NATIONAL TRANSPORT RESEARCH CENTRE

AXLE LOAD SURVEY

for the
NATIONAL HIGHWAYS BOARD
MINISTRY OF COMMUNICATIONS

NTRC-65

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PREFACE

This survey was carried out for the National Highways Board, Ministry of Communications as a requirement for the Third Highway Project financed by the I.D.A/World Bank. It fills up the gap in essential data required for highway planning, design and maintenance.

The results will be useful not only for the National Highways Board but also for Provincial Highway Departments, agencies concerned with planning, development and regulation of transport services in the country, professionals and students of transport planning in general.

The scope of work was determined by the National Highways Board and the selection of survey points, design of Questionnaire, etc. were also done with their approval. However, views expressed in this report are not the official views of the National Highways Board or the National Transport Research Centre but are of the author alone who also accepts responsibility for any lapses and deficiencies in the report.

The sources of material used have been acknowledge as far as possible. These are not the only work on the subject but were the ones readily available at a place of scarcity for such materials. The successful and timely completion of the project would not have been possible without the able guidance and support of Mr. M. Sadiq Swati, Chief, National Transport Research Centre and dedication and hardwork of officers and field staff. The latter were constantly exposed to hazards of Pakistan's unruly traffic. Their contribution is gratefully acknowledged.

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CONTENTS

LIST OF TABLES

SUMMARY

Scope and Coverage

The survey was carried out for one year from May 1981 to April 1982 at 35 points on main roads across the country. Observations at each place were made for 24 hours, three to four times during the year, covering in all 31,746 goods vehicle of which 30,112 were loaded and 1,634 empty. The vehicles surveyed constituted, on the average, 108% of the average daily traffic. Thus, statistically all traffic at selected road sites was covered. The results were cross checked by independent information on vehicle weights at Quetta Coal Mines and Karachi Octroi Posts and differences were found within acceptable limits of sampling variations. Besides, a separate survey of NLC vehicles was also carried out for multi axle vehicles.

Average Axle Loads

Axle Loads of loaded and empty vehicles have been found as follows:

Load Condition	Average Load (kg) Front Axle	Rear Axle	Gross Load	Standard Deviation Front Axle	Rear Axle	Gross Load
Loaded	4,343	10,020	14,377	705	1,931	2,438
Empty	2,868	3,308	6,177	475	952	1,219

Variations between Survey Points

In general, loads in the northern hilly areas were lower and on the main trunk roads near Karachi higher. The variations ranged between 12,764 kg on Rawalpindi-Murree Road and 15,312 kg on Rohri-Dadu Road in gross vehicle weight.

Distribution of load over front and rear Axles

The load of an empty vehicle is nearly evenly distributed over front and rear axles. Each additional unit of load is distributed over front and rear axles in the ratio of 1 to 4 and the initial ratio of 48:52 changes to 30:70 for fully loaded trucks.

Types of Commodities carried

The distribution of vehicles according to types of commodities carried was as follows:

Commodity Group	% of Vehicle
Agriculture, Food & Animal	35.6
Mining and Quarrying	24.6
Raw Materials and Bulk Manufactures	14.7
Fuel and Lubricants	6.3
Basic Manufactures and General Merchandize	18.8
	100.0

Heavily loaded commodities included, in order of magnitude, Rice, Wheat, Onions, Marble, Scrap, Coal, Cement, etc. The gross weight of vehicles carrying these commodities exceeded 15 tons.

Variations according to Season and Time

There was little variation in types of commodities carried during different seasons. The average load at night was slightly higher than during day. The difference was however 1.6% only.

Variations between Rounds

Some differences were observed between rounds due to tricking of weighing machines. The results of first round were 8% less and of second round 5% more than average. However, the differences cancel out each other and the overall average remains the same.

Vehicle Makes

In all 17 makes were identified during the survey. However, Bedford dominates the scene and accounts for 96.5% of the vehicles. This is followed by Nissan and Hino which are about 1% of total. All other Makes are less than .1%.

Overloading

Maximum Axle Load limit is 18000 Lbs or 8165 kg. More than 83% of loaded vehicle exceed this limit. Even if vehicles upto 9 tons rear axle load are not classified as overloaded, there will still be 75% vehicles overloaded by this criteria.

Axle Load Distribution

The distribution of vehicles according to rear axle load is as follows:

Upto 6.9 tons	7.4%	11-11.9 tons	20.8%
7-7.9 "	6.0 "	12-12.9 "	10.0 "
8-8.9 "	11.4 "	13-13.9 "	2.4 "
9-9.9 "	17.3 "	14 & over	1.0 "
10-10.9 "	23.7 "		
			100.0

Damaging Effect

25% of the vehicles not overloaded (including vehicles upto 9 tons which are slightly overloaded but not considered as such) cause only 6% damage, 42% vehicles with rear axle loads upto 10 tons cause 16% damage. On the other extreme, 3.4% vehicles with rear axle loads exceeding 13 ton cause 11.5% damage, 13% vehicles in load class 12 ton and over cause 32% of damage.

Equivalent Standard Axles

According to their damaging effect in terms of 18000 Lbs (8165 kg) equivalent standard axles, a loaded vehicle is equal to 3.3 standard axles and an empty vehicle equal to .12 standard axles. There is however, considerable variation between survey points. For example, at Rawalpindi-Murree Road, a loaded vehicle is equal to 1.75 standard axles as compared to 4.4 at Quetta-Naushki Road.

Previous Surveys

Axle Load Surveys carried out earlier in Punjab and Sind do not appear to be reliable due to small number of observations and errors of measurement.

Survey of NLC Vehicles

The survey covered 253 vehicles of which 166 (61%) were multi axle vehicles and 87(29%) conventional 2 axle vehicles. The loads of rear axles exceeded maximum limit of 8,165 kg by a wide margin. The maximum loads on any of the rear axles are as follows:

Type of Vehicle		Maximum Load
5 Axle	Tanker	13.2 tons
"	Truck	11.3 tons
4 Axle	Mercedes	13.2 tons
"	Fiat	11.4 tons
"	Hino	11.6 tons

In terms of damaging effect, equivalent standard axles of 18000 Lbs(8165 Kg) for various types of loaded vehicles weee as follows:

Make	18 kip Equivalent Standard Axles
5 Axle Tankers	9.2
" Trucks	5.5
4 Axle Mercedes Truck Trailer	11.4
" " Traction Unit	8.8
Fiat	8.2
Hino	9.7

Chapter-I

INTRODUCTION

Axle Load data is now a pre-requisite for highway planning, design and maintenance. Inspite of its vital importance, the collection and use of data has not been made in any systematic manner in the past. Instead, rules of thumb have been followed and in some cases ratios and approximations developed in other countries which are not relevant to our conditions, have been used. For example, the Manual for Rural Roads suggests that in the absence of load data, an equivalent factor of 0.45 may be assumed for converting commercial vehicles into equivalent standard axles.(1) Similarly, the NWFP Design Manual, inter-alia recommends, ratios of 1.08 and 0.72 for converting commercial vehicles into standard axles for roads carrying over 100 and between 250 to 1000 commercial vehicles respectively which are based on British data which is quite different from conditions in our country.(2)

A small number of axle load measurements taken recently by the Third Highway Project Consultants(3) for feasibility studies of various road sections on the main network indicated excessive overloading and pointed towards the need for a comprehensive survey to assess the overall situation. The present survey serves this purpose.

The objectives of the survey are to asses the degree of overloading by goods vehicles in Pakistan which produce axle loads in excess of legal limits and limits to which highways have been designed; to find out variations with respect to region, season, type of vehicle, type of commodity and to pin point the areas where remedial action will be required.

The survey entailed measuring of actual axle loads on the road side by means of portable axle weighing machines and interviewing of Drivers to obtain information on type of commodities carried, origin, destination and related factors. 35 points were selected on the main roads across the country in consultation with the National Highways Board. The survey at each point was carried out for 24 hours round the clock and repeated 3 to 4 times during the year.

Lateron, the scope of work was enlarged to include a review of vehicle weighing methods, equipment and inventory of such equipment available in the country with geographical distribution and suitability of such equipment for checking and regulation of loads. This assignment was completed in November, 1981.(4)

Subsequently, a Special Round of survey of Axle Loads of Multi Axle Vehicles operated by NLC was also carried out and results provided to National Highways Board. These are also included the present report.

In addition, a survey of truck weights at Coal Mines in Quetta and Karachi Octroi Posts was carried out to cross check the survey data. The results of above referred surveys are presented in this report.

The organization of the rest of the report is as follows. The basic concepts of Axle Load and pavement design are given in Chapter-II which provides necessary theoretical background for the lay-man indicating need and uses of the data in pavement design. Those who are familiar with concepts of pavement design may skip over this section. Chapter-III gives an outline of the survey including coverage and procedures used which will place the results in proper perspective and will be useful for future surveys of the kind. The results of the main survey are divided into three Chapters-V, VI and VII, which deal with sampling proportions, load distributions and damaging effects respectively. Verification of data and comparison with other sources are contained in Chapter-VIII and results of the survey of NLC vehicles are given in Chapter-IX. Chapter-X, contains summary and conclusions.

All Tables are given in statistical Appendix which is self-explanatory. Other related information is given in Annexure at the end of the Report.

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Chapter-II

AXLE LOADS AND PAVEMENT DESIGN CONCEPTS

Load Distribution

The load of a vehicle is transmitted to the road surface through the tyre contact area and distributed through successive layers of the structure to the sub-soil on which the road structure rests. If the sub-soil deflects, the overlaying flexible pavement will deform to a similar shape and extent and the structure will fail. The primary function of pavement design is to protect the sub-oil by distributing the applied vehicle load in such a way that maximum pressure applied to the sub-soil is within limits of its load bearing capacity. A system of layers of different specifications such as sub-base, base and surface course etc., make such a load distribution in a complex way.

The design of flexible pavement is affected by several factors, important ones being load of the traffic, load bearing capacity of the soil, quality of available materials and environmental factors, etc. Most design procedures attempt to evaluate the stability of the sub-grade in the given environment on the one hand and load of traffic on the other. Equating the two provides basis for determining the overlaying material needed to safely distribute the applied wheel load so as to keep the same within limits of load bearing capacity of the soil given the quality and type of construction material available etc. Our concern in this report is mainly for traffic load and the way it affects the pavement design and life of the road structure.

On an initial simplyfing assumption, the wheel-load distribution of a pneumatic tyre on uniform granular material is in the form of a cone supported by surrounding materials having a slope of approximately 45 degrees. The area over which load is spread increases with the depth and intensity of pressure decreases proportionately. The following descriptions are mostly based on references (1) & (2).

In the figure-I below πa^2 is the area where pressure P is initially applied and πr^2 is the area where the pressure is distributed. Intensity of pressure is reduced from $p/\pi a^2$ at the area of initial load application to $p/\pi r^2$ at the bottom of the layer. And if α = 45 degrees, then r = dta. Equating the load P to the load bearing capacity of the soil at the bottom of the layer, neglecting the weight of the cover material, the following equations result.

$$P = q\pi(a+d)^2 \qquad (i)$$

$$d = 1/\sqrt{\pi}(p/q)^{\frac{1}{2}} - a \qquad (ii)$$

Where

q = Average pressure on the sub-grade caused by a wheel load p acting through base and sub-base material.

π = Circumference of the circle 22/7 = 3.1416

a = ½ radius of tyre contact area

d = depth of pavement structure

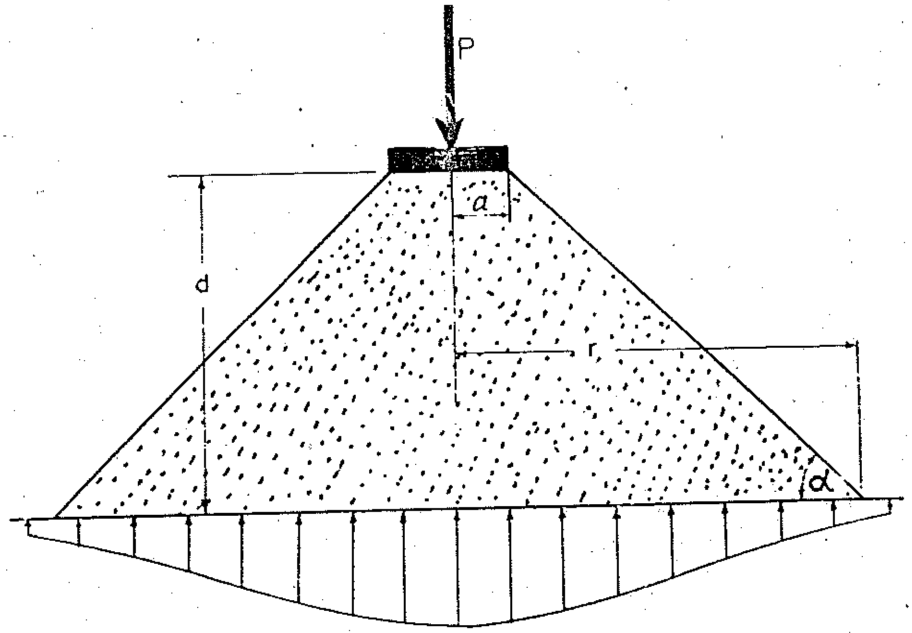
Thus, if an allowable unit pressure P for a particular sub-grade soil is given, the required thickness of cover can be readily determined for the maximum truck wheel load that is likely to be experienced.

The above formula clearly shows the inter dependence of pavement thickness and load bearing capacity of the soil. In case of poor soils larger thickness of pavement will be needed and vice versa.

Pressure Bulb Theory(3)

The pressure Bulb Theory explains the distribution of load when applied to the soil through a circular object. A Bulb of pressure is a surface obtained by connecting points of equal stress on the various horizonal planes at various depths. The pressure at any one point on the surface of a bulb is the same as at any other point. Because the contact area between a tyre and the ground approximates a circle, the theory can be

FIG. 1 : LOAD DISTRIBUTION THROUGH GRANULAR MATERIAL



(b)

applied to pressure in the soil under tyres with slight modification. Fig. 2 below illustrates the same. The above illustration shows ratios of unit pressures to ground contact pressure at varying depths below the surface of the ground for uniform granular material. At a distance of ½ D from the area of the contact, the pressure is 60% of applied load. At distance equal to 1 D, pressure is reduced to 30% of applied load and at distance of 2 D the pressure is left only 9% of the load applied at the surface. The unit load decreases with increase in depth. On the line at D 1 pressure at points, x, y and z is 9, 15 and 30 percent of applied load respectively.

Pavement Layers

The layers arrangement of the pavement absorbs greater amount of pressure and much less load is transmitted to the sub-base. This has been illustrated by Flaherty and others(4) as in Figure 3 below which compares distribution of load over a uniform layer and two layer system.

The above illustration brings out the main function of a pavement which is to reduce to an acceptable level the pressures applied to the sub-grade. As can be seen, the stresses in the sug-grade at a depth h_1 are considerably influenced by the insertion of stronger pavement material. With the pavement inserted, the vertical stress at the interface and directly below the centre of the applied load is estimated to be approximately 30 per cent of P, whereas without the pavement the stress at a depth h_1 is approximately 70 per cent of the applied unit load. Thus the system of pavement layers considerably reduces the unit load applied to the sub-base.

Effect of various Factors

The stress on the road by a given load is affected by a number of factors such as size and type of tyres, tyre pressure etc. A brief description of relevant factors is given in the following paragraphs.

FIG. 2 : VARIATION IN PRESSURE WITH DEPTH UNDER A LOAD

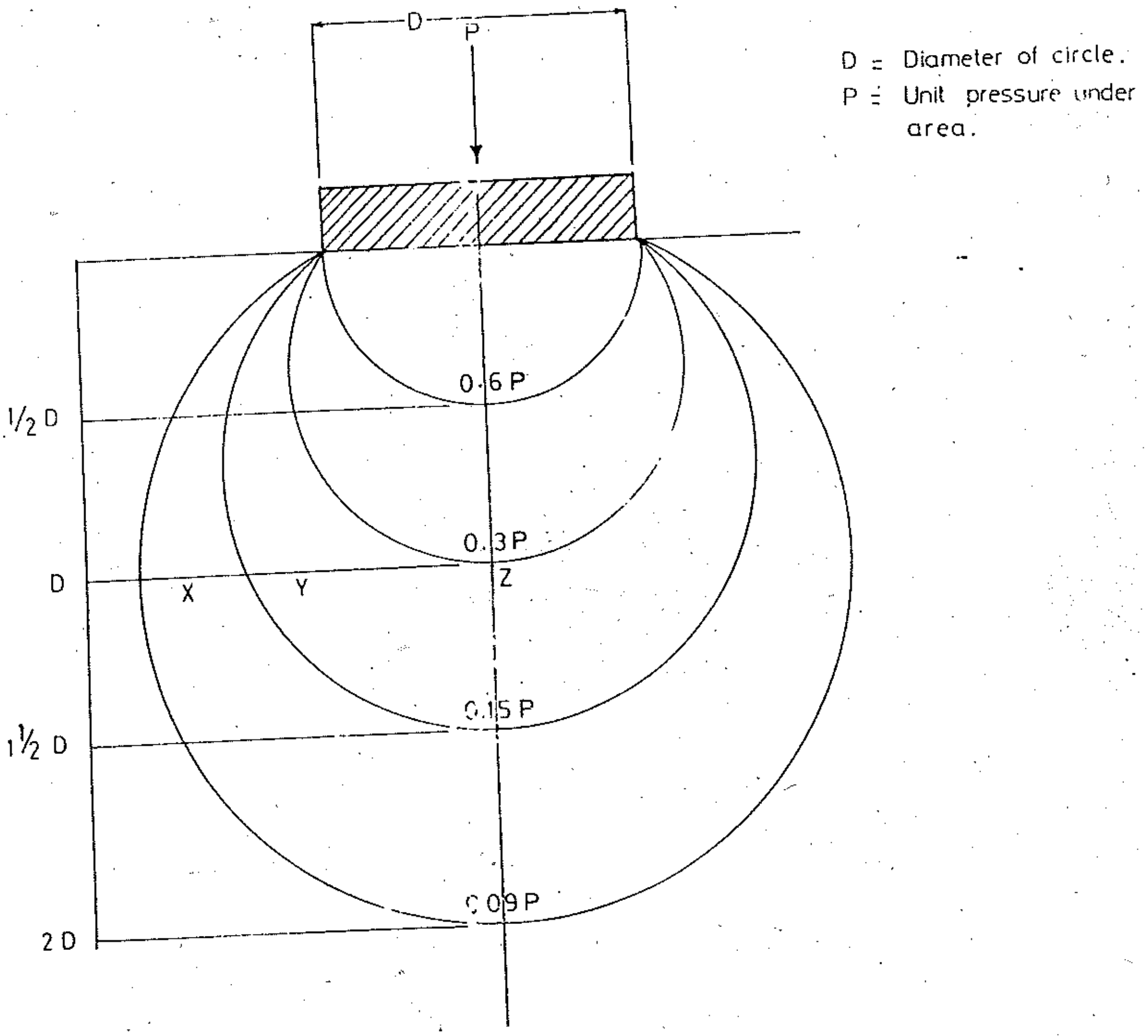
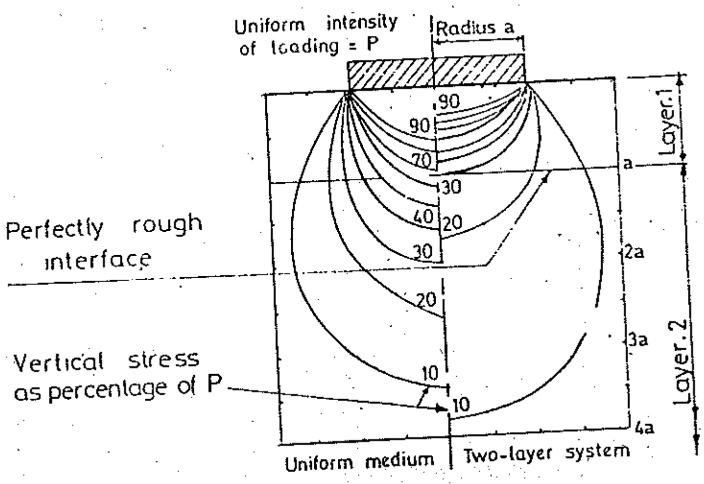


FIG. 3 : STRESS DISTRIBUTION IN A UNIFORM MATERIAL IN ONE & TWO LAYER SYSTEM



Tyre Size

Tyre size determines the area of contact with the road surface which in turn determines the area of load distribution and unit load. The smaller size tyres will make a sharp curve with the road surface and the area of contact would be small and unit load more. The stress or pressure would thus vary directly with size of the tyre.

It would be interesting to note that the Motor Vehicle Act of 1939 prescribed maximum permissible axle weights according to the diameter of the tyre and rim and separately for low and high pressures.

Tyre Pressure

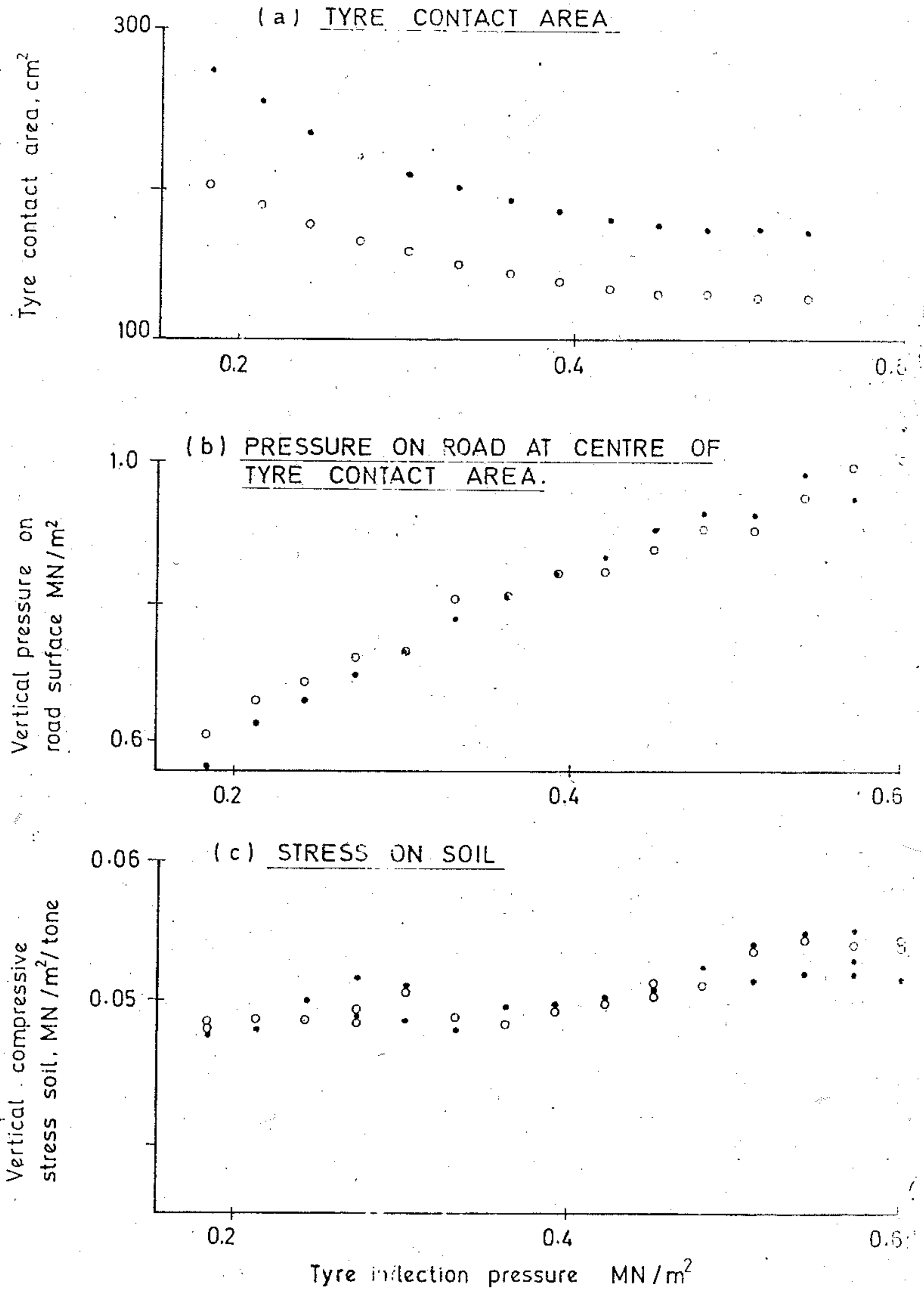
For a given size of tyre, the area of contact with road surface will inversly vary with tyre pressure. The higher pressure would result in smaller contact area and vice versa. The unit load will therefore directly vary with tyre pressure.

However, given the tyre pressure, increase in load would not increase the stress as much as the increase in load. As the area of contact would also increase with increase in load, the unit pressure would not increase as much as the increase in load. The relationships between tyre pressure, area of contact, pressure on the road surface and stress on soil are shown by O'Flaherty as in figure 4 below.

Figure 4(a) indicates how, for a given wheel load, the contact area decreases as the inflation pressure is increased. The extent of the decrease in any given situation will of ocourse depend on the initial wheel load and the quality of the tyre itself.

Figure 4(b) indicates the manner in which the actual pressure transmitted to the surface increases in an apparently near-linear fashion as the inflation pressure is increased. At any given time the applied surface pressure is always considerably greater than vertical pressure on the pavement surface appears to average about 200 per cent of the inflation pressure.

FIG. 4: RELATIONSHIP BETWEEN TYRE PRESSURE, PRESSURE ON THE ROAD AND STRESS ON SOIL.



The data in Figure 4(c) indicates the change in the vertical pressure measured at the pavement sub-grade interface i.e. the formation level, as a result of changing the tyre pressure. The measured stress at the formation is only increased significant for very substantial increases in the inflation pressure. Theoretical studies would seem to indicate that the stress at the formation is proportional to a x 1.9 'a' is the equivalent radius of the tyre contact areas.

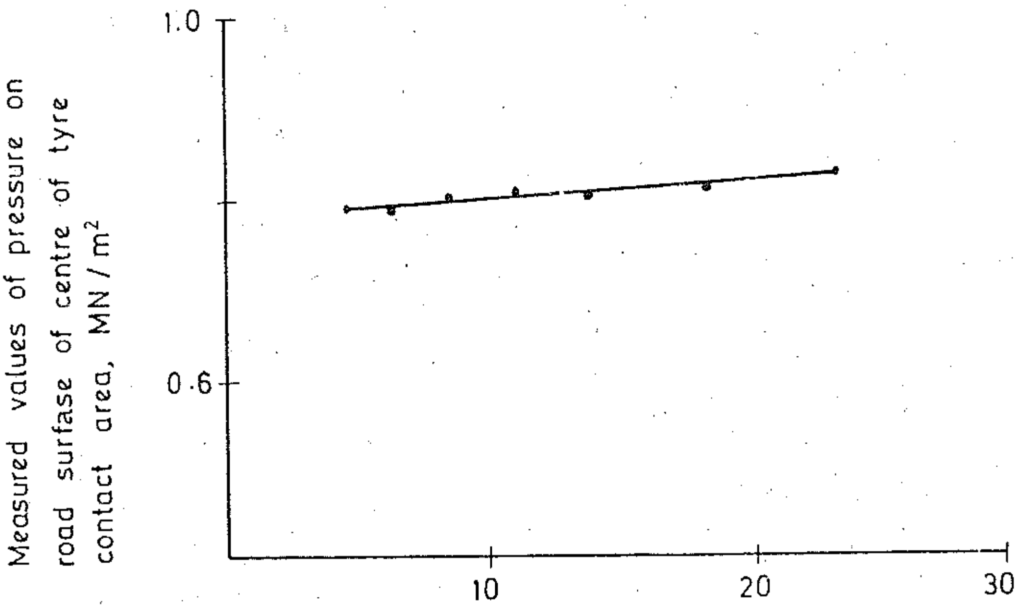
Figure 4(c) also indirectly reflects the role of the tyre pressure in inducing stresses in the pavement. The effects of high inflation pressures are most pronounced in the upper layers of a pavement and have relatively little differential effects at greater depths. In other words, for a given wheel load the tyre-inflation pressure has little effect on the depth of pavement required above the subgrade, but it is this pressure which controls the quality of the materials used in the upper layers.

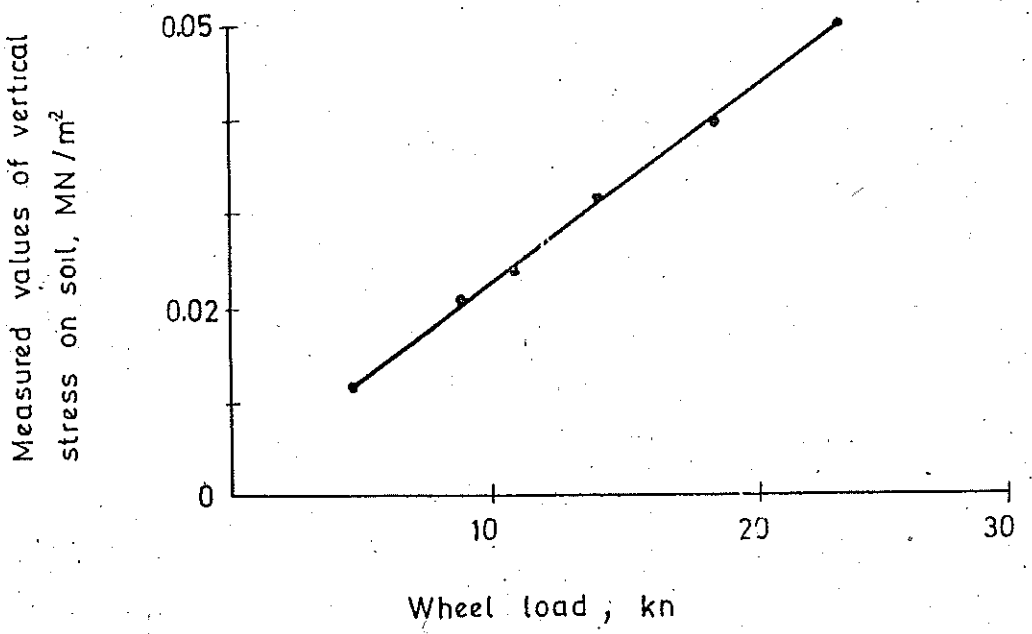
<u>Wheel Load</u>

It would be seen from the above that as the wheel load is increased, the tyre deflects and the contact area is increased. As a result, the peak unit pressure applied to the carriageway shows only a very small increase. The additional wheel load has however, the affect of causing the vertical stress at the pavement subgrade interface to be increased in direct proportion to the extra load. Thus it is clear that as the wheel load is increased the depth of pavement must also be increased so that the allowable subgrade stress is not exceeded.

The effect of changing applied wheel load on pressure on road surface and vertical stress on soil are shown by O'Flaherty[7] as in figure 5 which shows how the stress at the top and bottom of a pavement were changed when the tyre inflation pressure was kept constant at 414 kN/m^2 while the load applied to the smooth treated tyre was progressively increased from 4.45 to 22.24 kN.

FIG. 5: EFFECT OF CHANGING THE APPLIED WHEEL LOAD





Dual Wheels

Almost all buses and trucks in Pakistan have dual rear-wheels which can influence the stress distribution and deflections within and below the highway pavement. The most definitive investigations into the effect of various wheel arrangements have been carried out on airport pavements where they are of significant importance because of the greater wheel loads.

An illustration of the effect of dual tyre assembly on pavement is provided by Hay(8) and O'Flaherty(9). The descriptions below follow the latter.

Theoretically, it can be shown that the single wheel load required to reproduce the same maximum stresses in a homogeneous material as are given by a dual tyred assembly is

$$P_e = + \frac{PZ_5}{(z^2 + 5^2)\ 5/2}$$

Where

P_e = equivalent single wheel load

P = load on each dual-tyre

z = depth to the plane being stressed and

s = distance between the centres of individual tyres.

This relationship clearly illustrates the two most important features of the dual-tyred assembly. Firstly the calculated stresses at the pavement surface (when z = 0) are due only to the individual wheels of the assembly and there are no interacting effects. Secondly, the distance between the tyre centres plays an important part in the stress distribution beneath the surface. At greater depths, however, where the S-value is small in comparison with depth, the stress due to the dual-tyres becomes near additive. Figure 6 illustrates the same.

FIG. 6 : VERTICAL STRESS UNDER DUAL TYRE ASSEMBLY

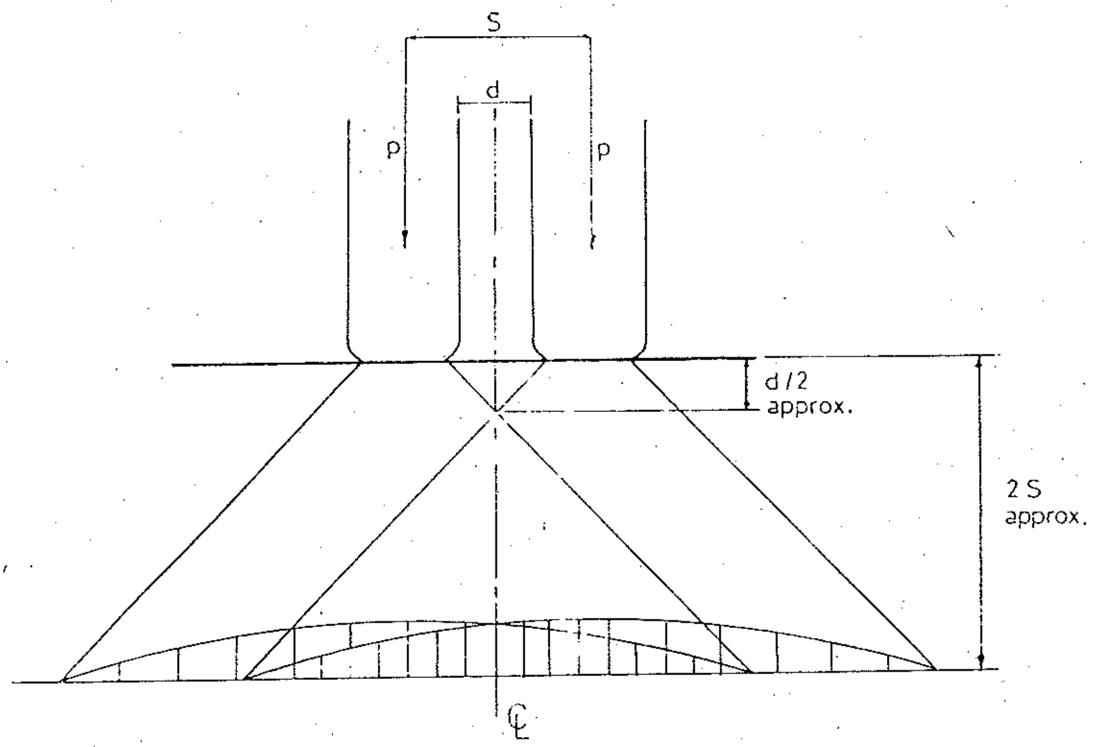
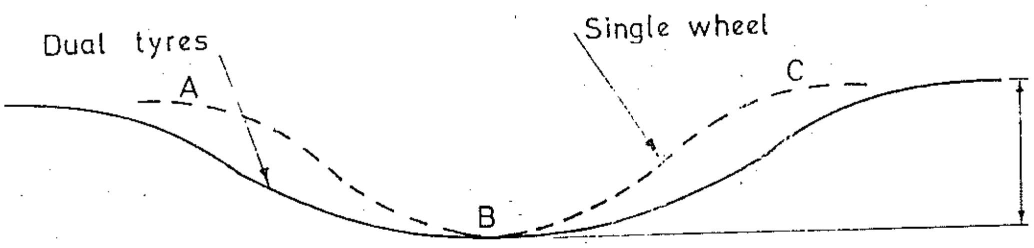


FIG.7: DEFLECTION UNDER SINGLE AND DUAL TYRED WHEEL ASEMBLIES



Axle Configurations

Axle configurations have a pronounced effect on stress distribution and deflections. A comparison between single axle loads and equivalent tandem axle loads based on the results of WASHO Road Tests[8] is given below.

Equivalent single and tandem axle loads

Surfacing*	Single-axle load kN	Equivalent tandem-axle load kN	
		Based on deflection	Based on distress
5 mm Ashphalt	80.1	155.7	125.9
	99.6	195.7	161.9
10 mm Ashphalt	80.1	135.7	125.9
	99.6	181.9	149.5

* Surface plus roadbase thickness is 152.5 mm.

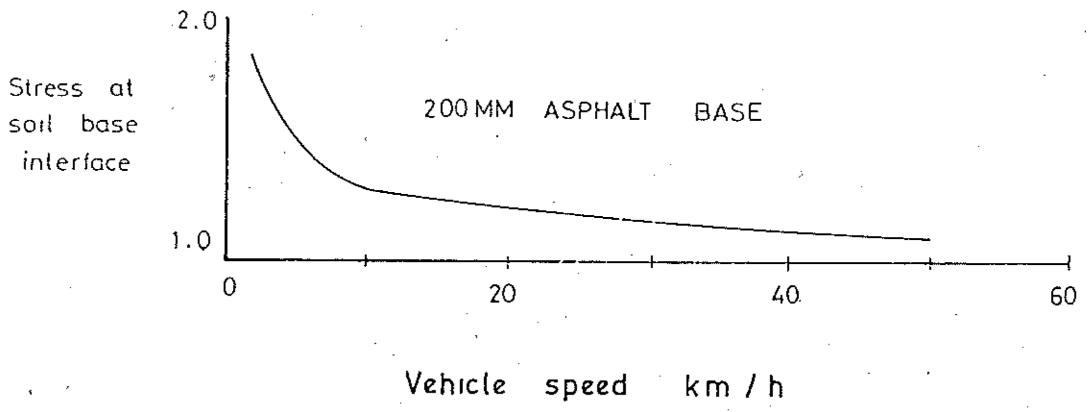
It is evident from the above that relative effects cannot be dealt with by simple summation. In no case the results obtained with an equivalent tandem-axle equal to twice that of a single axle. It is also evident from the above table that irrespective of the surfacing material or the measurement criterion, the load that a pavement can safely carry may be considerably increased if the vehicles have tandem axles.

Static Versus Moving Loads

Tests have indicated that stresses and derlictions tend to decrease as the vehicle speed increases from creep speed to about 24 Km/h. Above 24 Km/h the values tend to be constant. The relationship is shown in Figure 8 below.[9]

In the study from which these data were abstracted it was found that the speed effect was much greater when the road base consisted of bituminous-bound instead of cement-bound materials. These differences were considered to be due to the moduli of deformation changing when the rate of loading was changed.

FIG.8 : VARIATION OF VERTICAL STRESS AT THE SUBGRADE PAVEMENT INTERFACE WITH VEHICLE SPEED



In practice the vehicle speed effect is most noticeable on particular sections of roadway. For instance, for a given volume of traffic, greater thicknesses and or quality of paving materials may be required for pavements in urban areas than for those in rural areas because of the lower average speeds in urban areas. Similarly pavement requirement for uphill gradients may be more demanding than for downhill gradients, there is little doubt that the increased distress shown by uphill traffic lanes can at least be partly attributed to the vehicle speed effect.

Repetition of Loads

Although the effect of material fatigue on highway pavement behaviour is little understood at this time, there is no doubt that it plays a critical role in pavement failure. The cracking of the surface may be the result of fatigure characteristics of the bituminous material itself or it may reflect the effect of repeated loading on the roadbase, sub-base and/or subgrade materials. In this latter respect roadbase aggregate materials may be broken down under the action of repeated loads, just as soil materials in the sub-base or subgrade may be caused to work their way upwards under the kneading action of traffic.

Repetitive Load Applications

Under the conditions of elastic support, the structure and its support will deflect slightly under load but return to their initial positions when the load is removed. Each element in the roadway structure is subject to a repetitively applied deflecting and bending load as wheels of automotive vehicles pass. These repetitive loadings are likely to initiate fatigue failures and plastic deformations. The supports will not return to their initial positions when the load is removed.

The life of the pavements is thus determined in terms of number of load repetitions. Given the volume of traffic and growth rate it would not be difficult to find out the life of a pavement of given specifications or the period when an overlay would be required or the specifications required for a certain life of the pavement.

Results obtained during the AASHO Road Tests [10] suggest that for a given axle load, the pavement thickness required to provide a given terminal level of service is proportional to the logrithm of the number of repetitions of the axle load. The British test data also indicates that pavement deformation is a function of time and hence the number of load applications. The relationship between weighed applications and thickness is shown in the figure 9.

Standardized Axle Loads

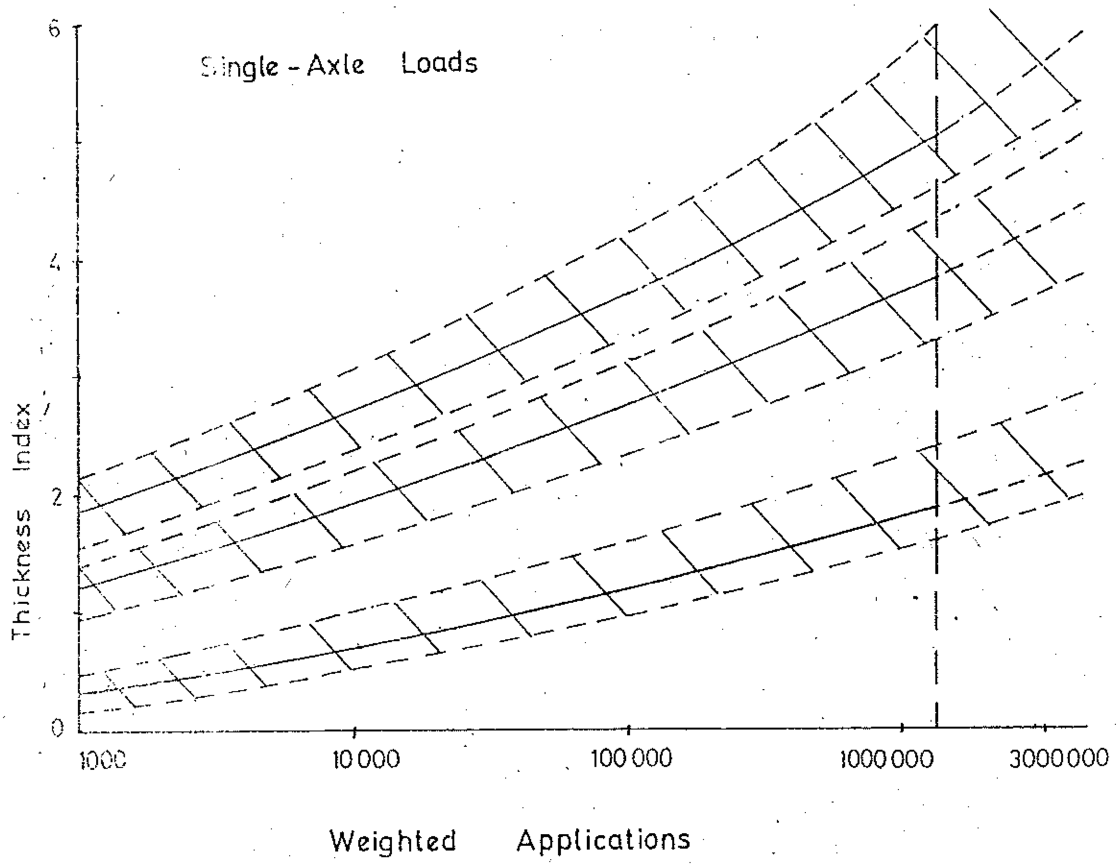
There are large variations in axle loads of different categories of vehicles and different vehicles of the same category due to differences in the type and amount of cargo carried. Accordingly, to bring all axle loads to a uniform scale, different axle loads can be converted to standard equivalent axles on the basis of damaging effect to the road structure.

As a general rule, the damaging effects of axle loads increase by 4.5th power of the load. If the effect of 18000 Lbs axle load is taken as 1, the effect of 30,000 Lbs would be about 10 times the effect of 18,000 Lbs axle as.

$$\left(\frac{30,000}{18,000}\right)^{4.5} = 9.96$$

In this case one 30,000 Lbs axle load passage will be equal to 10 passages of 18,000 Lbs axles. Such equivalent factors can be developed for any other standard. Certain methods require 5000 Lbs equivalent axles. However, most of the methods use 18000 Lbs equivalent axle loads.

FIG. 9: PAVEMENT THICKNESS AND LOAD APPLICATIONS



The AASHTO interm Gude for Design of Pavement Structures,[10] provides equivalence factors for a wide range of single and tandem axle loads, terminal service factors (pt) and Structural Numbers (SN). Tables for Single and Tandem Axles for Flexible Pavement with Pt = 2.0 and varying structural numbers are given in Appendix Table 22.

Apparently, the damaging effect of an overloaded vehicle is far greater than the increase in load. For example, a vehicle with 10 ton axle load has 2.5 times the effect of a standard axle, and a vehicle with 13 ton load (as for some of the NLC Vehicles), has more than 8 times the effect of a standard axle.

The effect of tandem axle is far smaller than single axle. A tandem axle load of 34000 Lbs will be equal 18000 Lbs single axle. The difference is much larger at higher loads. A 40,000 Lbs single and tandem axle load will be equal to 34.34 and 2.15 standard axles respectively a difference of about 16 times.

The foregoing analysis provides necessary theoretical background for proper appreciation and understanding of the survey results. It has also clearly shown the need and use of axle load data for pavement design and maintenance of network. However, inspite of its importance, the measurement and use of axle load data has not been made to any significant extent.

Attention had not been paid to excessive overloading of goods vehicles and resulting deterioration of the network either. To fill up the gap, an extensive study of the axle loads was long over due.

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(4) O'Flaherty, C.a., op. cit., p.278.

(5) Motor Vehicles Act 4 of 1939, Section 37(2) and Tables A and B.

(6) O'Flaherty, C.A., op., p.280.

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(8) Highway Research Board special Report No. 22 "The WASHO Road Test Part 2: The Test data, analysis, findings" Washington D.C. 1955. Quoted from O'Flaherty C.A., op.cit.

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Chapter III

THE SURVEY

Outline

The survey was carried out for one year from May 1981 to April 1982 at 35 points on main roads across the country. Observations at each point were made for twenty four hours round the clock and repeated three to four times during the year.

To cross check the survey data, vehicle weights at Quetta Coal Mines and Karachi Octroi Posts were also obtained for four days each from 21.4.82 to 24.4.82 and 26.4.82 to 29.4.82 respectively.

In addition, a special round of survey of NLC vehicles was carried out for two days each at six staging stations from 11 to 28 February, 1982.

Sampling Methods

The survey involved selection of survey points, timings of the survey and selection of vehicles at each point on smapling basis. Therefore, sampling methods can have an important bearing on results. A bias in selection of roads and vehicles can arise in several ways and lead to results which are different from actual. For example, a heavily overloaded vehicles can attract the attnetion of observers and can be picked up by them more frequently. This would result in over representatation of heavily loaded vehicles giving relatively higher average load. A brief elaboration of procedures followed in selection of raod sections, survey timings, selection of vehicles, etc. is provided here to be kept in view while examining the results.

Selection of Roads

The selection of roads was made intutively keeping in view the objectives of the study and requirements of the sponsoring agency. The selected road sections cover different types of areas - hilly, rolling, sparsely and densely populated; different types of roads - national highways, provincial and secondary roads, single lane, two lane, more than two lane; and roads of varying traffic densty.

A list of road sections where survey points are located with dates of survey at each place is given at Annexure-I. The accompanying map shows the location of survey points as well.

It will be seen that one third of the survey points are on the main trunk route Peshawar-Lahore-Karachi and the remaining two thirds on other main roads.

Location of Survey Points

The survey points were located mostly at or near district boundaries. The underlying reason is that most of the socio-economic data is available for districts. Therefore, in order to relate traffic data to such socio-economic variables, it is imperative that traffic data also conforms to districts.

Selection of Vehicles

A more delicate smapling is involved in selection of vehicles. One survey party could weigh only one vehicle at a time. It took about three minutes for interviewing and weighing one vehicle. Thus a maximum of 500 vehicles could be weighed in 24 hours at one place. The traffic at most of the roads was much higher than this. Besides, traffic follows the poisson distribution and often moves in bunches and only one or a few vehicles in a group can be checked to avoid hold ups. Thus it is difficult to weigh all vehicles even when the volume is less than the capacity of the survey team. The procedure used for the selection of vehicles is explained below.

After the installatation of weighing machines, the first vehicle coming from any side was stopped for weighing and one or two vehicles moving in the same direction were kept waiting. Others were allowed to pass. Once a queue in one direction was cleared, vehicles coming from the other side were stopped. When the volume of traffic was so high that queue in any direction will not be cleared, traffic in each direction was covered for one hour alternatly.

The proportion of vehicles surveyed varied inversely with the volume of traffic although absolute number of observations increased with volume. This is in accordance with the standard smaplying techniques. The larger populations require proportionately smaller samples and smaller populations require proportionately larger smaples. The method used allowed the largest number of vehicles to be surveyed with the minimum of cost.

Types of Vehicles Covered

The survey covered only goods vehicles including trucks, tankers, truck trailers, tractors etc. Agricultural tractors with trailers were not covered. However, the data of only two axle trucks including tankers has been processed on computer. All other vehicles were excluded from computer processing. The number of such observations was quite small, less than 250 as compared to more than 31746 conventional two axle vehicles. Separate compilation of results of multi axle vehicles was also not made as due to large variations in individual observations, results were not consistent. Partly for this reason, separate survey of multi-axle vehicles was carried out.

Survey Timings:

As regards timings of the survey, these are of interest for daily, weekly and seasonal variations. Twenty four hour counts at each place covered daily variations.

For seasonal variations the survey was repeated three to four times at each place after interval of three to four months.

Besides, the continuation of the survey over a period of one year is likely to take into account seasonal variations particularly the type of commodities carried by road vehicles. The proportion of vehicles found with different types of commodities for all rounds of the survey can be regarded as the average for the year.

Information Collected

Besides axle loads which were measured on the road side by means of portable weighing machines, information necessary for identification like vehicle number, date, time, etc. and related variables such as type of commodities carried, origin, destination was also obtained from Drivers. The Questionnaire used for recording the information and coding plan used for processing of data on computer are given at Annexure-III and IV respectively. These will be useful for those who might like to analyse the data further on computer.

Police Assistance

Police assistance was necessary and was obtained for stopping and managing the traffic at the survey site. Normally two police men of the rank of Constable/Head Constable were provided by the Provincial Police Authorities from the nearest local Police Station for 24 hours at each place. This was a long duty period. Nevertheless the arrangement worked well as at every point new Police staff became available.

The presence of Police Constable ensured the compliance of instructions of survey staff by drivers. It also ensured safety of survey staff at distant places. The experience has indicated that in the absence of Police, some drivers would flout instructions of the survey staff. It is therefore, recommended that traffic surveys requiring stopping of vehicles may be carried out with the help of police who should be present at the site to deal with any traffic problem or untoward incident.

In order to ensure normal traffic conditions, police authorities were advised not to carry out checking and challans of vehicles. Particularly the overloading of vehicles was not to be questioned by the Police in any case.

Weighing Method

Weighing was carried out by means of portable axle weighing machines. Two machines were used at a time. Weights of individual wheels were recorded and compiled separately. However, the results are presented for axle loads only.

Uneven level of vehicle wheels due to machines or road surface or both combined could result in tilting of vehicles and shifting of load. Potoki(2) has examined effects of such tilting on distribution of loads and found the difference upto 10% in most of the cases. The effect of tilting would vary directly with the height of machine and inversely with distance between the two points. Considering the height of machine of 3.5 inches and distance of more than 15 feet between the wheels, the tilt would be of less than 1 degree and its effect on load shifting insignificant.

Weighing Machines

Weighing machines of large capacity are far and few. Mostly fixed type weigh bridges are installed by Municipal Administrations of large cities, business houses, and industrial units. A survey of weighing methods and equipment has been made separately and may be referred to for further details.(1) Suffice it to say here that there is not much choice and variety in portable vehicle weighing machines. The need for such machines has arisen only recently as for the present axle load survey.

The experience with the use of machines can serve as a guide for similar other surveys and has therefore been narrated in some detail.

The machines used for the survey were portable wheel-load weighers of MD 400 and MD 500 series manufactured by General Electrodynamics Corporation of USA. Their specifications are given below.

Specifications of Weighing Machines

	MD 400	MD 500
Overall length	20.5"	20.5"
Width Main Body		
Excluding handle	10"	13.3"
Including	13.75"	17.75"
Width of weighing surface	10"	13.3"
Length of weighing surface	11"	11"
Normal Height	3.1"	3.1"
Units of Measurement	Kg	Kg/Lbs

The National Highways Board had four such machines, two of MD 400 series and two of MD 500 series for use by consultants for the Third Highway Project Studies. These machines were provided by the Board for the Survey. In addition, two new machines of MD 500 series with measuring scale in Kgs were also purchased when the old machines had gone out of order.

These machines have a number of points for and against. The points in favour are that these machines are small, handy, not heavy, can be carried from place to place, can be used on any surface, require no digging and pits, need no ramps, vehicles can climb easily. Nevertheless, the performance of the machines for the axle load survey of the size leaves much to be desired. For example, the weighing platforms of the machines are smaller than required for double tyres of trucks. The weighing platform of MD 400 model is only 10 inches wide and width of platform of Model MD 500 is 13 inches only. As against this, dual tyres of trucks are 21 inches wide and cannot rest properly on plateform of either model particularly on roads of the type in Pakistan which are not smooth. Secondly, the scale read out window of the Machines is very small and attached to the body of the machine. For reading the scale the observer has to bend down close to the wheel which is very unsafe. The wheels of trucks being winder than the weighing platform would often cover the scale window making it still more difficult to read the weight measurement. Thirdly, the minimum division of scale is in hundreds of Lbs and Kg and large roundings have to be made. Fourthly, the maximum limit of the machines is exceeded by several trucks. This may cause damage to the machine. Finally, there were frequent break downs. Out of a total number of six machines five went out of order one by one. The survey ended with only one machine in working order. the possibility of errors due to defective working of the machine cannot be ruled out. Some variations in results are in fact traceable to defective working of machines. A record of break down of Machines is given at Annexure IV.

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(1) Government of Pakistan, National Transport Research Centre, "A Review of Vehicle Weighing Methods, Equipment and Inventory" NTRC-60, November, 1981. (Memographed).

(2) POTOCKI, F.P. "The Effect of Vehicle Tilt on Measured Wheel Loads" Transport and Road Research Laboratory, Supplementary Report 708, Crowthorne, Berkshire, 1981.

Chapter IV

TRAFFIC VOLUME & PROPORTION OF VEHICLES GOVERNED

Traffic Volume

Information on volume of traffic is needed for determining the proportion of different types of vehicles in the traffic Stream and the proportion which the vehicles surveyed formed to the total traffic. With this end in view, information on traffic volume was collected concurrently with first round of the survey and is given in Appendix Table 1. For subsequent rounds, traffic volume was not obtained and is assumed to be the same as for the first round.

There is considerable variation in the volume of traffic at different survey points. The highest traffic was 6633 vehicles on Lahore Gujranwala road (survey point 12) and lowest traffic was 363 vehicles at Dadu-Larkana road (survey point No. 30).

The number of trucks as a proportion of total traffic (col.12 Table 1) varied from 15% at Abbottabad Mansehra road (survey point 2) to 80% at D.G. Khan Fort Munro Road (survey point 22). However, when the data is grouped with class intervals of 1000 vehicles, the proportion of trucks varied between 38% and 45% of volume, the average being 42% as follows:

Traffic Volume and Proportion of Trucks

Sl. No.	Traffic Volume vehicles per day	Trucks as % of total	No. of survey points
1.	Upto 1000	44	10
2.	1001-2000	41	11
3.	2001-3000	45	7
4.	3001-4000	38	4
5.	4001 and over	43	3
	Total:	42	35

Source: Compiled for Table 1.

Proportion of Trucks Surveyed

In all 31,746 trucks were surveyed excluding observations rejected due to in-accuracy or inconsistency. As compared to this, the 24 hour volume of trucks on all the 35 road sections is 29,487. Thus the number of vehicles surveyed during four rounds are 108% of 24 hour volume. This means that statistically all traffic at selected road sites has been covered.

There were four survey rounds at first 17 points and three rounds at the other 18 points. The number of trucks surveyed at the first 17 points amounted to 129% volume and at the later 18 stations 90% of volume. Details for individual survey points are given in Appendix Table 2.

Relationship between volume and proportion covered:

The proportion of trucks surveyed varied inversely with volume i.e. where the volume was low the coverage was high and vice versa. However, the absolute number of trucks surveyed initially increased with increase in volume but after the capacity of the survey team was reached, the number remained constant. This is amply shown in table below:

Volume of traffic and proportion of trucks surveyed

Average daily volume of trucks	Average surveyed	Percent surveyed	No. of points
Upto 500	141	53	13
501-1000	224	35	11
1001-1500	455	32	5
1501-2000	428	25	4
2001 and over	485	18	2
Total:	272	32	35

Source : Compiled from Table IV-1 and 2.

It will be seen from the above table that at places with less than 500 trucks daily, 141 trucks were surveyed. The number increased to 224 when the volume of trucks increased to 500-1000. With further increase in traffic to 1000-1500 trucks, the numbers surveyed reached to 455. With further increase in volume of trucks, the coverage did not increase. Thus the proportion of trucks surveyed declined from 53% to 18% with increase in volume from 500 to 2000 and over.

Distribution according to survey round and load condition

The number of trucks survey during each round were as follows:-

No. of trucks surveyed according to round and load condition

Survey Round	Period	Nos. surveyed Total	Loaded	Empty
1st	2.5.81 - 14.7.1981	8876	7965	911
2nd	8.8.81 - 1.11.1981	8883	8765	118
3rd	12.11.81 - 27.12.1981	9912	9893	19
4th	14.3.82 - 9.4.1982	4075	3489	586
	Total :	31746	30112	1634

Source : Compiled from Appendix Table 8.

The increase in number of trucks surveyed during the third round was broadly the result of experience gained by the staff during earlier rounds. The less number of observations during the fourth round is due to the fact that only 17 survey points were covered during this round as against 35 points covered in the first three rounds.

Loaded and Empty Vehicles

Out of 31,746 vehicles surveyed, 30,112 (95%) were loaded and 1,634 (5%) empty. Most of the empty vehicles were surveyed during first and fourth rounds. As little variation was expected in the weights of empty vehicles, the number of observations of such vehicles made during first round were considered to be sufficient to give reliable results. As such, weighing of empty vehicles was not emphasised during second and third rounds. During these rounds, empty vehicles were surveyed far and few only at places and at times when loaded vehicles were not available. However, variations in average load between the first two rounds lead to the need for additional data. Accordingly, the weighing of empty vehicles was again increased during the fourth round to verify the results of the first round. Hence the proportion of empty vehicles in the fourth round is about 16.7% which is the highest of all.

The proportion of empty vehicles indicated above is in no way representative of composition of loaded and empty goods vehicles which should be determined independently. Other surveys carried out by this Centre indicated that on the average 30% of trucks are empty.

Chapter V

AXLE LOADS

Average Loads

The main results of the survey provide average axle loads with standard deviations for each survey point and round. Taking all survey points together the average axle loads of loaded and empty vehicles have been found as follows:

Average Axle Loads (Kg)
(with standard deviations)

Load Condition	Front Axle	Rear Axle	Total
Loaded	4343 (705)	10,020 (1931)	14,377 (2438)
Empty	2868 (475)	3308 (952)	6177 (1219)

The average Rear Axle Load of 10,020 Kg is about 23% above the maximum limit of 8,165 Kg = 18000 Lbs.

The details of average loads for each survey point are given in Appendix Table 3. Variations according to survey points, rounds, etc. are examined in subsequent paragraph.

Variations between survey points

Average vehicle loads varied between survey points both for loaded and empty vehicles. The distribution is shown below:-

Distribution of Survey Points according to vehicle loads

Loaded Vehicles: Average Load 1000 Kg	No. of survey Points	Empty Vehicles: Average load 1000 Kg	No. of survey points
12.00 - 12.99	3	5.50 - 5.99	9
13.00 - 13.99	7	6.00 - 6.49	11
14.00 - 14.99	17	6.50 - 6.99	6
15.00 - 15.99	8	7.00 - 7.49	6
		7.00 - 7.99	3
Total:	35	Total:	35

In the case of loaded trucks, 17 of the 35 survey points have average load of 14.00 - 14.99 tons another 15 survey points are within ± 1 ton. Three survey points have less than 13 ton weight. These were Rawalpindi-Murree, Abbottabad-Havelian and Peshawar-Torkham - all hilly areas in the north. The highest load was 15.423 tons at Quetta Nushi road. This was followed by Larkana-Dadu (15.312 tons), Rohri-Khairpur (15.254 tons). Other places were in between the two extremes.

In the case of empty vehicles, 11 of the 35 survey points have average load of 6.00-6.49 tons and another 15 points are within ± 0.5 tons. There are 6 survey points with 7-7.5 ton average load and 3 points with 7.5 to 8 tons. Extreme values exceeding 7.5 tons may be due to heavy weight vehicles or due to errors of coding and data processing. The number of observations in this category are only 18.

As a general observation, loads in the northern hilly areas are lower and on main trunk roads near Karachi higher.

Distribution of load over Front and Rear Axles

The distribution of load over front and rear axles varied according to gross vehicle load. The date shows that for a gross load of upto 6 tons, that is, when the vehicle is empty, the load is nearly evenly distributed over and front and rear exles in the ratio of 48:52. The addition of load on the vehicle increases the load over both front and rear axles, but the increase on the front axle is one fourth of the increase on the rear axle. The ratio of 48:52 for the empty vehicles is changed to 30:70 for loaded vehicle. The relationship is shown in Appendix Table 4. The regression of load on front and rear axles as a function of gross load in linear and log form using the data in Appendix table 4 provides the following results:

Results of Regression Analysis

Form of Equation	a	b	r^2
i) $Y_f = a + b\ X_g$	1.47	0.21	.92
ii) $Y_r = a + b\ X_g$	(-) 0.34	0.72	.95
iii) $Y_f = ax^b$	3.01	0.56	.84
iv) $Y_r = ax^b$	(-) 0.64	1.02	.85

Y_f = Load on Front Axle

Y_r = Load on Rear Axle

X_g = Gross Load

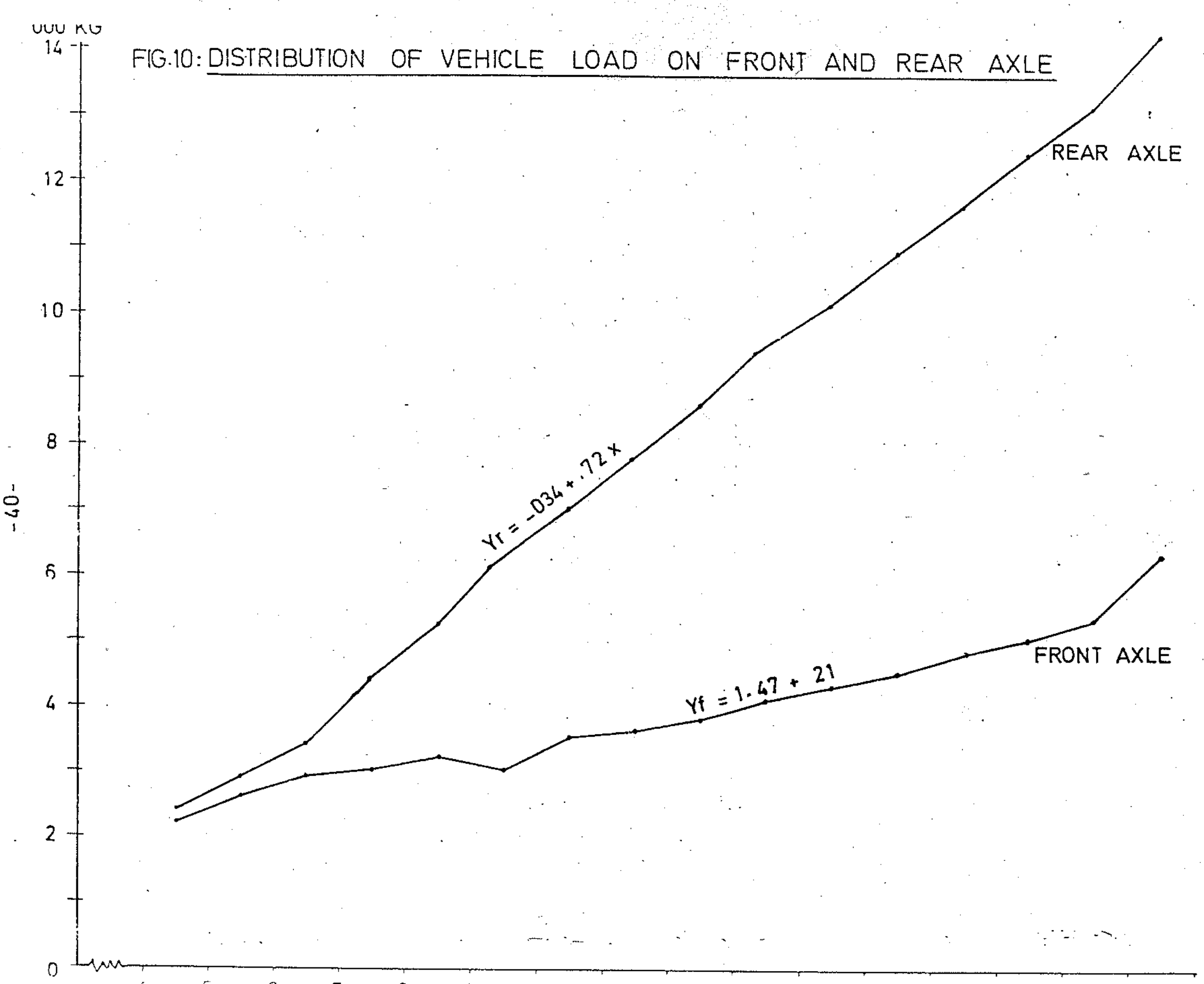
a = Constant

b = Coefficient

r^2 = Coefficient of Determination

The following graph illustrates the distribution of load over front and rear axles.

FIG.10: DISTRIBUTION OF VEHICLE LOAD ON FRONT AND REAR AXLE



Distribution of Vehicles according to rear axle load - overloading

The percentage distribution of vehicles according to rear axle loads has been found as follows·

Percentage distribution of vehicles according to Rear Axle Loads (Loaded Vehicles)

Load Class	% of Vehicle	Load Class	% of Vehicle
0-4.9	1.6	10-10.9	23.7
5-5.9	2.3	11-11.9	20.8
6-6.9	3.5	12-12.9	10.0
7-7.9	6.0	13-13.9	2.4
8-8.9	11.4	14-14.9	0.7
9-9.9	17.3	15 & over	0.4

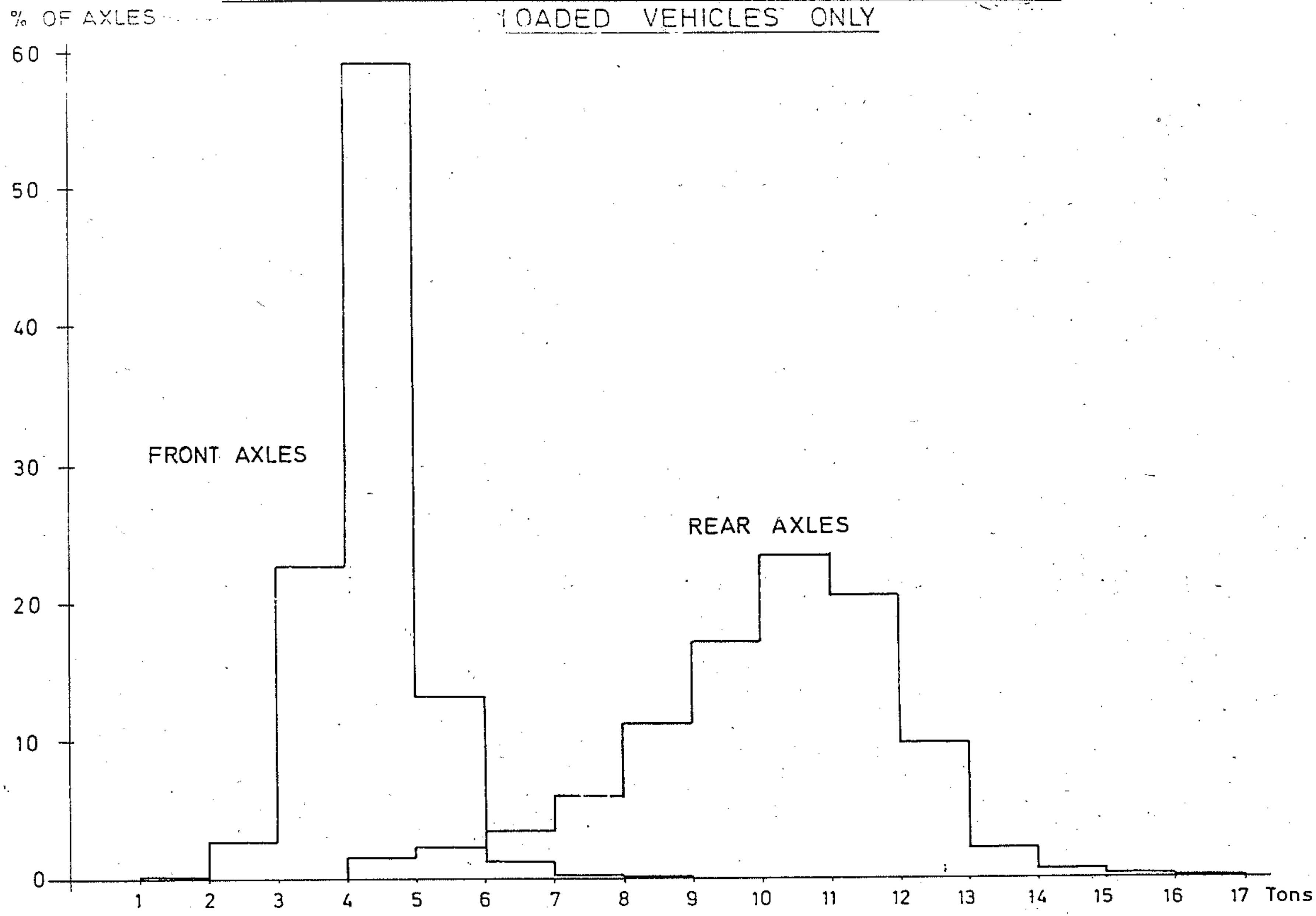
More than 8.2 = 83.7%

Average axle load of 10,020 kg and standard deviation of 1930 mean that 83% of the vehicles will be overloaded.* This is exactly the ratio given by actual distribution. Details for each survey point are shown in Appendix Table 5.

Assuming normal distribution

$$* \quad Z = \frac{M-\bar{X}}{\quad} = \frac{8165-10020}{1930} = .96 = .1685-1 = 83.15\%$$

FIG.11: DISTRIBUTION OF VEHICLES ACCORDING TO AXLE LOADS
LOADED VEHICLES ONLY



As will be evident from Table 5, 13% of the loaded vehicles have less the 8000 kg axle load, slightly lower than the maximum limit of 8165 kg, 17% of the vehicles are less than 8,200 kg (Maximum limit rounded to nearst 100 kg. If, however, a 10% plus variation is allowed in maximum limit, say, for errors of measurements etc. and vehicles in 8 to 8.99 ton load class are not considered as overloaded, there will still be 75% vehicles which will be overloaded by this criteria. Above that limit 58% are more than 10 tons, 35% more than 11 tons, 14% more than 12 tons and 4% more than 13 tons. The significance of vehicles in each load class for road damage will be considered in a subsequent section.

Distribution of survey points according to Percentage of vehicles overloaded

The distribution of survey points according to percent of vehicles overloaded is as follows:

Distribution of survey points according to % of Vehicles Overloaded

% of Vehicle overloaded	No. of Survey points
60-69	4
70-79	9
80-89	11
90 and over	11
	35

Variations between survey points are not much. Evidently, there is no survey point with less than 60% vehicles overloaded. There are 4 points with 60-69% vehicles overloaded, 9 points with 70-79% and 11 points each with 80-89% and 90% and more vehicles overloaded.

Vehicle according to commodities

Average axle loads and standard deviations according to types of commodities carried are shown in Appendix Table 6. For classification of commodities, Pakistan Standard Trade Classification upto three digit level has been followed.

Commodities which were found to be most heavily loaded are given below:

Heavily Loaded Commodities

S.No.	Commodity	Gross Load (Kg)
1.	Rice	15,962
2.	Wheat	15,715
3.	Onions	15,564
4.	Marble	15,602
5.	Scrap	15,688
6.	Animal	15,485
7.	Coal	15,186
8.	Cement	15,131
9.	Gur	15,087

Distribution of Vehicles according to Type of Commodity Carried

The grouping of vehicles into broad commodity categories shows that 33% of vehicles carried Agriculture and Food products, 25% carried Mining, Qarrying, 16% Manufactured goods, 10% Miscellaneous (General Merchandize), 6.3% P.O.L and the remaining 10% all other commodities. Details are shown below.

Distribution of Vehicles according to main commodity groups

Code	Commodity Group	No. of Vehicle	% of Total
100	Agricultural Products	4,720	15.7
200	Food preparations	5,118	17.0
300	Animals & animal products	871	2.9
400	Raw Materials	2,050	6.8
500	Bulk Manufactures	2,370	7.9
600	Basic Manufactures	2,300	7.6
700	Miscellaneous	3,163	10.5
800	Mining and Qarrying	7,409	24.6
900	Fuel and Lubricants	1,906	6.3
A00	Miscellaneous	205	0.7
	Total:	30,112	100.00

Seasonal Variations

Four rounds of the survey over a period of one year corresponded to seasons of the year. It was expected that differences in average loads between rounds would reflect seasonal variations. However, average loads appear to have been affected by so may other factors that it seems difficult to isolate the effect of seasonal variations directly from average axle loads during four rounds.

Seasonal variations can arise largly due to differences in types of commodities carried at different times of the year with varying load factors.

Besides, some differences in average loads for the same commodity can arise due to the fact that when a commodity is available in large quantities in season, vehicles will be fully loaded. Off the season, there might be sundary loads of such a commodity and average loads can be lower than in the season. However, such differences will be nominal.

Mostly, agricultural commodities subject to seasonal variations - wheat, rice, cotton, sugarcane, etc. will be found in bulk during their harvest seasons. Some industrial inputs like fertilizers have also seasonal character. The average loads will be lower in the season when relatively more cotton is carried and higher in the other season when more wheat is carried. The proportion of vehicles carrying different types of commodities will therefore determine the extent of variations in vehicle loads. Therefore, in order to find seasonal variations in axle loads, differences in types of commodities carried during four rounds may be examined.

Differences in Commodities carried between survey rounds

The percentage distribution of vehicles according to main commodity groups and survey rounds is shown in Appendix Table 7.

It would appear therefrom that there is little variation between rounds. For example, proportion of trucks carrying agricultural commodities varied from 31.2% in Round I to 36.5% in Round II with average of 34.1%. Similarly manufactured goods varied from 26.9% in Round III to 31.8% in Round I with average of 28.8% for all rounds. However, the proportion of vehicles against mining and qarrying is higher and against fuel and lubricants lower in Round IV than the other three rounds. This may be due to the reason that Round IV was incomplete. The places with mining quarrying traffic were surveyed and those with more P.O.L. traffic near Karachi were not. As such the proportion of one is higher and of the other lower.

It is evident that seasonal variations, as result of differences in types of commodities carried, are not significant. Variations on this account, if any, are over-shadowed by other factors such as errors to measurement and differences in loads carried by individual vehicles.

Variations between survey Rounds

Variations in average load at a given survey point at different times of the year can arise due to differences in types of commodities carried which in turn may be the result of seasonal variations in demand or supply of different commodities. However, differences in individual commodities will cancel each other resulting in a relatively smaller variation within groups of commodities. For example more wheat may be carried during summer and more rice during winter. Loadability of the two commodities is similar. Therefore, taking agriculture as a whole, there may be little seasonal variation. Differences between groups will be smaller than between individual commodities.

In addition, if the commodities subject to seasonal variation are a smaller proportion of overall volume, changes in their composition will have little effect on overall average.

For example, mining and quarrying account for 15% of loaded vehicles. A 10% variation in the weight of vehicles carrying such commodities will result in only 1.5% variation in overall average weight. This may be quite small particularly when several other factors are also affecting the average load.

It has been shown in the preceding section that differences in types of commodities carried during different survey rounds are not statistically significant. As such, differences in average loads due to changes in types of commodities carried between survey rounds should also not be significant.

From a detailed examination of variations according to survey rounds in Appendix Table 8, the following points emerge:

i). Average loads for First Round of the Survey are lower than average for all rounds. The difference increases with weight and is more for loaded vehicles than for empty vehicles, and for Rear Axles than for Front Axles.

ii). The average vehicle loads for first rounds are 8% less than average for all rounds. The difference in rear axle load is 9% and in front axle 6%.

iii) The load of empty vehicle is only 2% less than average with rear axle being 1% less and front axle 3% less than average.

iv) The average loads of II round are higher than average for all rounds. The difference is of 5% in vehicle load, 4% in rear axle load and 6% in front axle load.

v) The difference between the First and Second Rounds is of the order of 13%. The average loads of first and second round combined are however close to overall average.

Further examination of loads for individual commodities indicated that average loads of round I are lower than overall average for commodities which are subject to seasonal variation and others equally. The percentage differences in the loads of a few selected commodities in four rounds are shown below for illustration.

Percentage differences in loads of selected commodities during diff. rounds

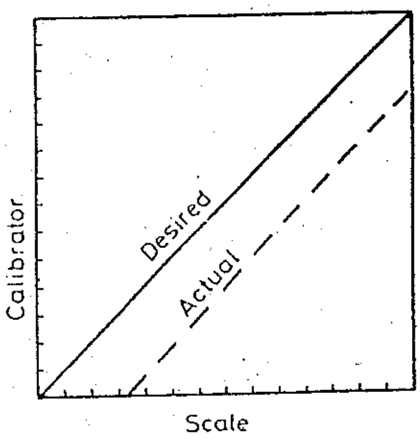
Commodity	R.I	R.II	R.III	R.IV	Total
Wheat	88	104	102	105	100
Rice	91	104	101	97	100
Cement	92	103	101	101	100
Fertilizer	96	104	101	100	100
Coal	93	106	100	101	100
Diesel	96	104	100	98	100

The results are the same ad indicated before, that is, average loads for I Round are less than average for all rounds the difference being 4% to 12% for different commodities. The average load for II Round is higher by 3% to 6%. The average for III and IV Rounds is similar to average for all rounds.

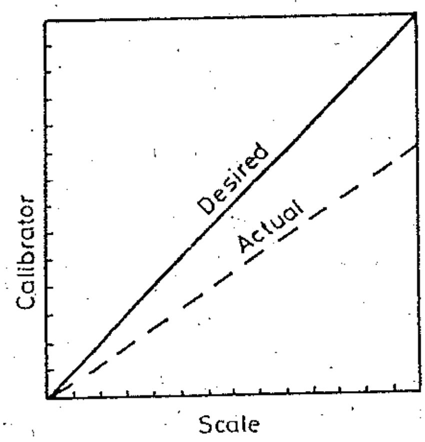
Some of the differences in loads were found to coincide with changes in weighing machines. The first machine broke down at survey point No. 24 during I Round and a spare machine was inducted. The average weight increased by 2% points on succeeding survey points. The second machine broke down at the end of the first round. Therefore, in the second round both the previous machines were out and other machines were in use The average weight was higher the Third machine broke down near the end of Second Round the other was withdrawn as reserve and two new machines were purchased and used in the third round. The average loads became normal. An account of break down and usage of different machines is given at Annexure III.

The fact that differences in average loads are more for loaded vehicles than empty vehicles and for rear axles than for front axles is explained by the type of distortions caused by certain types of defects in machines. Two types of distortions can occur in such machines.(1) These are shown in the diagram on the next page.

Fig. 12



CASE - I



CASE - II

In case I the measured weight is lower than the actual by a constant amount. In case II, the difference increases with weight. The second type of error seems to have occured between Round I and II.

In view of the differences indicated above, it was considered whether any correction should be applied to I and II Round data or one or the other round should be excluded from tabulations, However, it appeared that errors of measurement of the two Rounds cancel out each other and average results are the same as for all the four Rounds. It was therefore not considered necessary to introduce any correction which may introduce its own distortions. Besides, there are advantages in retaining larger data for various other statistics such as type of commodities carried, origin, destination, Make, retained in its original form.

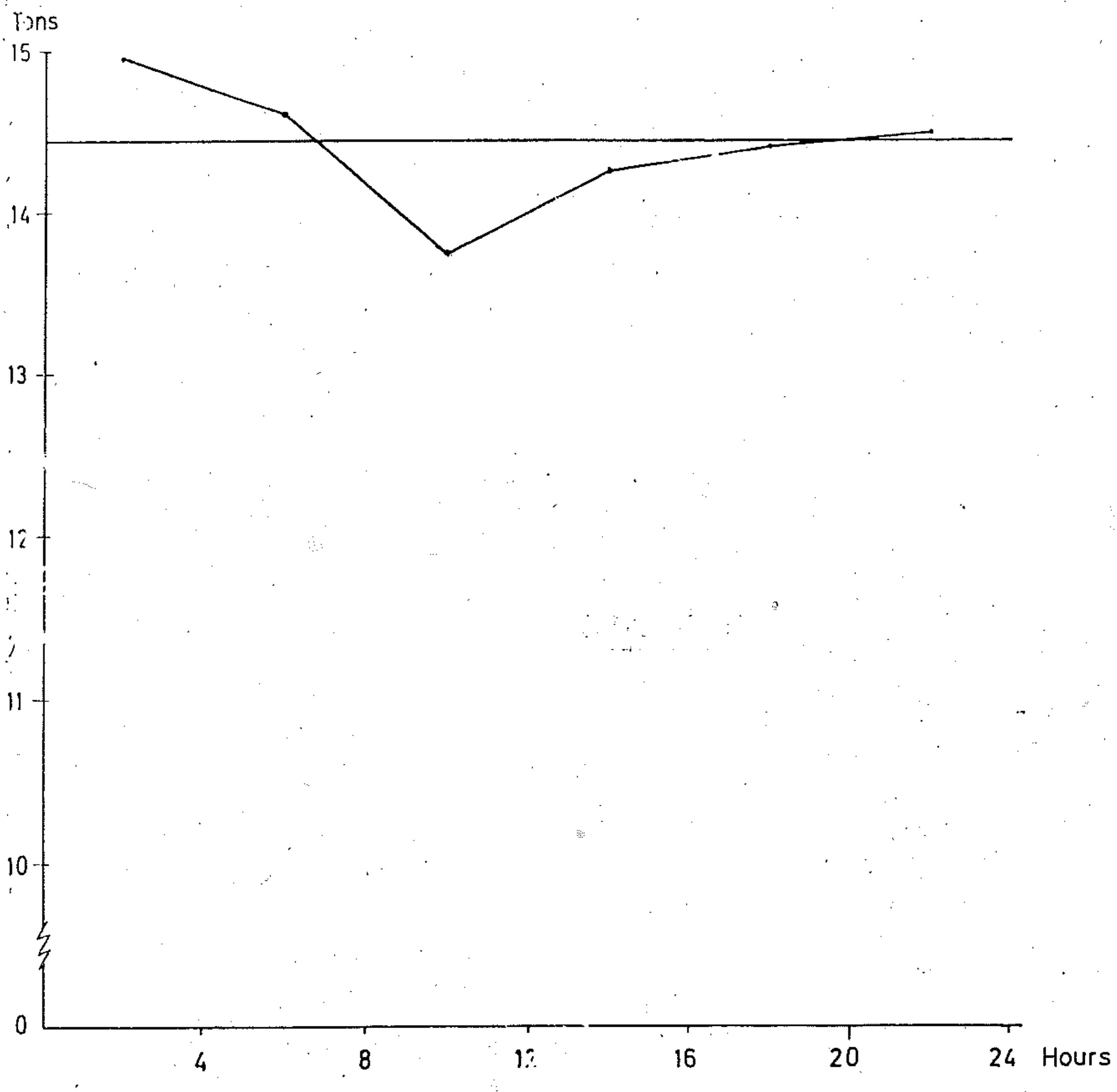
In view of the differences in results of Rounds I and II it became necessary to check the reliability and accuracy of data. For this purpose, a special survey of truck weights at Quetta Coal Mines and Karachi Octroi Post was carried out. The results are described in a subsequent section.

Variations according to Time of the day

The present survey was carried out for 24 hours continuously at each place. The cost of such surveys can be reduced considerably if operations are confined to day time only or part of the day provided differences in loads according to time of the day, if any, are known. Accordingly, in order to find out if there are differences in loads by time of the day and the extent of such differences, the data was compiled according to time of the day with four hour intervals. The results are given Appendix Table 9. The data is also shown on the graph that follows.

FIG-13:

GROSS VEHICLE LOADS ACCORDING TO TIME OF THE DAY



Although the highest loads are at mid night from 00-04 hours and lowest in the morning from 08-12 hours, the difference between the two extremes is only 8.8%. The difference between day and night time loads is only of 3.2%. Night time loads are 1.6% above 24 hour average and day time loads 1.6% below 24 hour average. The day time loads can thus be inflated by 1.6% to arrive at 24 hour average. However, before using such ratios, more statistical analysis would be necessary which is beyond the scope of present report.

It may also be noted here that Standard Deviations for the night time loads are smaller than for day time loads. This implies that variations in load are less during night hours.

There are two possible reasons for loads at night being higher than during the day. First overloaded trucks find it convenient to travel at night when traffic is relatively sparse. Second, the local retail cargos which are picked up and delivered during business hours are not found at night. Their exclusion increases the average load at night. This aspect needs further analysis before arriving at any firm conclusions.

Distribution of Vehicles according to Make

Although Bedford is the make which dominates the scene, there is a variety of other Makes as well. Particularly, some Japanese makes are coming up fast in the market. By virtue of their design certain makes have larger capacities, heavier axle loads and more damaging effect than others. In order to identify such makes and precise amounts of their axle loads, information on Make of the vehicle was also added in the questionnaire. However, recording of the information was missed for 4315 cases which remain un-specified.

In all 17 Makes were identified. The number of vehicles observed for each Make are given in Appendix Table 10. Evidently Bedford dominates the scene and accounts for 96.5% of the vehicles. This is followed by Nissan and Hino which are about 1% each. Other Makes are less than .1%. The vehicle fleet is thus well standardized.

Axle Loads according to Make

Average Axle Loads for main Makes with more than 50 vehicles in loaded and empty from are given in Appendix Table 11. It would be seen that Mercedes and Nissan are the heaviest vehicles with unladen weight of 8,475 Kg and 8,794 Kg and gross load of 19,497 Kg and 18,952 Kg respectively. As compared to this, unladen weight and gross load of Bedford is 6,371 kg and 14,619 kg respectively. The rear axle load of Mercedes and Nissan are 12,885 kg and 13,071 kg respectively as compared to 10,206 kg for Bedford. Other vehicle types are similar to Bedford except Hino and Isuzu which are slightly heavier than Bedford.

Distribution of Bedford Vehicles according to year of Manufacture

Information on Model (Year of Manufacture) was also collected alongwith Make. The results are meaningful for Bedford vehicles only as the number of observations were large enough to enable compilation. In other cases, the number of observations are quite small and therefore compilation is not meaningful. Some of the old vehicles like Austin, Dodge etc. are left-overs of old Makes. Others are of recent years.

The distribution of Bedford vehicles according to year of manufacture is given below:

Percentage Distribution of Bedford Vehicles according to year of Manufacture

Year (Model)	Percent of Vehicle
1960-65	6.0
1966-70	17.3
1971-75	30.4
1976-81	46.3
Total:	100.0

Further details are given in Appendix Table 12.

It would be evident from the above that 46% vehicles are 1-6 years old, 30%, 7-12 years old and 23% are more than 12 years old. The entry of new vehicles in the fleet has not been smooth in the past. Rather, there have been wide fluctuations. If the entry of new vehicles was smooth over the years, the number of vehicles of any year would have been larger than preceding year. This is not however the case.

REFERENCE

(1) General Electrodynamics Corporation, "Operation, Service and Maintenance Manual of Portable Wheel Load Weigher", USA.

Chapter VI

EQUIVALENT STANDARD AXLES IN TERMS OF DAMAGING EFFECT

Relation of Load to Damaging Effect

The damaging effect of an axle load increases not in proportion to weight, but by 4.5th power of the weight. Research has indicated that for identical roads carrying identical number of commercial vehicles, the useful life may, in extreme cases, vary by a factor of ten due to differences in distribution of axle loads. Therefore, for purposes of pavement design, varying axle loads are expressed by a common denominator in terms of 18000 Lbs standard axles according to their damaging effect. Rating the standard 18000 Lbs axle as unity, and using the 4.5th power relationship, a 10,000 Lbs (4540 kg) axle would be equal to 0.07 standard axles and 1/.07 or 14 passes of this axle would have the same damaging effect as the one standard axle. At the other extreme an axle load of 40,000 Lbs (18140 Kg) will have 36 times the damaging effect of a standard axle.

The whole axle load data is geared to the concept of damage caused by a standard 18000 Lbs (8165 Kg) axle and the number of passes of other axle loads required to cause the same damage. Accordingly, 18000 Lbs (8165 kg) equivalent standard axles for have been calculated for loaded vehicles for each road section in Appendix Table 13.

It will be noted that an average loaded vehicle is equal to 3.22 standard axles on the whole. However, there is considerable variations between survey points. For example, at Rawalpindi-Murree Road an average loaded vehicle is equal to 1.75 standard axles as compared to 4.4 at Quetta-Naushki Road.

The distribution of survey points according to equivalent standard axles is given below.

Distribution of survey points according to equivalent standard axles per loaded vehicle

Equivalent Standard Axles	No. of Survey Points
1.50 - 1.99	1
2.00 - 2.49	5
2.50 - 2.99	5
3.00 - 3.49	12
3.50 - 3.99	11
4.00 - 4.49	1
Total :	35

There are 23 stations with equivalent factors of 3 to 4 10 stations with equivalent factor from 2 to 3 and one station each with equivalent factor less than 2 and more than 4 respectively.

Proportionate Damage by Vehicles in different load classes

As has been indicated before, the damaging effect of an axle load increases at a much higher rate than the increase in load. The overloaded vehicles thus cause disproportionately large damage to the road structures. The percentage of damage caused by vehicles in different load classes is shown in the Appendix Table 14.

The conclusions are obvious, 25% of the vehicle not overloaded, including vehicles in load class 8-8.9 tons which are slightly overloaded but not considered as such, cause only 6% damage, 42% vehicles upto load class 9.9 tons cause 16% damage. On the other extreme, 3.4% vehicles in load class 13 tons and over cause 11.5% damage, 13% vehicles in load class 12 tons and over cause 32% of damage.

Damaging Effect of Loaded and Empty Vehicles

The major proportion of damage is caused by rear axles of loaded vehicles. The front axles of loaded vehicles and empty vehicles have far smaller damaging effect.

The distribution of loaded and empty vehicles according to loads of front and rear axles and damaging effect of each axle based on 4.5th power of the ratio of load in each class to the standard axle are shown in Appendix Table 15.

It will be seen therefrom that a loaded vehicle is equal to 3.37 standard axles of which 3.3 are due to rear axle and .07 due to front axle. Any empty vehicles is equal 0.124 standard axles of which .080 are due to rear axle and .041 due to front axle. The essential point to prove here is that major proportion of damage (98%) is due to rear axle loads of loaded vehicles. Accordingly, it would be sufficient to consider only rear axles of loaded vehicles for simplyfing the survey and computations.

Damaging Effect of Average Load vs.average Damaging Effect of Individual Loads

It may be added here that damaging effect of average load and average damaging effect of given axle loads are quite different. In the former case, the loads are first averaged and then the damaging effect of this value is calculated. In the latter case, damaging effect of individual loads is calculated and then averaged. An example will make the point clear.

Damaging Effect of average load and average effect of individual loads

S.No.	Axle Load Tons	Equivalent Factors
1.	4	.04
2.	6	.25
3.	8	.91
4.	10	2.49
5.	12	5.65
Total:	40	9.34
Average	8	1.868
Equivalent Standard Axles	0.91	1.868

In the above example, the average load of 8 tonsis equal to 0.91 standard axles whereas average of standard axles of individual loads is 1.868 standard axles.

The average axle load found during the survey is 10,020 Kg. The damaging effect of this figure will be 2.46 standard axles. However, the average of damaging effect of individual loads is 3.3 standard axles, a difference of 34%.

In certain design Manuals equivalent standard axles are claculated on the basis of average vehicle load which is not the correct method. However, with the availability of present axle load data, it would be possible to calculate equivalent axle loads on the basis of load distributions.

Chapter VII

VERIFICATION OF DATA & COMPARISON WITH OTHER SOURCES

Cross Checks

In order to cross check the survey data, information was collected from alternative sources independently and weights of trucks carried out at Quetta Coal Mines and Karachi Octroi Posts on fixed type weighing bridges were obtained through a special survey. At Quetta the weighing of trucks is done for sale of coal and is therefore supposed to be more accurate than for other purposes. The trucks are first weighed in empty form and then after loaded of coal. The difference between the gross and unladen weight provides the net weight of the commodity for trade. At Karachi the weighing of incoming trucks is done for collecting Octroi. The results of weights at two places are given in Appendix Tables 16 and 17 respectively and evaluated below.

Weights at Quetta Coal Mines

The average load of 14,562 Kg at Quetta is 4% less than average load of all coal trucks in Axle Load Survey for all rounds combined (15,184 Kg). However, the overall average for Quetta includes 57 vehicles having destinations within Quetta region and 66 vehicles with destinations in other Provinces. The average load of the former category is lower (14,123 Kg) than the latter (14,940 Kg). The latter category of vehicles are the ones most commonly found during Axle Loads Survey and comparable to it.

The differences between Axle Load Survey and trucks with destinations out side Quetta Region is only 1.6% or 244 Kg. This may be due to the fact that during axle load survey trucks were weighed with labour and their belongings on the vehicle while at Quetta only truck with one driver is weighed. The difference of 244 kg can be accounted for by 3 to 4 extra persons on the vehicle.

In the case of empty trucks the difference is of 6%. This may be partly due to the reason given above and partly due to the fact that empty trucks contain some left over commodities which are removed before reloading the vehicle. Some difference may be due to type of weighing machines and weighing methods.

Weights at Karachi Octroi Posts

The average loads at Karachi Octroi Posts are some-what higher than axle load survey. The difference between Octroi Post weights and axle load survey for all vehicles is 4%. The reason is obvious. Axle Load Survey includes 35 places with varying average loads. The survey points near Karachi would be more relevant to compare. The difference between Octroi Post and Axle Load weights at Karachi Hyderabad Super Highway is 1.6%. The Octroi Post and axle load weights at National Highway are very close to each other. Thus the loads at Karachi Octroi Posts are also comparable to Axle Load Survey.

The above evidence fully proves the accuracy and reliability of axle load survey results. In fact one of the advantages of a larger survey is that differences due to several factors cancel each other and a stable and consistent average is obtained.

Comparison with other sources

Prior to the present survey, preliminary axle load surveys were carried out in Punjab and Sind by the Third Highway Project Consultants in 1977 and 1978. The results of these surveys are given in Appendix Table 18 with corresponding figures of the present survey for comparison.

In the first instance it may be indicated that the number of observations in previous surveys in Punjab and Sind are far smaller than the present country.wide survey. The observations for Punjab are less than the average observations made at any place in 24 hours in the present survey. The observations for Sind are also about the maximum made at several places during the present survey.

The number of observations for empty vehicles are still smaller only 6 in Punjab and 14 in Sind. This number is not sufficient to give reliable estimates. Perhaps this might have been the reason for carrying out a country wide survey.

As for the results, it would be seen that in Punjab average weight of a loaded vehicle is higher and of empty truck lower than in Sind.

The average loads of loaded trucks are within the range of variations observed during the survey. The differences can be due to differences in commodities carried by vehicle at different places as appears to be the case for Punjab and Sind.

As regards empty trucks, the average load in Sind is also close to the survey results. However, the average wieght in Punjab (5.5 tons) appears rather low. The lowest average load of empty vehicles observed during axle load survey at any of the 35 survey points was 5.633 tons.

The lower value of empty vehicles in Punjab seems to be the error of measurement due to trickling of machine. The same element appears to be present to some extent in loaded vehicles in Sind.

In view of the above, previous surveys do not appear to be adequate to provide reliable results due to their limited scope and coverage.

Chapter VIII

SURVEY OF N.L.C. VEHICLES

Background

During normal survey operations, coverage of multi axle vehicles in general and of N.L.C. vehicles in particular was inadequate for several reasons. First, the proportion of such vehicles in the traffic stream is very small and chances of their selection for survey still smaller. Secondly, the weighing of such vehicles required more time and longer space which was some-times not available at survey points along road side. This discouraged the selection of long vehicles. Thirdly, the N.L.C vehicles move in conveys and would not stop individually. This further reduced representation of such vehicles in the sample. Besides, a small number of vehicles checked at different survey points varied greatly providing means with large standard deviations. Such results are not much reliable.

The NLC vehicles have recently entered the road freight market with truck trailers and tractor trailers of container type, carrying bulk commodities over long distances. Considerable interest has evinced in the operation of such vehicles. It was generally felt that loads carried by these vehicles exceed the design limits by a wide mergin causing proportionately greater damage to roads.

In addition to above, information on NLC heavy duty trucks and tractor trailers was also required for the bridge design Manual to be prepared by the National Highways Board who desieed a specific survey for the purpose.

It may be mentioned that NLC operations are highly organized. Their vehicles move in groups with an Officer Incharge and report at different staging stations. It is possible to check these vehicles with the cooperation of NLC authorities.

Therefore, in order to obtain information on axle loads of multi axle vehicles in general and NLC vehicles in particular, a survey of NLC vehicles was carried out at their staging stations.

The data was compiled manually and main tabulations were supplied to the National Highways Board soon after the survey for their immediate use. The results are also presented in this report.

Time, Place and Number of Observations

The survey was carried out for two days each at six staging stations covering in all 253 vehicles as follows:

S.No.	Place	Survey Date	No. of Obs.
1.	Gujranwala	11-12 Feb. 82	9
2.	Multan	13-14 Feb. 82	47
3.	Bahawalpur	16-17 Feb. 82	62
4.	Khairpur	20-21 Feb. 82	65
5.	Hyderabad	23-24 Feb. 82	55
6.	Karachi	27-28 Feb. 82	15
		Total:	253

The number of trucks for different destinations on any one date can vary considerably. There were very few trucks at Gujranwala and Karachi on the survey dates. Hence the small number of observations at these places.

Vehicles according to number of Axles

Of the 253 vehicles surveyed 8 (3%) were of 5 axles 158 (62%) were of 4 axles and 87 (30%) of 2 axles. According to load condition 216 vehicles were loaded and 37 empty. The details are given in Appendix Table 19.

Axle Loads

Average Axle Loads with Standard Deviations for different categories of vehicles are given in Appendix Table 20 and a brief analysis of these is given in the following paragraphs.

Gross and Net Loads

The gross load varied according to size of the vehicle. In the case of 5 axle vehicles, the highest load was 47.25 tons for Hino tanker. The load of corresponding empty tanker was about 20 tons resulting in a net load of 27 tons. This is about three times the load carried by an ordinary 2 axle truck. The gross load of 5 axle truck trailer was 43.45 tons. Any empty vehicle in this category was not available.

In the case of 4 axle vehicles, the average weight of loaded and empty vehicles was 37.14 and 14.84 tons respectively resulting in a net weight 22.3 tons. In this category, there are 3 makes of two types viz; Mercedes truck trailers, Fiat and Hino Tractor Trailer Semi Trailers. There are considerable differences between these makes. The weight of loaded and empty vehicles and resulting net load of commodities carried was respectively 37.61, 14.68,& 22.93 tons for Mercedes Truck Trailers 35.71, 13.25 and 22.5 tons for Fiat Truck Trailer and 38.31, 17.15 and 21.16 tons for Hino Trucks Trailers. Thus the Hino Truck Trailer is heaviest in unladen weight, carries relatively less commodities and still has higher gross load. The gross load of 4 axles Fiat Tanker was 31.65. The corresponding load of empty tanker was not available.

In the case of 2 axle vehicles, the weights of loaded vehicles, empty vehicle and net load carried are 20.0, 9.0 and 11.0 tons for Mercedes; 15.2, 6.4 and 8.8 tons for Hino and 13.6, 5.4 and 8.2 tons for Saviem respectively. Mercedes trucks in this category are the tractor units of truck trailer combination.

Axle Load Distribution

In the case of loaded vehicles, except for the Front Axles, weights of all axles exceeded the maximum limit of 8,165 Kg or 18000 Lbs., with one or two exceptions only.

In most of the cases, loads of rear axles are higher than average rear axle loads of 2 axle civilian vehicles which already exceed the maximum limit. The excess was particularly high for 5 axle Tankers and 4 axle Mercedes truck trailers.

In the case of 5 axle vehicles, heaviest load was on 4th and 5th Axles, 13.2 and 12.6 tons for tanker and 10.87 and 11.30 tons for trucks. In the case of 4 axle vehicles heaviest load on second axle was 13.196 tons for Mercedes 11.4 tons for Fiat and 11.6 tons for Hino. The distribution of load over different axles is more even for Hino than Fiat or Mercedes.

The axle loads of 2 axle vehicles are smaller than of civilian vehicles except for Mercedes trucks which have a gross load of about 20 tons and Rear Axle Load of 13.075 tons. This is the traction unit of trailer combination.

Equivalent Standard Axles

The severity of excessive axle loads can be measured by means of equivalent standard axles which have been claculated in Appendix Table 21. It may be noted that 5 axle Hino vehicles have two tandem axles, 4 axles Hino and Fiat vehicles have one tandem axle each. 4 axle Mercedes truck trailers and 2 axle vehicles have all single axles.

For a given weight, equivalent standard axles for tandem axles are much less than for single axles. Therefore, Mercedes truck trailers have higher values of equivalent standard axles than Fiat and Hino which have one tandem axle each.

As would be seen from Table 21 Mercedes truck trailers are equal to 11.4 standard axles and 2 axles trucks equal to 8.8 standard axles. As compared to this, 4 axle Fiat and Hino trucks are equal to 8.2 and 9.7 standard axles, 5 axles trucks and tankers are equal to 5.5 and 9.2 standard axles respectively.

Standard Axle Loads considered in terms of per ton of net load carried are also highest for Mercedes truck trailers and traction units without trailers, .5 and .8 standard axles per ton respectively. As compared to this, the values for 5 Axle Hino with 2 tandems and 4 axle Fiat and Hino with one tandem axle are .34, .32 and .4 respectively.

It would appear from the foregoing that Mercedes Truck Trailers have the highest damaging effect, equal to 11 standard axles. This is followed by Hino Truck Trailer which is equal to 8.7 standard axles. The existing vehicles are with NLC only. Their damaging effects can be reduced by loading less commodities. Future import and registration of such vehicles should also be restricted.

STATISTICAL APPENDIX

24 HOUR VOLUME OF TRAFFIC AT AXLE LOAD SURVEY POINTS DURING ROUND-I

Sl. No.	Name of Road Section	Date of Obs.	Motor cycles	Car/ Jeep	Wagon	Pick-up	Bus	Truck	Other	Total	Trucks as % of total
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
01	Rawalpindi-Murree	2.5.81	66	478	203	252	326	335	-	1660	20
02	Abbottabad-Mansehra	4.5.81	25	431	352	489	293	288	12	1890	15
03	Abbottabad-Havelian	5.5.81	47	682	553	629	499	910	11	3331	27
04	Rawalpindi-Peshawar	6.5.81	47	800	350	176	582	1291	13	3264	40
05	Mardan-Dargai	8.5.81	59	465	43	193	422	343	32	1557	22
06	Peshawar-Tourkham	10.5.81	122	677	102	304	479	811	70	2565	32
07	Peshawar-Kohat	11.5.81	83	579	300	298	553	766	33	2602	29
08	Bannu-D.I.Khan	13.5.81	32	73	8	42	166	311	[illegible]	640	49
09	Talagang-Pindigheb	14.5.81	72	89	71	64	192	514	25	1027	50
10	Mandra-Chakwal	16.5.81	100	162	169	213	214	253	14	1135	23
11	Rawalpindi-Jhelum	17.5.81	49	933	628	237	728	1739	35	4399	41
12	Lahore-Gujranwala	19.5.81	135	1758	994	577	1315	1741	113	6633	26
13	Sheikhupura-Faisalabad	21.5.81	228	783	376	133	1140	884	29	3573	24
14	Faisalabad-Chiniot	23.5.81	113	328	26	69	562	1585	47	2730	58
15	Jhang-Bhakar	24.5.81	10	73	9	8	189	166	10	465	36
16	Sargodha-Jhang	26.5.81	59	118	14	24	285	325	13	838	39
17	Khushab-Mianwali	28.5.81	20	66	5	15	206	211	10	533	40
18	Lahore-Okara	14.6.81	29	410	52	75	662	1254	65	2547	49
19	Multan-Sahiwal	16.6.81	34	244	19	15	572	996	23	1903	52
20	Jhang-Multan	17.6.81	31	188	9	15	310	1118	8	1679	67
21	D.G.Khan-Kot Adu	19.6.81	45	95	39	29	174	582	3	967	60

Contd...p/69

Sl. No. 1.	Name of Road Section 2.	Date of Obs. 3.	Motor/ Cycles 4.	Car/ Jeep 5.	Wagon 6.	Pick-up 7.	Bus 8.	Truck 9.	Other 10.	Total 11.	Truck as % of Total 12.
22	D.G.Khan-Fort Munro	20.6.81	18	17	1	3	46	378	9	472	80
23	Multan-Bhawalpur	22.6.81	61	202	23	35	461	1816	28	2628	69
24	Muzaffargarh-Uch	23.6.81	24	66	19	23	234	1053	6	1425	74
25	Kashmore-Ubaro	25.6.81	41	62	10	14	163	356	12	658	54
26	Rohri-Khairpur	27.6.81	94	400	171	340	388	2097	22	3512	60
27	Jaccobabad-Sibi	28.6.81	47	147	5	107	190	756	5	1257	60
28	Quetta-Chamman	30.6.81	22	498	113	476	318	754	15	2196	34
29	Quetta-Naushki	2.7.81	49	157	153	258	146	175	11	949	18
30	Larkana-Dadu	5.7.81	14	134	82	55	98	126	15	524	24
31	Kotri-Dadu	6.7.81	-	74	12	31	70	174	2	363	48
32	Hyderabad-Mirpur	8.7.81	26	473	16	359	367	622	6	1869	33
33	Karachi-Thatta	9.7.81	61	375	29	258	209	612	-	1544	40
34	Karachi-Gadani	12.7.81	77	736	127	272	129	817	1	2159	38
35	Karachi-Hyderabad	13.7.81	20	552	71	262	465	3266	12	4648	70
		Total:-	1,960	13,315	5,152	6,350	13,153	29,487	725	70,142	42

Table 2

Number of Truck Surveyed

Sl. No.	Name of Road Section	No.of Rounds	No.of Truck Surveyed			Average per round	
			No.of truck	24 hour volume	Survey as % volume	Nos.	% of volume
1	2	3	4	5	6	7	8
1.	Rawalpindi-Murree	4	618	335	184	156	46
2.	Abbottabad-Mansehra	4	594	288	206	148	52
3.	Abbottabad-Havelian	4	1117	910	129	294	32
4.	Rawalpindi-Peshawar	4	1655	1291	128	414	32
5.	Mardan-Dargai	4	694	343	202	174	50
6.	Peshawar-Tourkham	4	689	811	85	172	21
7.	Peshawar-Kohat	4	1036	766	135	259	33
8.	Bannu-D.I.Khan	4	626	311	201	156	50
9.	Talagang-Pindigheb	4	1019	514	198	255	49
10.	Mandra-Chakwal	4	509	263	194	127	48
11.	Rawalpindi-Jhelum	4	1758	1789	98	440	25
12.	Lahore-Gujranwala	4	1378	1741	79	344	20
13.	Sheikhupura-Faisalabad	4	1116	884	126	279	32
14.	Faisalabad-Chiniot	4	1767	1585	111	442	28
15.	Jhang-Bhakkar	4	347	166	209	87	52
16.	Sargodha-Jhang	4	776	325	239	194	59
17.	Khushab-Mianwali	4	458	211	217	114	54
18.	Lahore-Okara	3	839	1254	67	280	22
19.	Multan-Sahiwal	3	908	996	91	303	30
20.	Jhang-Multan	3	1121	1118	100	374	33
21.	D.G.Khan-Kot Adu	3	892	582	159	297	28
22.	D.G.Khan-Port Munro	3	621	378	164	207	35
23.	Multan-Bhawalpur	3	1462	1818	80	487	27
24.	Muzaffargarh-Uch	3	1363	1053	135	454	43
25.	Kashmore-Ubaro	3	573	356	161	191	54
26.	Rohri-Khairpur	3	1611	2097	77	537	26
27.	Jaccobabad-Sibi	3	1105	756	146	368	49
28.	Quetta-Chaman	3	360	754	48	120	16
29.	Quetta-Naushki	3	197	175	113	66	38
30.	Larkana-Dadu	3	340	126	270	113	90
31.	Kotri-Dadu	3	690	174	396	230	32
32.	Hyderabad-Mirpur	3	697	622	112	232	37
33.	Karachi-Thatta	3	738	612	121	246	40
34.	Karachi-Gadani	3	713	817	87	238	29
35.	Karachi-Hyderabad	3	1299	3266	40	433	13
		Total:	31,746	29,487	108	260	32%

Table 3

Average Axle Loads with Standard Deviations according to survey point

Sl. No.	Name of Road Sections	No.of Obs.	Average Weight(Kg) Front Axle	Rear Axle	Total	Standard Deviation Front Axle	Rear Axle	Total
				LOADED VEHICLES				
01	Rawalpindi-Murree	484	4066	8687	12753	625	1817	2216
02	Abbottabad-Mansehra	513	4190	8917	13107	717	2228	2725
03	Abbottabad-Havelian	1021	3892	9040	12933	664	2051	2537
04	Rawalpindi-Peshawar	1499	4122	9358	13481	760	2280	2838
05	Mardan-Dargai	604	4154	9448	13602	752	2128	2670
06	Peshawar-Torkham	540	3942	9013	12955	936	2119	2821
07	Peshawar-Kohat	910	4067	9491	13559	667	1833	2291
08	Bannu-D.I.Khan	558	4118	9919	14038	694	1902	2415
09	Talagang-Pindigheb	933	4117	9693	13811	714	1930	2477
10	Mandra-Chakwal	450	4059	9512	13572	684	1743	2220
11	Rawalpindi-Jhelum	1704	4223	9788	14011	747	2180	2774
12	Lahore-Gujranwala	1336	4205	9825	14030	768	2130	2619
13	Faisalabad-Sheikhupura	1085	4213	9837	14050	657	2154	2631
14	Faisalabad-Chiniot	1704	4376	10440	14816	661	1690	2196
15	Jhang-Bhakkar	308	4165	9103	13268	735	2236	2816
16	Sargodha-Jhang	741	4311	10074	14386	601	1810	2266
17	Khushab-Mianwali	439	4241	9925	14167	612	1986	2454
18	Lahore-Okara	817	4462	10410	14872	823	1878	2392
19	Multan-Sahiwal	876	4356	10181	14537	593	1971	2403
20	Jhang-Multan	1116	4340	10360	14701	547	1465	1844
21	D.G.Khan-Kot Adu	867	4413	10173	14586	553	1560	1954
22	D.G.Khan-Fort Munro	594	4506	10358	14864	526	1402	1779
23	Multan-Bahawalpur	1445	4491	10587	15079	594	1508	1944
24	Muzaffargarh-Uch	1349	4481	10432	14913	522	1574	1948
25	Kashmore-Ubaro	561	4530	10577	15107	463	1375	1641
26	Rohri-Khairpur	1578	4615	10639	15254	611	1670	2078
27	Jaccobabad-Sibi	1094	4701	10523	15224	807	1630	2187
28	Quetta-Naushki	356	4556	9770	14327	675	1861	2381
29	Quetta-Chaman	188	4912	10510	15423	826	2301	2966
30	Larkana-Dadu	337	4683	10599	15283	573	1741	2150
31	Kotri-Dadu	687	4602	10710	15312	561	1598	1953
32	Hyderabad-Mirpurkhas	691	4779	10278	15057	808	1661	2022
33	Thatta-Karachi	730	4505	10406	14911	696	1811	2179
34	Karachi-Gadani	707	4305	9791	14096	555	1957	2331
35	Karachi-Hyderabad	1290	4502	10190	14693	614	1827	2289
	Total:	30112	4343	10020	14364	705	1931	2438
				EMPTY VEHICLES				
	Total:	1634	2868	3308	6177	475	952	1219

Table 4

Distribution of gross Loads over Front and Rear Axles(Kg)

Class Interval	No.of Obs.	Gross Load	Front Axle	Rear Axle	Percent on Front Axle	Percent on Rear Axle
4 - 5	116	4700	2253	2446	48	52
5 - 6	770	5623	2690	2932	48	52
6 - 7	713	6411	2979	3432	46	54
7 - 8	347	7512	3085	4427	41	59
8 - 9	570	8539	3256	5282	38	62
9 - 10	842	9546	3069	6175	33	67
10 - 11	1149	10576	3526	7049	33	67
11 - 12	1847	11569	3681	7888	31	69
12 - 13	3014	12581	3897	8664	31	69
13 - 14	3959	13545	4123	9422	30	70
14 - 15	5315	14544	4361	10183	29	71
15 - 16	5712	15535	4599	10990	31	69
16 - 17	4411	16497	4811	11686	29	71
17 - 18	1971	17455	5025	12429	28	72
18 - 19	585	18439	5336	13103	28	72
19 - 20	418	20634	6347	14286	90	70

Table - 5

Percentage distribution of Rear Axles according to Weight(Tons)

Stn. No.	No. of Obs.	0-4.9 / 5-5.9	6-6.9 / 7-7.9	8-8.9 / 9-9.9	10-10.9 / 11-11.9	12-12.9 / 13-13.9	14-14.9 / 15 & over	More than 8.2
01	484	5.37	5.79	23.55	17.77	1.45	0.00	66.12
		3.10	11.98	21.90	9.09	0.00	0.000	
02	513	6.82	5.46	12.09	25.73	4.29	0.00	70.37
		8.19	5.46	18.71	12.67	0.58	0.00	
03	1021	3.82	6.27	13.32	20.37	3.92	0.20	69.44
		6.46	9.40	21.84	13.81	0.49	0.10	
04	1499	4.80	7.00	12.34	21.01	6.20	0.73	70.58
		5.07	8.41	14.41	17.68	2.07	0.28	
05	604	3.15	3.97	14.24	25.00	2.98	0.00	76.16
		4.80	6.79	20.53	16.06	0.99	1.49	
06	540	4.07	6.11	23.70	14.26	2.41	1.01	68.52
		3.33	10.19	23.70	8.70	1.30	1.02	
07	910	1.98	3.08	18.24	18.68	5.82	0.00	78.46
		2.75	9.23	23.52	15.71	0.77	0.22	
08	558	2.33	2.15	9.14	28.14	6.81	0.72	84.59
		3.58	5.02	19.00	20.97	1.97	0.18	
09	933	1.71	4.93	12.22	21.11	9.65	0.64	78.14
		1.93	10.08	18.97	17.15	1.61	0.00	
10	450	2.00	4.89	12.67	27.33	5.11	0.00	81.33
		2.44	7.56	24.44	13.11	0.45	0.00	
11	1704	2.11	6.75	9.39	21.01	9.92	0.59	75.94
		4.17	9.04	14.32	19.54	2.58	0.48	
12	1326	2.84	4.72	9.96	19.99	10.18	0.82	78.74
		3.37	7.78	15.49	22.60	2.02	0.23	
13	1085	2.67	4.15	12.44	18.99	10.51	0.83	79.17
		3.50	7.47	15.85	21.11	2.03	0.45	
14	1704	0.47	1.82	8.57	26.47	11.21	0.94	91.02
		1.17	3.81	17.19	23.88	3.99	0.48	
15	308	4.22	9.42	10.06	15.58	6.82	0.00	64.61
		6.17	11.04	14.94	21.10	0.55	0.00	
16	741	0.94	3.24	11.34	23.62	9.45	0.54	85.02
		1.21	6.75	18.76	21.19	2.56	0.00	
17	439	2.51	5.47	7.52	25.51	7.74	0.00	81.55
		2.96	5.92	12.98	28.25	1.14	0.00	
18	817	1.35	2.82	9.67	21.79	16.77	1.22	88.74
		1.35	4.65	14.69	22.28	3.06	0.35	
19	876	0.80	3.42	11.30	21.35	13.36	0.46	83.45
		2.40	8.22	13.93	21.69	2.51	0.55	
20	1116	0.45	1.70	9.41	29.12	9.05	0.09	92.65
		0.63	2.96	19.80	25.90	0.72	0.18	

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Stn. No.	No. of Obs.	0-4.9 5-5.9	6-6.9 7-7.9	8-8.9 9-9.9	10-10.9 11-11.9	12-12.9 13-13.9	14-14.9 15 & over	More than 8.2
21	867	0.35	1.85	14.07	25.61	7.84	0.23	88.47
		0.58	5.65	18.45	23.18	2.19	0.00	
22	594	0.17	1.35	8.59	34.34	6.23	0.17	92.76
		0.57	2.53	20.88	28.23	1.52	0.34	
23	1145	0.07	1.59	8.51	28.80	9.90	0.62	93.15
		0.42	2.77	16.96	27.13	3.18	0.55	
24	1549	0.22	1.19	13.42	24.54	14.08	0.14	91.18
		0.44	4.37	17.35	21.28	2.97	0.00	
25	561	0.18	1.07	5.17	37.08	9.63	0.53	93.94
		0.71	2.85	14.26	27.09	1.43	0.00	
26	158	0.00	1.65	9.57	23.32	16.54	1.84	91.63
		0.89	3.93	15.34	22.88	3.80	0.24	
27	094	0.91	1.55	8.41	24.41	10.69	0.91	92.78
		0.55	2.38	15.36	32.18	1.92	0.73	
28	356	0.84	3.37	17.42	21.63	7.30	1.12	80.06
		2.53	7.58	19.38	15.17	3.37	0.29	
29	188	0.00	4.26	11.70	15.43	11.17	3.72	80.85
		1.60	6.91	12.23	22.87	5.85	4.26	
30	337	0.89	2.97	5.64	24.33	11.87	0.89	90.50
		0.89	3.86	11.87	32.34	4.15	0.30	
31	687	0.44	1.46	5.24	29.11	16.30	1.31	93.60
		1.16	1.31	14.85	23.44	5.09	0.29	
32	691	0.72	2.46	10.27	31.40	10.27	0.58	90.16
		1.01	3.62	17.80	19.54	2.17	0.16	
33	730	0.96	2.60	8.36	23.97	19.45	0.55	88.36
		2.05	3.15	15.62	21.51	1.78	0.00	
34	707	1.84	4.10	14.00	24.47	9.34	0.42	78.78
		1.56	7.78	19.80	12.16	4.24	0.29	
35	1290	0.39	2.95	15.97	26.16	12.79	1.40	86.05
		0.54	5.66	18.22	17.29	4.11	0.54	
	30112	1.63	3.48	11.39	23.73	9.96	0.67	83.67
		2.26	6.00	17.34	20.81	2.37	0.36	

Table 6. Average Axle Loads with Standard Deviations According to type of Commodity

All Rounds

Commodities Code	Description	No.of obs.	Average Load (Kg) Front Axle	Rear Axle	Total	Standard Deviations Front Axle	Rear Axle	Total
100	AGRICULTURE							
110	Wheat	1347	4681	11034	15715	693	1612	2075
120	Rice	795	4676	11286	15962	471	1289	1573
130	Maize	86	4543	10364	14907	675	1577	3031
140	Other	340	4567	10756	15323	532	1503	1824
150	Sugar-cane	331	4130	10255	14386	489	1328	1580
160	Cotton	572	4160	9219	13379	578	1657	2108
170	Jute	20	4261	9877	14138	371	1166	1255
180	Tobacco	133	3684	7516	11201	457	1437	1751
185	Oil Seeds	402	4483	10341	14824	581	1437	1848
190	Fooder	605	3744	8311	12055	870	2247	2754
195	Agri.Product	89	4478	10159	14637	923	2201	2835
200	FOOD							
210	Flour	680	4428	10223	14651	683	1582	2058
220	Vegetable	407	4157	9303	13460	744	1865	2276
230	Onion	796	4635	10929	15564	608	1533	1936
240	Fruit	1919	4440	10176	14616	655	1667	2103
250	Industrial Raw.	1	4800	10350	15150	-	-	-
260	Ghee	707	4225	9711	13935	588	1341	1741
270	Sugar	271	4576	10342	14918	693	1815	2336
280	Gur	272	4438	10649	15087	492	1461	1777
190	Others	65	3972	9276	13249	596	1784	2258
300	ANIMALS & ANIMAL PRODUCTS							
310	Animal	777	3585	6394	9997	544	1528	1894
320	Meats	22	3647	6689	10336	662	2696	3272
330	Hides	29	3975	8691	12666	555	1904	2271
340	Wool	31	3721	7686	11407	437	1492	1818
390	Others	12	4050	9342	13392	573	1341	1540
400	RAW MATERIALS							
410	Timber	435	4109	10085	14194	777	1741	2262
420	Pulp	194	4267	10106	14372	616	2137	2628
430	Scrap	831	4585	11103	15688	634	1719	2133
490	Others	2	4695	8142	12837	839	658	1355
500	BULK MANUFACTURES							
510	Cement	859	4532	10599	15131	591	1271	1632
520	Fertilizer	551	4532	10361	14893	566	1289	1601
530	Medicine	55	4205	9117	13322	837	2444	3110
540	Chemicals	176	4351	10127	14477	606	1653	2067
550	Tea	73	4063	8889	12952	494	1676	1940

Commodities		No. of Obs.	Average Load (Kg)			Standard Deviations		
Code	Description		Front Axle	Rear Axle	Total	Front Axle	Rear Axle	Total
560	Beverage	178	4066	8807	12873	591	1523	1921
570	Animal Food	449	4542	10943	15485	509	1510	1840
580	Dried Milk	27	4270	9258	13528	485	1736	1964
590	Other Bulk	2	4607	11438	16045	388	969	1347
600	BASIC MANUFACTURES							
610	Tex Fibr	234	4014	8919	12933	544	1514	1924
620	Tex Manufacture	227	4172	9273	13445	723	2214	2771
630	Jute Manufacture	112	4109	8990	13099	624	2173	2607
640	Leather	92	4219	8987	13206	651	2057	2520
650	Wood Manufacture	129	3819	7321	11140	704	2595	3146
660	Rubber Manuf.	58	4139	8227	12366	1889	2589	3882
670	Iron Pipe	459	4374	10608	14982	700	1956	2368
680	Metal Product	188	4290	10105	14396	783	2635	3214
685	Cement Manuf.	34	4041	9248	13288	756	2036	2505
690	Bricks	757	4091	9657	13748	654	1480	1935
695	Others	10	4285	10230	14515	477	1280	1628
700	MISCELLANEOUS MANUFACTURES							
710	Machinery	83	4017	8253	12270	883	2703	3395
720	Machine El.	42	3800	7814	11614	750	2512	2979
730	Domestic	29	4251	8867	13118	854	2583	3267
735	Paper	215	4086	9224	13310	700	2100	2585
740	Cycles	3	3673	6574	10247	429	1881	2309
750	Cars Vehicles	55	3886	7176	11062	1141	2609	3528
755	Spare Parts	7	3861	8214	12076	693	1422	2033
760	Cigerettes	104	3660	7087	10747	550	1691	2074
770	General Goods	2392	4423	10273	14696	755	2001	2517
775	Soop Set	71	4249	9612	13861	717	2029	2490
777	Sp. Goods	3	4089	9897	13986	562	616	1136
780	Pottery	74	4133	8875	13008	731	2403	2961
785	Ice	16	3929	7365	11294	743	2090	2564
790	Cans. Drums	59	3977	7319	11295	895	2724	3458
795	Others	10	1	9	13	411	1308	1516
800	MINING AND QUARRYING							
810	Gravel Stone	2795	4441	10529	14970	606	1467	1894
820	Sand	1336	4322	10191	14512	701	1628	2144
830	Lime Stone	75	4327	10208	14535	750	2177	2696
840	Marble	168	4640	10963	15602	762	1535	2111
850	Gypsm	3	4891	7888	12780	295	4876	4583
860	Salt Rok	97	4430	10519	14949	620	1387	1820
870	C. Clay	13	4539	10838	15377	635	1498	2039
880	E. Clay	127	4393	10403	14796	578	1625	2025
895	Others	5	4740	10688	15427	1060	1430	1807
900	FUEL LUBRICANTS							
910	Coal	2790	4536	10648	15184	618	1194	1608
920	Bitumn	20	4341	9723	14064	611	1922	2416

Commodities Code	Description	No.of Obs.	Average Load(Kg) Front Axle	Rear Axle	Total	Standard Deviations Front Axle	Rear Axle	Total
930	Petrol	539	4042	8990	13032	630	1322	1820
940	Diesel	903	4044	9213	13256	680	1401	1891
950	Koresine	181	3927	8794	12722	675	1397	1908
960	Furneal	62	4252	9561	13813	602	1283	1776
970	Lubricant	84	6546	12320	14867	650	1615	2120
980	G. Product	113	3995	8336	12331	656	1723	2190
990	F. Wood	588	4308	9875	14183	598	1713	2120
995	Miscellaneous	3	4324	10780	15105	77	537	597
A 10	Mails Postal	1	4082	5806	9888	-	-	-
A 20	House Hold	164	3632	6139	9771	616	1878	2288
A 99	Unspecified Goods	40	4002	8248	12249	796	2326	2898
000	EMPTY	1634	2868	3309	6177	475	952	1219

Table 7

Percentage distribution to vehicles according to commodity group and survey Round

Commodity Groups	Survey Round				
	I	II	III	IV	Total
Agriculture and Food (1)	31.7	34.0	36.5	34.1	34.1
Manufacturing (2)	31.8	28.3	26.9	29.6	28.8
Mining and Quarrying (3)	13.5	14.2	14.9	23.8	15.3
Fuel and Lubricant (4)	18.3	19.4	18.9	7.4	17.5
Other (5)	5.2	4.1	2.8	7.1	4.3
Total :	100.0	100.0	100.0	100.0	100.0

(1) Commodity groups 100, 200, and 410.
(2) Commodity groups 500, 600, 700 and 430.
(3) Commodity group 8 or
(4) Commodity group 9
(5) All other including group 300.

Table 8

Average Loads according to Survey Rounds

Survey Round	No. of Obs.	Average Load (Kg) Front Axle	Rear Axle	Total	Standard Deviations Front Axle	Rear Axle	Total
				LOADED VEHICLES			
I	7965	4075	9121	13196	825	1909	2421
II	8765	4584	10467	15052	672	1866	2342
III	9893	4349	10322	14671	562	1708	2147
IV	3489	4336	10092	14429	627	2057	2547
Average:	30112	4343	10020	14364	705	1921	2438
				EMPTY VEHICLES			
I	911	2771	3264	6035	532	1031	1291
II	118	3178	3782	6960	460	1594	1914
III	19	3315	4334	7650	656	2057	2666
IV	586	2942	3248	6191	294	374	599
Average:	1634	2868	3308	6177	475	952	1219
				PERCENTAGES			
				Loaded			
I		94	91	92			
II		106	104	105			
III		100	103	102			
IV		100	101	100			
Total:		100	100	100			
				Empty			
I		97	99	98			
II		111	114	113			
III		116	131	124			
IV		103	98	100			
Total:		100	100	100			

Table 9

Vehicle loads according to Time of the day

Time of day	No. of obs.	Average Vehicle Load	S.D.
00 - 04	501	14,963	(2284)
04 - 08	531	14,611	(2379)
08 - 12	414	13,754	(2772)
12 - 16	566	14,267	(2586)
16 - 20	742	14,412	(2605)
20 - 24	710	14,494	(2499)
Average			
Day 8 A.M. to 8 P.M.	1742	14,206	2653
Night 8 A.M. to 8 P.M.	1722	14,664	2410
24 hours	3464	14,437	(2544)

Table 10

No. of vehicles according to Make

S.No.	Make	No.of Vehicles	%
1.	Austin	6	1
2.	Bedford	26,485	96.5
3.	BMC	81	0.3
4.	Dodge	7	-
5.	Espel	3	-
6.	Fiat	9	-
7.	Ford	22	0.1
8.	Hino	244	0.9
9.	International	94	0.3
10.	Issuzu	102	0.4
11.	Leyland	11	..
12.	MAN	2	..
13.	Mercedes	50	0.2
14.	Merry	2	..
15.	Mazda	3	..
16.	Nissan	294	1.1
17.	Toyota	6	..
18.	Others	10	..
	Total:	27,431	99.8
	Unspecified	4,315	
	TOTAL :	31,746	

Table 11

Axle Loads according to Make and Land Condition

Sl. No.	Make	Load Condition	No. of Obs.	Axle Load: Front Axle	Axle Load: Rear Axle	Axle Load: Total
1.	Bedford	Loaded	25568	4413	10206	14619
		Empty	917	2987	3384	6371
2.	BMC	Loaded	80	4383	9994	14378
		Empty	1	2600	3000	5600
3.	Hino	Loaded	238	4529	10616	15145
		Empty	6	3158	3342	6500
4.	International	Loaded	86	4261	10081	14342
		Empty	8	3519	3850	7369
5.	Mercedes	Loaded	44	6611	12885	19497
		Empty	6	4117	4358	8475
6.	Nissan	Loaded	282	5881	13071	18952
		Empty	12	4304	4490	8794

Table 12

Distribution of Bedford Vehicles according to year of Manufacture

Year	No. of Vehicles	%
Upto 1960	51	
1961	72	1.2
1962	88	
1963	47	
1964	592	2.8
1965	434	2.1
1966	669	3.2
1967	582	2.8
1968	523	2.6
1969	968	4.6
1970	676	3.2
1971	551	2.7
1972	905	4.3
1973	1096	5.3
1974	2084	9.9
1975	1802	8.5
1976	1711	8.1
1977	1070	5.0
1978	1373	6.6
1979	2663	12.6
1980	2105	10.0
1981	934	.5
Total:	20,996	100.0

Table 13

Equivalent Standard Axles according to Survey Points

Stn. No.	Name of Road Section	No.of Vehicle		Equivalent Standard Axles		Standard Axles per Loaded Veh.
		Loaded	Empty	Loaded	Empty	
01	Rawalpindi-Murree	484	134	848	4.4	1.75
02	Abbottabad-Mansehra	513	81	1109	4.6	2.16
03	Abbottabad-Havelian	1021	156	2229	5.8	2.18
04	Rawalpindi-Peshawar	1499	156	4015	5.1	2.67
05	Mardan-Dargai	604	90	1641	2.4	2.71
06	Peshawar-Tourkham	540	149	1268	6.0	2.35
07	Peshawar-Kohat	910	126	2298	4.2	2.52
08	Bannu-D.I.Khan	558	68	1691	4.7	3.03
09	Talagang-Pindigheb	933	86	2628	2.4	2.82
10	Mandra-Chakwal	450	59	1112	1.8	2.47
11	Rawalpindi-Jhelum	1704	54	5314	2.8	3.12
12	Lahore-Gujranwala	1336	42	4134	11.9	3.09
13	Sheikhupura-Faisalabad	1085	31	3408	2.2	3.14
14	Faisalabad-Chiniot	1704	63	6169	1.7	3.62
15	Jhang-Bh.kar	308	39	730	1.4	2.37
16	Sargodha-Jhang	741	35	2380	2.9	3.21
17	Khushab-Mianwali	439	19	1345	0.5	3.06
18	Lahore-Okara	817	22	3061	1.8	3.75
19	Multan-Sahiwal	876	32	3042	6.0	3.47
20	Jhang-Multan	1116	05	3737	0.3	3.35
21	D.G.Khan-Kot Adu	867	25	2757	0.9	3.18
22	D.G.Khan-Fort Munro	594	27	1980	0.7	3.33
23	Multan-Bhawalpur	1445	17	5414	0.9	3.75
24	Muzaffargarh-Uch	1349	14	4771	5.0	3.54
25	Kashmore-Ul aro	561	12	2018	1.4	3.60
26	Rohri-Khairpur	1578	33	6198	1.3	3.93
27	Jacobabad-Sibi	1094	11	4098	1.5	3.75
28	Quetta-Chaman	356	04	1039	0.4	2.92
29	Quetta-Naushki	188	09	839	0.5	4.41
30	Larkana-Dadu	337	03	1307	0.1	3.88
31	Kotri-Dadu	687	03	2721	0.5	3.96
32	Hyderabad-Mirpur	691	06	2363	0.2	3.42
33	Karachi-Thatta	739	08	2665	1.0	3.65
34	Karachi-Gaddani	707	06	2101	6.9	2.97
35	Karachi-Hyderabad	1290	09	4422	3.0	3.43

Proportionate damaging effect by vehicles in different load classes

Load Class	Mid Value	Equivalent Factor	Percent of Vehicles		Equivalent Standard Axles	Percent of Total	
			Each Class	Cumulative		Each Class	Comu-lative
4-4.9	4.5	.0685	1.63	1.63	.112	.03	.03
5-5.9	5.5	.1690	2.26	3.89	.382	.12	.15
6-6.9	6.5	.3584	3.48	7.37	1.247	.38	.53
7-7.9	7.5	.6823	6.00	13.37	4.094	1.24	1.77
8-8.9	8.5	1.1983	11.39	24.76	13.649	4.13	5.90
9-9.9	9.5	1.9768	17.34	42.10	34.277	10.38	16.28
10-10.9	10.5	3.1013	23.73	65.83	73.595	22.28	38.56
11-11.9	11.5	4.6702	20.81	86.64	97.187	29.42	67.98
12-12.9	12.5	6.7966	9.96	96.60	67.694	20.49	88.47
13-13.9	13.5	9.6095	2.37	98.97	22.774	6.89	95.36
14-14.9	14.5	13.2542	0.67	99.64	8.880	2.69	98.05
15-15.9	15.5	17.8933	0.36	100.00	6.441	1.95	100.00

Table 15

Percentage Distribution of Axles According to Load and standard equivalent axles

LOADED VEHICLES

Load Class (Kg)	Mid Value	Equivalent Factor	Percent of Axles Front	Percent of Axles Rear	Equivalent Standard Axles Front	Equivalent Standard Axles Rear
1-1.9	1.5	.0005	0.12	-	-	-
2-2.9	2.5	.0048	2.88	-	0.014	-
3-3.9	3.5	.0221	22.80	-	0.504	-
4-4.9	4.5	.0685	59.48	1.63	4.074	.112
5-5.9	5.5	.1690	13.68	2.26	2.312	.382
6-6.9	6.5	.3584	1.04	3.48	0.373	1.247
7-7.9	7.5	.6823	-	6.00	-	4.094
8-8.9	8.5	1.1983	-	11.39	-	13.649
9-9.9	9.5	1.9768	-	17.34	-	34.277
10-10.9	10.5	3.1013	-	23.73	-	73.595
11-11.9	11.5	4.6702	-	20.81	-	97.187
12-12.9	12.5	6.7966	-	9.96	-	67.694
13-13.9	13.5	9.6095	-	2.37	-	22.774
14-14	14.5	13.2542	-	0.67	-	8.880
15-15.9	15.5	17.8933	-	0.36	-	6.441
		Total:	100.00	100.00	7.277	330.337

Front + Rear = 337.614

EMPTY VEHICLES

Load Class (Kg)	Mid Value	Equivalent Factor	Percent of Axles Front	Percent of Axles Rear	Standard Equivalent Axles Front	Standard Equivalent Axles Rear
1-1.99	1.5	.0005	-	-	-	-
2-2.99	2.5	.0048	3.30	0.98	0.016	0.005
3-3.99	3.5	.0221	62.70	39.47	1.386	.872
4-4.99	4.5	.0685	31.3	49.02	2.144	3.358
5-5.99	5.5	.1690	2.3	6.43	0.389	1.087
6-6.99	6.5	.3584	0.2	2.14	0.072	0.767
7 & Over	7.5	.6823	0.2		0.136	0.587
		Total:	100.00	100.00	4.143	8.013

Front + Rear = 12.526

Table 16

Vehicle Loads at Quetta Coal Mines and Axle Load Survey

Load Condition	Destination	No. of Obs.	Average Load	Standard Deviation
Loaded	Quetta Region	57	14123	952
	Other Provinces	66	14940	931
	Total:	123	14562	1029
Empty		123	5731	294
Axle Load Survey				
All Coal Trucks		2790	15184	1608
Empty		1643	6177	1219

Table 17

Vehicle Loads at Karachi Octroi Posts and Axle Load Survey

Description	No. of Obs.	Average Load (Kg)	Standard Deviation
Karachi Octroi Posts			
Loaded	621	14,364	2,508
Unladen Weight	621	5,515	589
Axle Load Survey			
Loaded			
All Vehicles	30,112	14,364	2,438
Karachi Hyderabad Super Highway	1,290	14,693	2,289
National Highway	730	14,911	2,179
Empty	1,634	6,177	1,219

Table 18

Previous Survey Results

Survey Description	Load Condition	No. of Obs.	Average Load(tons)	Standard Deviation
Punjab	Loaded	252	14.6	..
	Empty	6	5.5	..
Sind	Loaded	493	13.5	..
	Empty	14	6.0	..
Axle Load Survey	Loaded	30112	14.4	2.438
	Empty	1634	6.2	1.219

Table 19

No. of NLC Vehicles surveyed according to type and load

S.No.	Number of Axles	Number of Vehicles		
		Loaded	Empty	Total
1.	5 Axle	6	2	8
2.	4 Axle	132	26	158
3.	2 Axle	78	9	87
	Total :-	216	37	253

Table 20

Average Axle Loads of NLC Vehicles

Type of Vehicle	Load Condition	Make	No. of obs.	Axle Loads: Front Axle	Second Axle	Third Axle	Fourth Axle	Fifth Axle	Gross Load
5 Axle Tractor Trailer	Loaded	Hino	2	4500	8300	8475	10875	11300	43450
Tanker	"	Hino	4	5175	8462	7813	13200	12600	47250
"	Empty	Hino	2	4275	3900	3550	4225	4000	19900
4 Axle Truck Trailers	Loaded	Mercedes	69	7019	13196	9318	8080	-	37612
"	"	Fiat	30	4593	11432	10103	9585	-	35713
"	"	Hino	9	5033	11578	10917	10778	-	38666
		Total:	108	6179	12571	9669	8723	-	37142
"	Empty	Mercedes	18	4241	4725	2817	2900	-	14688
	"	Fiat	4	3912	3825	2663	2850	-	13250
	"	Hino	4	4100	4475	4225	4350	-	17150
		Total:	26	4169	4548	3010	3116	-	14842
4 Axle Tanker	Loaded	Fiat	24	4579	9263	9040	8970	-	31852
2 Axle Truck	Loaded	Hino	21	5212	10009	-	-	-	15221
	"	Mercedes	6	6842	13075	-	-	-	19917
	"	Saviem	33	4283	9289	-	-	-	13572
	"	Ford	17	4315	9459	-	-	-	13774
	"	Bedford	1	4300	10900	-	-	-	15200
		Total:	78	4737	9832	-	-	-	14569
2 Axle Truck	Empty	Hino	3	3567	2833	-	-	-	6400
	"	Saviem	5	2540	2820	-	-	-	5360
	"	Dodge	1	2350	2400	-	-	-	4750
		Total:	9	2861	2778	-	-	-	5639

Table 21

Equivalent Standard Axles of Multi Axle Vehicles of NLC

Type of Vehicle	Equivalent Standard Axles	Net Load	Standard Axles per ton
5 Axle Hino Truck	5.5		
Tanker	9.2	27.0	.34
4 Axle Mercedes	11.9	23.0	.52
Fiat	7.1	22.5	.32
Hino	8.7	21.5	.40
2 Axle Mercedes	8.8	11.0	.80
Hino	2.6	8.8	.30
Saviem	2.0	8.2	.24

Table 22

AASHTO Traffic Equivalence Factors for Flexible Pavements

Single Axles, p_t = 2.0

Axle Load Kips	Axle Load KN	SN 1	SN 2	SN 3	SN 4	SN 5	SN 6
2	8.9	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
4	17.8	0.002	0.003	0.002	0.002	0.002	0.002
6	26.7	0.01	0.01	0.01	0.01	0.01	0.01
8	35.6	0.03	0.04	0.04	0.03	0.03	0.03
10	44.5	0.08	0.08	0.09	0.08	0.08	0.08
12	53.4	0.16	0.18	0.19	0.18	0.17	0.17
14	62.3	0.32	0.34	0.35	0.35	0.34	0.33
16	71.2	0.59	0.60	0.61	0.61	0.60	0.60
18	80.1	1.00	1.00	1.00	1.00	1.00	1.00
20	89.1	1.61	1.59	1.56	1.55	1.57	1.60
22	97.9	2.49	2.44	2.35	2.31	2.35	2.41
24	106.8	3.71	3.62	3.43	3.33	3.00	3.51
26	115.7	5.36	5.21	4.88	4.68	4.77	4.96
28	124.6	7.54	7.31	6.78	6.42	6.52	6.83
30	133.4	10.38	10.03	9.24	8.65	8.73	9.17
32	142.3	14.00	13.51	12.37	11.46	11.48	12.07
34	151.2	18.55	17.87	16.30	14.97	14.87	15.63
36	160.1	24.20	23.30	21.16	19.28	19.02	19.93
38	169.0	31.14	29.95	27.12	24.55	24.03	25.10
40	177.9	39.57	38.02	34.34	30.92	30.04	31.25

Tandem Axles, p_t = 2.0

Axle Load Kips	Axle Load KN	SN 1	SN 2	SN 3	SN 4	SN 5	SN 6
10	44.5	0.01	0.01	0.01	0.01	0.01	0.01
12	53.4	0.01	0.02	0.02	0.01	0.01	0.01
14	62.3	0.02	0.03	0.03	0.03	0.02	0.02
16	71.2	0.04	0.05	0.05	0.05	0.04	0.04
18	80.1	0.07	0.08	0.08	0.08	0.07	0.07
20	89.0	0.10	0.12	0.12	0.12	0.11	0.10
22	97.9	0.16	0.17	0.18	0.17	0.16	0.16
24	106.8	0.23	0.24	0.26	0.25	0.24	0.23
26	115.7	0.32	0.34	0.36	0.35	0.34	0.33
28	124.6	0.45	0.46	0.49	0.48	0.47	0.46
30	133.4	0.61	0.62	0.65	0.64	0.63	0.62
32	142.3	0.81	0.82	0.84	0.84	0.83	0.82
34	151.2	1.06	1.07	1.08	1.08	1.08	1.07
36	160.1	1.38	1.38	1.38	1.38	1.38	1.38
38	169.0	1.76	1.75	1.73	1.72	1.73	1.74
40	177.9	2.22	2.19	2.15	2.13	2.16	2.18
42	186.8	2.77	2.73	2.64	2.62	2.66	2.70
44	195.7	3.42	3.36	3.23	3.18	3.24	3.31
46	204.6	4.20	4.11	3.92	3.83	3.91	4.02
48	213.5	5.10	4.98	4.72	4.58	4.68	4.83

Source: AASHTO Interim Guide for Design of Pavement Structures, 1972.

ANNEXURES

Axle Load Survey - List of Road Sections and dates of Survey

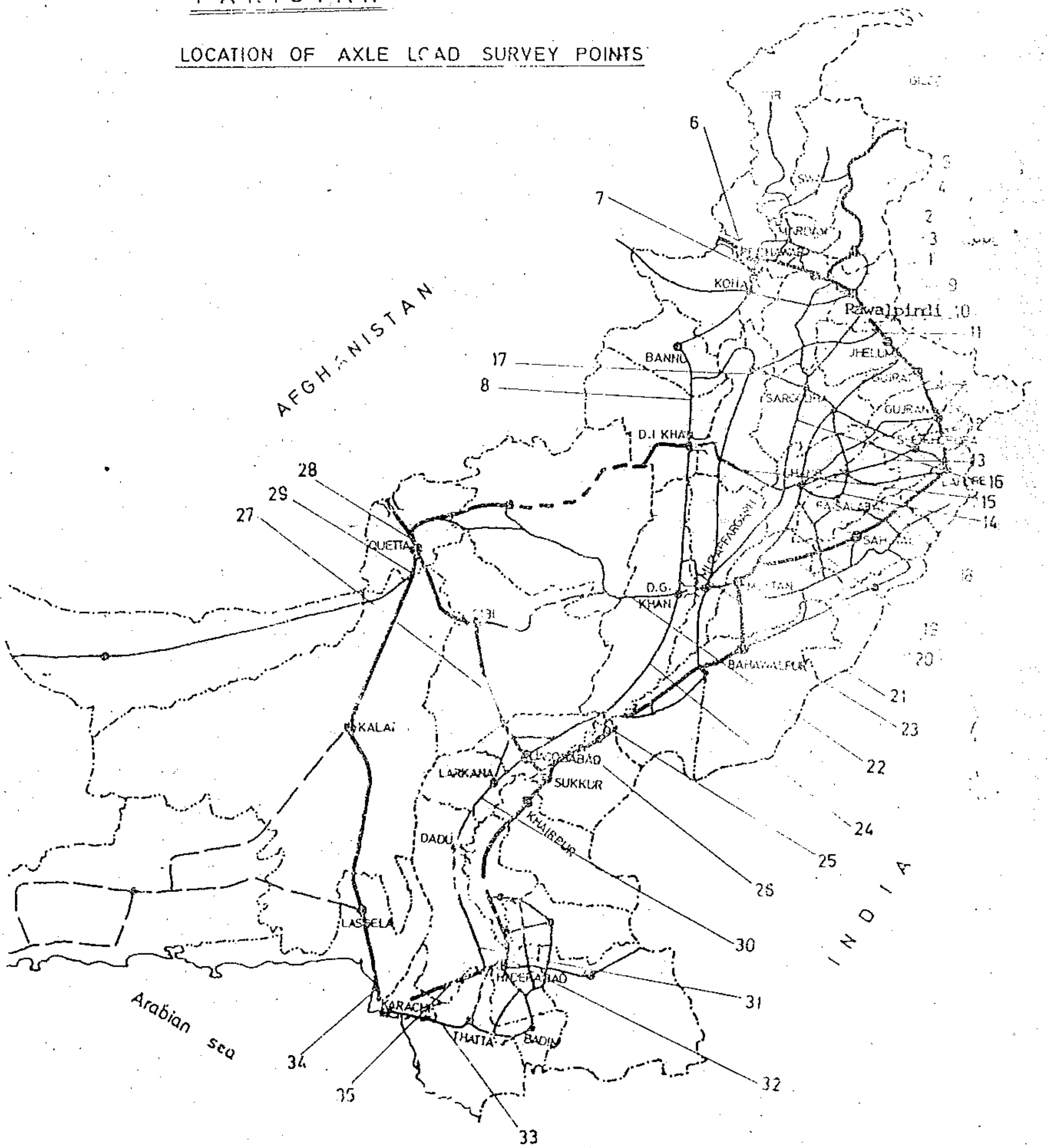
Sl. No.	Name of Road Sections	Ist Round Commencement date	2nd Round Commencement date	3rd Round Commencement date	4th Round Commencement date
1.	Rawalpindi - Murree	2.5.81	8.8.81	12.11.81	6.3.82
2.	Abbottabad-Mansehra	4.5.81	10.8.81	14.11.81	8.3.82
3.	Abbottabad-Havelian	5.5.81	11.8.81	15.11.81	10.3.82
4.	Rawalpindi-Peshawar	6.5.81	13.8.81	17.11.81	13.3.82
5.	Mardan - Dargai	8.5.81	14.8.81	19.11.81	14.3.82
6.	Peshawar-Tourkham	10.5.81	16.8.81	20.11.81	16.3.82
7.	Peshawar-Kohat	11.5.81	18.8.81	22.11.81	17.3.82
8.	Bannu - D.I.Khan	12.5.81	20.8.81	24.11.81	20.3.82
9.	Talagang-Pindigheb	14.5.81	22.8.81	26.11.81	22.3.82
10.	Mandra-Chakwal	16.5.81	23.8.81	27.11.81	24.3.82
11.	Rawalpindi-Jhelum	17.5.81	25.8.81	29.11.81	25.3.82
12.	Lahore-Gujranwala	19.5.81	27.8.81	01.12.81	27.3.82
13.	Sheikhupura-Faisalabad	21.5.81	29.8.81	03.12.81	28.3.82
14.	Faisalabad-Chiniot	23.5.81	30.8.81	05.12.81	30.3.82
15.	Jhang-Bhakar	24.5.81	14.9.81	07.12.81	31.3.82
16.	Sargodha-Jhang	26.5.81	12.9.81	09.12.81	03.4.82
17.	Khushab-Mianwalai	28.5.81	11.9.81	11.12.81	04.4.82
18.	Lahore-Okara	13.6.81	17.9.81	26.12.81	
19.	Multan-Sahiwal	15.6.81	18.9.81	28.12.81	
20.	Jhang-Multan	16.6.81	20.9.81	29.12.81	
21.	D.G.Khan - Kot Adu	17.6.81	21.9.81	31.12.81	
22.	D.G.Khan - Fort Munro	20.6.81	23.9.81	02.01.82	
23.	Multan-Bahawalpur	21.6.81	25.9.81	04.01.82	
24.	Muzaffargarh-Uch	23.6.81	27.9.81	05.01.82	

Sl. No.	Name of Road Sections	1st Round Commencement date	2nd Round Commencement date	3rd Round Commencement date	4th Round Commence-ment date.
25.	Kashmore-Ubaro	25.6.81	29.9.81	7.1.82	
26.	Rohri-Khairpur	27.6.81	14.10.81	9.1.82	
27.	Jaccobabad - Sibi	28.6.81	27.10.81	24.1.82	
28.	Quetta-Chaman	30.6.81	29.10.81	26.1.82	
29.	Quetta-Naushki	1.7.81	31.10.81	27.1.82	
30.	Larkana-Dadu	4.7.81	25.10.81	22.1.82	
31.	Kotri-Dadu	6.7.81	23.10.81	20.1.82	
32.	Hyderabad-Mirpur	7.7.81	10.10.81	11.1.82	
33.	Karachi-Thatta	11.7.81	18.10.81	13.1.82	
34.	Karachi-Gaddani	12.7.81	19.10.81	16.1.82	
35.	Karachi-Hyderabad	13.7.81	21.10.81	18.1.82	

Annexure -II-

PAKISTAN

LOCATION OF AXLE LOAD SURVEY POINTS



ANNEXURE - III

Break downs of Weighing Machine

Machine S.No.	Type of Machine	Date of Break down	Round/Survey Station No.
Ist Machine	MD 500	23.6.81	I/24
2nd Machine	MD 400	13.7.81	I/35
3rd Machine	MD 500	18.10.81	II/28
4th Machine	MD 400	28.12.81	III/19
5th Machine	MD 500	25.3.82	IV/11

Usage of Weighing Machines

Round	Station Nos.	Nos.	Type of Machine	Measurement Scale
I	1-24	2	MD-500 Machine	Lbs
	25-30	1	MD-500 Machine	Lbs
	31-35	2	MD-400	Kg
II	1-28	1	MD-500 and	Lbs
		1	MD-400 Machine	Kg
	29-35	1	MD-400 Machine	Kg
III	1-2	1	MD-400 Machine	Kg
	3-35	2	MD-500 Machine New	Kg
IV	1-11	2	MD-500 Machine New	Kg
	12-17	1	MD-500 Machine New	Kg

ANNEXURE-IV

AXLE LOAD SURVEY

GOVERNMENT OF PAKISTAN
PLANNING AND DEVELOPMENT DIVISION
NATIONAL TRANSPORT RESEARCH CENTRE

1. Form No. 1-5

2. Round / Stn.No. ______ 6-8

AXLE LOAD SURVEY

3 Date - -198 9-12

4. Time ______ 13-16

5. Rgn. No. ______ 17-23

6. Make ______ 24-25

7. Model (Year) 19 ______ 26-27

8. Vehicle Type

Truck	Tanker	Truck Trailer	Tractor Trailer	Other
1	2	3	4	5

28

9. Load Cond.

Fully Loaded	Partly Loaded	Empty
1	2	3

29

UNITS 58

WHEEL WEIGHTS	Lbs 1	Kg 2
	LEFT	RIGHT
Front	59-63	64-68
2nd	69-73	74-78
3rd	6-10	11-15
4th	16-20	21-25
Rear	26-30	31-55

10. Commodity ______ 30-41 ______ 42-44

11. Unit / Qty. ______ 45 ______ 46-49

12. Origin ______ 50-52

13. Destination ______ 53-55

14. Enumerator Name ______ 56-57

ANNEXURE - V (i)

AXLE LOAD SURVEY

Districts Codes

Col: 50-52 and 54

1. N. W. F. P.

(110) Peshawar Division

111. Mardan District
112. Peshawar District
113. Kohat District

(120) Hazara Division

121. Abbottabad District
122. Mansehra District
123. Kohistan District

(130) D.I. Khan Division

131. D.I. Khan District
132. Bannu District

(140) Malakand Division

141. Dir District
142. Chitral District
143. Swat District
144. Malakand District

2. PUNJAB

(210) Rawalpindi Division

211. Attock District
212. Rawalpindi District
213. Jhelum District
214. Gujrat District

(220) Sargodha Division

221. Sargodha District
222. Mianwali District
223. Faisalabad District
224. Jhang District

(230) Lahore Division

231. Lahore District
232. Gujranwala District
233. Sheikhupura District
234. Sialkot District
235. Kasur District

(240) Multan Division

241. D.G. Khan District
242. Muzaffargarh District
243. Multan District
244. Sahiwal District
245. Vehari District

(250) Bahawalpur Division

251. Bahawalpur District
252. Bahawalnagar District
253. Rahimyar Khan District

3. SIND

(310) Khairpur Division

311. Jacobabad District
312. Sukkur District
313. Larkana District
314. Nawabshah District
315. Khairpur District
316. Shikarpur District

(320) Hyderabad Division

321. Hyderabad District
322. Dadu District
323. Tharparkar District
324. Sanghar District
325. Thatta District
326. Badin District

(330) Karachi Division

331. Karachi District

4. BALUCHISTAN

(410) Quetta Division

411. Quetta District
412. Pishin District
413. Loralai District
414. Zhob District
415. Chagai District

(420) Kalat Division

421. Kalat District
422. Kharan District
423. Lasbela District

(430) Sibi Division

431. Naseerabad District
432. Sibi District
433. Kachhi District
434. Koholu Agency
435. Khuzdar District

(440) Mekran Division

441. Panjgur District
442. Turbat District
443. Gowadar District

(500) Northern Areas

501. Gilgit District
502. Skardu District
503. Diamer District

(600) Azad Kashmir

601. Muzaffarabad District
602. Mirpur District
603. Rawalakot District
604. Kotli District

(700) Federally Administered Tribal Areas/Agencies

712. Khyber Agency
713. Khurrum Agency
731. South Waziristan Agency
732. North Waziristan Agency
744. Bajaur Agency and Mohmand Agency

(800) Other Countries

801. Afghistan
802. India
803. Iran

AXLE LOAD SURVEY

COMMODITY CODES COL. 42-44

CODE	DESCRIPTION	CODE	DESCRIPTION
	100 AGRICULTURE		
110	Wheat	120	Paddy and Rice
130	Maize	140	Other Grains and Pulses
150	Sugar Cane	160	Cotton
170	Jute	180	Tobacco
185	Oil Seeds	190	Grass, Fodder, Bhoosa, Moonj, Dry Spores, Straw
195	Other Agricultural Products		
	200 FOOD		
210	Flour and its preparations	220	Vegetables excluding potatoes and onion
230	Potatoes and onion	240	Fruit
250	Industrial raw food (oils)	260	Vegetable Ghee and refined edible oil's(processed)
270	Sugar refined	280	Jaggery (Gur,Shakar,Desikhand)
290	Others		
	300 ANIMAL AND ANIMAL PRODUCTS		
310	Animals	320	Meats, eggs and dairy products, fish
330	Hides and Skins	340	Whool raw
390	Other animal product		
	400 RAW MATERIAL		
410	Timber, logs, Bamboos	420	Pulp,waste paper and molasses waste cotton
430	Other ores except metallic	490	Other raw material
	500 BULK MANUFACTURES		
510	Cement	520	Fertilizer
530	Medicine, and Drugs	540	Chemicals
550	Tea, Cofee, etc.	560	Beverage(filled or unfilled)
570	Animal food oilcake	580	Dried Milk
590	Other Bulk goods		

ANNEXURE- V(ii)

600 BASIC MANUFACTURES

610	Textile Fibre	620	Textile Manufactures
630	Jute Manufactures: bags, carpets	640	Leather and Leather products
650	Wood manufactures, fixture paints and others	660	Rubber manufactures
670	Iron and Steel:- Billets,pipes, Tubings, Girders, Pigiro	680	Iron and Steel finished products and other metal products
685	Cement manufactures, Concrete, Slabs, Sleepers, Pipes.	690	Bricks
695	Others		

700 MISCELLANEOUS MANUFACTURES

710	Machinery: Other than electrical	720	Machinery electrical (non-domestic)
730	Domestic electrical appliance, Ratio, T.Vs etc.	735	Paper, Gatta Books and other paper products
740	Cycles and Autooycles	750	Tractor,Cars, Auto-rickshaw pickup, wagons and other vehicles,(Jeep, Trolly and other vehicles)
755	Spare Parts	760	Cigarettes
770	General Merchandize	775	Soap, detergent
777	Sports goods	780	Pottery and Mouldings,fire bricks(plastic,earthen,china clay,glass were products)
785	Ice	790	Cans, Barrels, drums, tins, jery canes etc.
795	Others		

800 MINING AND QUARRYING

810	Ballast, Gravel, Stone	820	Sand and Sand Silica
830	Lime Stone and Powder	840	Marble and its Granuals
850	Gyspsum	860	Salt: Rock
870	China Clay	880	Earthen C'ay
890	Other Metallic Ores	895	Other Mining and Quarrying

ANNEXURE - V(ii)

900 FUEL, LUBRICANTS (MINERALS)

910	Coal, Coke, Briquettee	920	Bitumen, Pitchtar, Asphalt, Charcoal
930	Petrol	940	Diesel
950	Kerosine Oil	960	Furnance Oil
970	Lubricants	980	Gas, Products, Cylinders
990	Fire Wood	995	Miscellaneous

A00 MISCELLANEOUS GOODS NOT CLASSIFIED

A10	Mails, Postal Package, etc	A20	(Household effects)
A30	Official stores	A40	War firearm, Ammunition
A50	Dead Body	A60	Military supply
A99	Unspecified goods		

OTHER CODES

Make	Col. 24-25
Bedford	01
Fiat	02
Ford	03
Hino	04
Isuzu	05
International	06
Ley Land	07
Mercedes Benz	08
Nissan	09
Toyota	10
MAN	11
BMC	12
Dodge	13
Mazda	14
Cheyer or Late	15
Others	99
Non-Specified	00

ANNEXURE- V(iv)

Weight Unit of Commodity (Col. 45)

Lbs	1
Kgs	2
Mds	3
Tons	4
Cub.Ft	5
Cub. Metre	6
Litre	7
Gallon	8
Numbers.	9

Weighing Machine Scale Units

Lbs	1
Kg	2
Left wheel Kg & right wheel Lbs	3
Left wheel Lbs & right wheel Kg	4