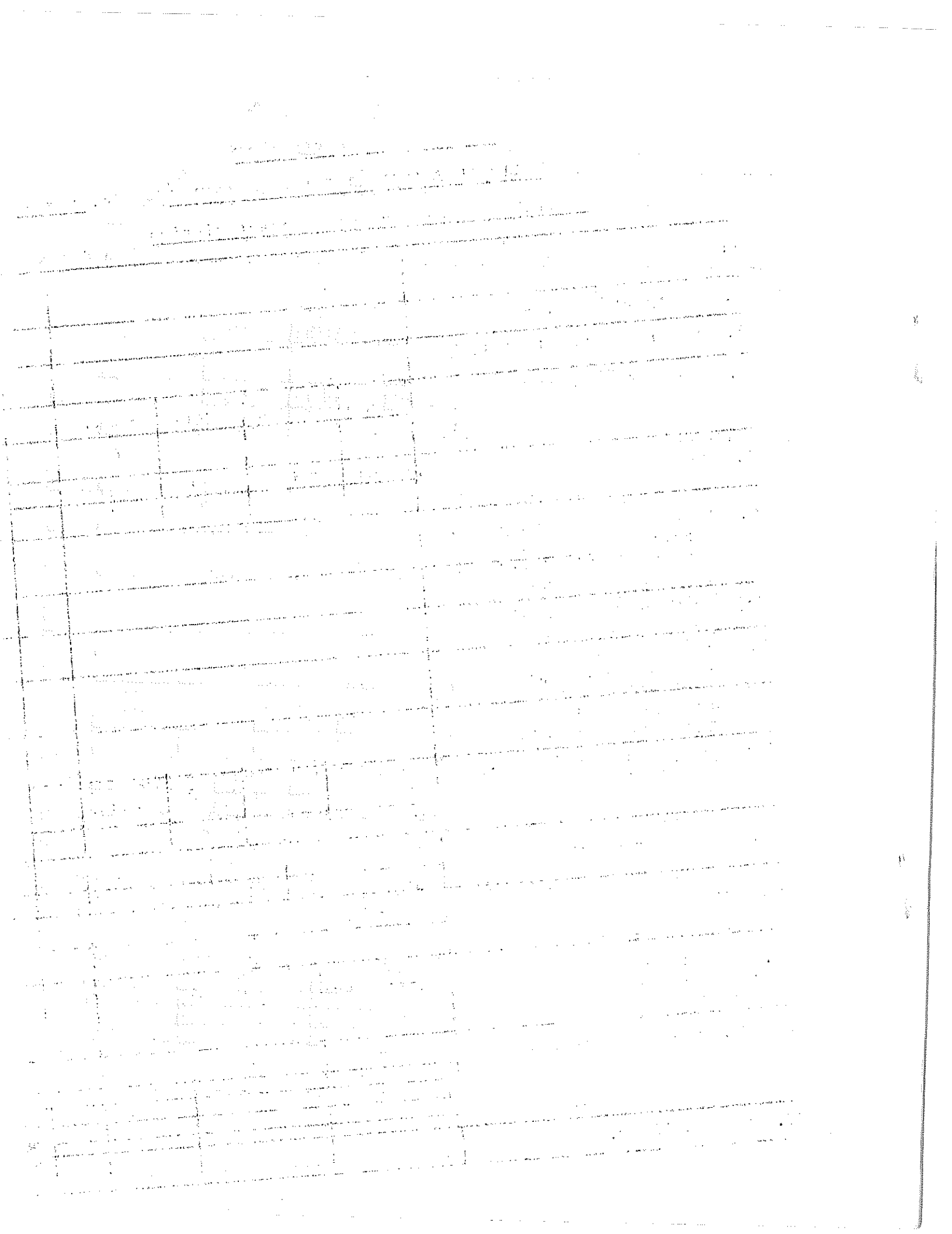
NATIONAL TRANSPORT RESEARCH CENTRE

No. x x x x

Travel Speed Study - Road Characteristics

					Codes
1. Name of Road Section					
2. District/Province					
3. Length of Section(Miles					
4. Type of area	Plain	Rolling	Hilly	Desert	
	1	2	3	4	
5. Type of Road	Earth	Shingle	Metlld	Carptd	
	1	2	3	4	
6. In case of Metalled & Carpetted Roads: a) Width of Pavement b) Shoulders both sides					
7. Location of Obs.Point					
8. Width of Pavement at Observation Point					
9. Width of Shoulders at Observation Point (ft)					
10. Maintenance condition. Tick one or more	Shoulders Proken	Holes	Puts	Corru-gation	
11. Date of Observation	Day	Month	Year		
12. Time	Obs.start	Obs.closed			
13. Exceptional weather condition or other incident	Hours From	To	Exceptional condition		
14. No. of Forms used: Form 1	From	To	Total		
Form 2					
Form 3					
Form 4					
15. Remarks, if any.					

Signature of Enumerator .....



Annexure-VIII
(Continued)

SPECIMEN OF FORM USED
FOR VOLUME COUNT
NATIONAL TRANSPORT RESEARCH CENTRE

Ref. No. | Date Day | Mnth. | 1978 | Hour Commencing Hrs. | Mnts | Contd. 1 | Cncld. 2

PEDAL CYCLES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92

ANIMAL DRAWN VEHICLES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69

MOTOR CYCLE, SCOOTER, RICKSHAW

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92

CAR, JEEP, MINI WAGON (SMALL SIZE VEHICLES)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102
103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138
139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156
157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174
175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210

STATION WAGON, PICK-UP (MEDIUM SIZE VEHICLES)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102
103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	136	138

BUSES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
	85	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102
103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138
139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156

TRUCK, TRAILER, TANKER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102
103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138
139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156

CYCLES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92

Annexure-VIII
(Continued)

SPECIMEN OF FORM USED FOR RECORDING SPEED MEASUREMENTS.

NATIONAL TRANSPORT RESEARCH CENTRE

Travel Speed Study-

Speed Observations at a Point

No.

Date: Day | Month | 1978

Location | Ref.Code

Name of Road Section:

Length(ft) | Sheet No.

Location of Observation Point:

Hr.Commcd. | Contd. Cycle 1 2

Motor Cycle Scooter	01			02			03			04			05			06			07				
	08			09			10			11			12			13			14				
	15			16			17			18			19			20							
Car Jeep Mini	01			02			03			04			05			06			07				
	08			09			10			11			12			13			14				
	15			16			17			18			19			20			21				
	22			23			24			25			26			27							
Station Wagon	01			02			03			04			05			06			07				
	08			09			10			11			12			13			14				
	15			16			17			18			19			20							

Buses	01			02			03			04			05			06							
	07			08			09			10			11			12							
	13			14			15			16			17			18							
	19			20			21			22			23			24							
	25			26			27			28			29			30							
	31			32			33			34			35			36							
	37			38			39			40			41										
Truck Trailer, Tanker	01			02			03			04			05			06							
	07			08			09			10			11			12							
	13			14			15			16			17			18							
	19			20			21			22			23			24							
	25			26			27			28			29			30							
	31			32			33			34			35			36							
	37			38			39			40			41										
