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"ORIGIN & DESTINATION STUDY OF TRAFFIC OF GREATER DELHI"

By

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CONTENTS

SYNOPSIS

Origin and destination of vehicle provides necessary data required for planning, design and location of routes to serve best the demand of traffic flow. This Paper describes the results of an origin-destination survey of Delhi undertaken jointly by the Central Road Research Institute and the Town Planning Organisation, Delhi.

For purpose of this survey, the urban territory of Delhi has been divided into 48 zones based on natural and artificial boundaries and roads serving particular areas. Survey stations selected on the loop lines, indicating inner and outer cordon lines, are 31 in number. On these survey stations, vehicles were stopped on sampling basis and interviewed by the roadside, asking them their points of origin, destination, purpose, income and frequency of trips.

The data thus collected has been mechanically analysed. These basic tables have been submitted to rigorous analysis through tables and maps. Origin and destination of each trip has been established separately for motors-vehicle, animal-driven vehicles and cyclists. Correlation has been studied between (i) mode of conveyance and occupation, (ii) purpose

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of the trip and mode of conveyance, (iii) mode of conveyance and income group, and (iv) distance covered and mode of conveyance.

The utillty of this information in relieving congestion on roads has been discussed in detail.

1. INTRODUCTION

1.1. Delhi, the oldest metropolis of the world, has fastly developed in recent years. The population of Delhi in 1921 was 304,420 * which gradually rose to 695,686 in 1941. In 1947, partition of India brought an influx of 400,000 displaced persons from West Pakistan. All round the city several colonies were opened to house the refugees.

1.2. In recent years, new hotels, Government blocks, private houses and buildings of all kinds have sprung up. The popupulation of Delhi in 1951 was 1,437,134*. The present estimated population of Delhi is about 2.2 millions.

1.3. Subsequent to the implementation of 1st and 2nd Five-year Plans, the transport facilities in Delhi have greatly

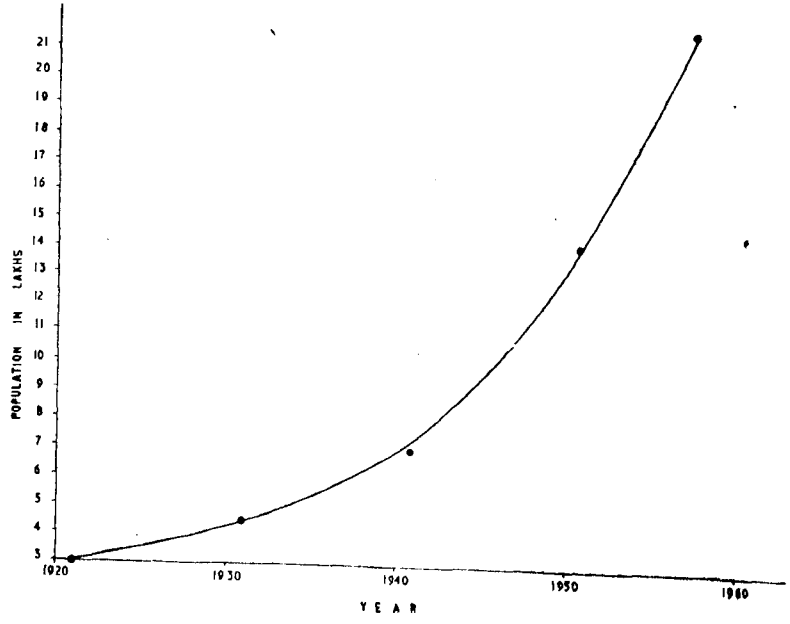

Fig. 1. **Showing the population increase in Delhi since 1921**

* Interim General Plan for Greater Delhi-1956.

increased to meet the ever increasing demand. The number of vehicles on roads in the metropolitan city was 12,455 at the beginning of the first Five-year Plan, rising to about 16,500 at the beginning of the 2nd Five-year Plan, excluding the number of cyclists and animal driven vehicles. At present there are nearly 30,000 motor vehicles, 300,000 cyclists and about 10,000 slow moving vehicles in Delhi.

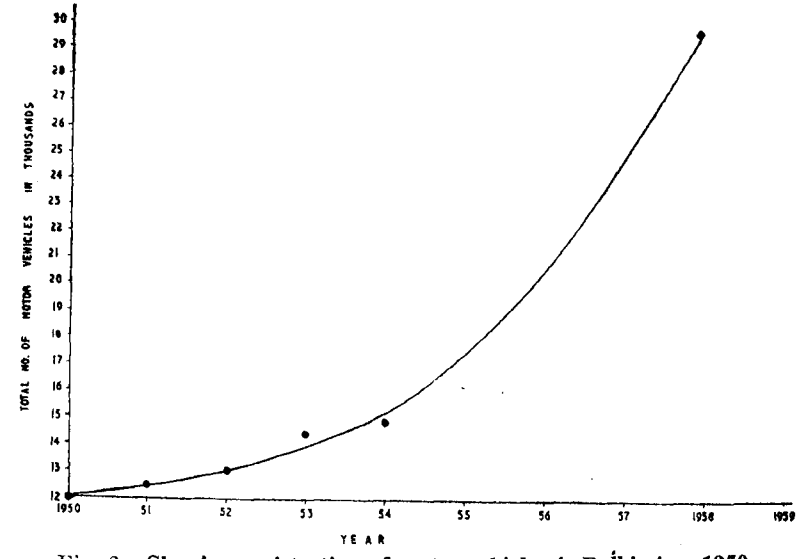

Fig. 2. **Showing registration of motor vehicles in Delhi since 1950.**

2. THE PROBLEM

2.1. The fast development of Delhi in an unplanned manner has created a number of traffic problems. Today we find that the average speed on most of the routes is very low. The roads are overcrowded and the result is the high rate of accidents. There were about 2,840* road accidents in Delhi in the year 1958, i.e., about 8 road accidents per day. As compared to this, in 1957 there were 1,800 road accidents, i.e., 5 road accidents per day.

2.2. In order to solve the traffic problem in a scientific manner, it is essential to have an origin - destination @

* Road Accident Study—C.R.R.I.

@ Origin - The starting point of a trip is that trip's origin.
Destination - The end point of a trip is that trip's destination.

survey of different types of vehicles in Delhi. The survey will give the travel patterns with respect to origin and destination of each trip. A trip may be considered as "one way travel from an origin to a destination for a primary purpose". The destination of one trip becomes the origin of the next trip. The data from such a survey will provide a basis for determining the demand, location, type and magnitude of new facilities and help in rating priority for improvement of the existing roads. Keeping this in view, an origin - destination survey of Delhi was undertaken jointly by the Central Road Research Institute and the Town Planning Organisation in October 1957.

3. PROCEDURE

3.1. For the purpose of this study, the area of Greater Delhi was divided into 48 zones, based on natural and artificial boundaries and roads serving particular areas. The zones were further grouped into three principal areas of traffic origin and destination based on the land use. These are:

(i) The central core area or the inner cordon area, comprising government offices and business area,

(ii) The surrounding urban development of residential area or the mid-cordon area, and

(iii) The less populous adjacent rural lands, called in the Paper as the outer cordon area.

Fig. 3 in. Plate I shows the map giving the 48 zones, the principal areas and cordon lines.

3 2. On the cordon lines, survey stations for roadside interviews of traffic were selected so as to cover the major routes both on the inner cordon as well as on the outer cordon lines. In all there, were 31 survey stations, 22 on the inner cordon and 9 on the outer cordon line. A list of the survey stations is given in Appendix II.

3.3. Traffic was interviewed on outer survey stations for 24 hours and from 6 A.M. to 10 P.M. on the inner cordon survey stations.

3.4. The vehicles were stopped on sampling basis with the help of traffic police and asked the following simple questions:

(i) Origin of the trip.

(ii) Destination of the trip.

(iii) Income of the person undertaking the trip.

(iv) Purpose of the trip.

(v) Occupation of the person undertaking the trip, and

(vi) Frequency of trips.

Interview time was never more than 2 minutes. Separate questionnaires were prepared for fast moving vehicles, slow moving vehicles and cycles, for recording data as a result of interviews. In addition, continuous volume counts of traffic were also taken on each of the survey stations in a separate proforma prepared for this purpose. A copy of each of these proformas is given in Appendix I.

3.5. For survey work, over 200 interviewers and enumerators were employed and given a thorough training before they were detailed on duty. Proper arrangements of chairs, tables, transport and gas lamps at night were made for efficient functioning.

4. THE SAMPLE

4.1. As it was not possible to stop every vehicle because of heavy flow, random sampling technique was adopted.

4.2. A broad classification of all the vehicles was made into three categories as (i) fast moving vehicles, (ii) slow moving vehicles, and (iii) cycles. The fast moving vehicles include privatecars, motor cycles, taxis, trucks and motor cycle rickshaws. The slow moving vehicles covered tongas, bullock carts, rehras and cycle rickshaws. For the purpose of interview, every 10th fast moving and slow moving vehicle was stopped. In the case of bicycles, every 20th cyclist was interviewed, i.e., 10 per cent sample for slow and fast vehicles and 5 per cent sample for cycles.

5. CODING

5.1. The analysis of about 30,000 interviews obtained from this survey was carried out with the help of Hollerith Punch cards. For this purpose, the whole of the data was codified giving numerical code to each information. Fresh secondary sheets were manually prepared in a tabular form to record the coded information and get it punched on punch cards. Following is the brief description of the coding scheme.

5.2. Time has been recorded on the field sheets in one quarter hour intervals and is accordingly coded in quarter hour frequencies, 1 to 96, starting at 12 midnight under col. 1 and

2 of the punch card. For working purposes, these time intervals have been further condensed into four "time periods" and coded for this column as follows:

Morning peak period	8 to 9.45 A.M.	1.
Evening peak period	5 to 6.45 P.M.	2.
Night hours	9 P.M. to 5.45 A.M.	3.
Off peak hours	All others.	4.

5.3. Inbound direction has been coded by 1 and outbound direction by 2 under col. 4 of the punch card.

5.4. Outer cordon stations, No. 1 to 9, have been coded as such, whereas the inner stations marked on the map by letters 'a' to 'v' have been coded by two digits running from 10 to 31.

5.5. Mode or type of vehicles was coded and punched under column 9 of the punch card. Although field sheets did not provide a separate column for cycle rickshaws, the interviewers made a separate note of each cycle rickshaw interviewed and, therefore it has been allotted a separate code—code 8 under column 9.

For most of the working purposes, these vehicle types were grouped under three broad headings as (i) motor traffic (fast moving), (ii) animal drawn (slow moving), and (iii) cycles, and are coded under column 10 of the punch card as follows:

Fast moving vehicles	1.
Slow moving vehicles	2.
Cycles	3.

5.6. All origin zones are classified into 48 areas as shown in Fig. 3 in Plate I. (Also, see Appendix IV). Zone coding has a numerical designation from 1 to 48, but for simplifying the analysis work, certain zones were grouped (see Appendix IIIA) keeping in view the road system and other topographical features.

5.7. Same groups and codes were used for destination zones also.

5.8. In cases where interviews were recorded with several persons in a vehicle while coding information about purpose of the trip, income and occupation of the person undertaking the trip and frequency of trip, only one interview was coded. A copy of the coding scheme along with the code sheet has been given in Appendix III B.

6. ANALYSIS and DISCUSSION

6.1. As one punch card represents one interview, 30,000 such cards were punched to accommodate the full-information. Fig. 4 in Plate I shows the design of the card. The Hollerith tabulations were obtained from these punch cards mainly to establish the following:

(i) To establish the spot volumes at each of the inner survey stations, for each type of vehicle.

(ii) To establish relationship between (I) purpose of trip and mode of conveyance; (II) purpose of trip and period of the day; (III) income and mode of conveyance; (IV) occupation and mode of conveyance; and (V) mode of conveyance and length of trip.

(iii) To study thoroughly the origin - destination data with a view to relieve congestion in the central area.

6.2. The basic Hollerith tables were transformed into rectangular origin-destination tables for preparing the desire line * charts. A collection of trips with common origin and destination has been represented by a band of desire lines which give an indication of the directions in which the traffic wishes to travel.

6.3. The desire line maps are presented as Figs. 5, 6 and 7 (Plates I and II) separately for fast, slow and cyclists' traffic respectively. These desire line charts indicate the general daily pattern of travel of different modes of vehicles in Delhi and New Delhi, not as it actually moves but as it would have moved, had there been no physical obstructions in straight line path. A desire line map for the traffic crossing Jamuna River has also been developed as shown in Fig. 8 (Plate II).

6.4. In order to interpret the desire line maps, actual travel line maps have also been prepared. For this purpose existing major routes of traffic flow were marked on the city map of Greater Delhi and trips have been put on the existing probable shortest routes in the travel line maps shown in Figs. 9 and 10 in Plate III separately for fast and cyclists' traffic.

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*A desire line is a straight line joining the points of origin and destination indicating the line of least distance of travel had there been no physical barriers.

In the above maps, combined morning and evening peak hours' traffic is also distinctly shown in the centre of the desire lines.

6.5. Pie-charts, shown in Figs 11 to 18 in Plate IV, represent inbound and outbound traffic for each zone separately for different types of traffic.

In traffic analysis these pie-charts are generally drawn on the city map with a view to show the relative magnitude of traffic problem in each locality. In the present case, it was not possible to draw these pie-charts on the city map of Delhi because of the following reasons:

(i) The mixed fast, slow and cycle traffic required a separate 'pie' for different types of vehicles for each zone in order to be helpful in traffic analysis. This meant prawing 3 'pies' in each zone which was not possible to adjust in most of the smaller zones in the inner cordon area.

(ii) The variation between zone to zone traffic was quite large and thus these pies could not be drawn to any convenient scale within the zone size.

(iii) A rigorous traffic analysis necessitated information on the distribution of inbound and outbound traffic of a particular zone with respect to other zones. This demands drawing of 3 'pies' for inbound as well as for outbound traffic in each zone. Thus to accommodate eight pies in each zone was not at all possible.

For these reasons, therefore, pie-charts have been prepared on separate papers. The bigger circle in every case has been divided into 3 sectors according to the percentages of fast, slow and cyclists' traffic. The smaller circles show the contribution of the various zones towards the inbound traffic and in the case of outbound traffic these show the distribution of outgoing traffic to other zones.

6.6. Tables 1 shows the composition of fast, slow and cycle traffic for all group survey stations (Appendix III, coding scheme during different periods of the day.

Note:—Travel line map for slow moving vehicles was not prepared due to their limited field of operation. It can be seen from the desire line map for slow moving vehicles that a majority of them operate between certain zones of Old Delhi only.

TABLE 1

Traffic volumes

Group survey stations	Fast moving vehicles							Slow moving vehicles						
	Morning peak period 8 to 9.45A.M.	Evening peak period 5 to 6.45P.M.	Night hours 9 P.M. to 5.45 A.M.	Off peak hours. All others	Total	Percentage of F. M. V.		Morning peak period 8 to 9.45A.M.	Evening peak period 5 to 6.45P.M.	Night hours 9P.M. to 5.45 A.M.	Off peak hours. All others	Total	Percentage of S.M.V.	
1	2													
19	686	557	460	4,589	6,292	17.42		1,524	1,510	1,376	8,361	12,771	35.37	
20	1,560	1,703	613	9,410	13,286	45.02		85	147	—	1,308	1,540	5.22	
21	2,383	3,520	1,770	12,994	20,667	50.09		171	229	354	1,073	1,827	4.43	
22	2,101	2,030	821	8,519	13,471	47.14		121	197	28	399	745	2.61	
23	1,046	1,054	283	3,697	6,080	37.29		96	55	53	271	475	2.92	
31	665	602	—	1,888	3,155	37.61		24	—	—	75	99	1.18	
40	1,889	2,065	2,046	9,455	15,455	13.64		2,487	2,659	2,242	14,820	22,208	19.61	
41	4,572	5,012	1,786	18,460	29,830	27.99		105	215	53	762	1,135	1.07	
42	5,163	4,690	2,739	18,520	31,562	26.84		881	484	882	3,828	6,075	5.17	

(*Table 1 contd.*)

(Table 1 contd.)

Group survey stations	CYCLES: Morning peak period 8 to 9.45 A.M.	Evening peak period 5 to 6.45 P.M.	Night hours 9 P.M. to 5.45 A.M.	Off peak hours. All others	Total	Percentage of cycles	Total frequency group survey stationwise
19	2,191	3,057	877	10,920	17,045	47.21	36,108
20	3,314	2,516	206	8,651	14,687	49.76	29,513
21	3,237	4,131	787	10,635	18,760	45.48	41,254
22	2,175	4,575	341	7,270	14,361	50.25	28,577
23	2,139	2,220	516	4,873	9,748	59.79	16,303
31	1,409	827	25	2,873	5,134	61.21	8,388
40	14,096	14,674	5,390	41,464	75,624	66.75	1,13,287
41	17,964	21,425	2,400	33,805	75,594	70.94	1,06,559
42	18,513	20,428	2,641	38,352	79,934	67.99	1,17,571

6.7. Mode of Transport versus Trips

Table 2 classifies trips according to the mode of transport used. Goods are transported by trucks, bullock carts and rehras. Hand thellas are relatively less utilized due to their limited field of operation. Amongst the private vehicles, cycle is the predominant mode of conveyance. About 88 per cent of the trips made by private vehicles are by cycles. Private cars make 9 per cent of the trips. Rest of the trips are by motor-cycles. Taxis, motor-cycle rickshaws and tongas are competing each other among the hire vehicle trips. Tonga trips are mostly in Old Delhi.

TABLE 2

Daily trips made by different forms of transport

1			2			3		
Goods vehicles	No. of trips	Per cent	Private vehicles	Total	Per cent	Hire vehicles	Total	Per cent
Truck	10,720	43.30	Private car	39,630	9.01	Motor cycle-rickshaw	20,400	36.54
Bullock-cart and rehra	10,600	42.81	Motor cycle	13,750	3.13	Taxi	14,790	26.49
Hand thella	3,440	13.89	Cycle	3,86,460	87.86	Tonga	17,650	31.61
						Cycle rickshaw	2,990	5.36
Total	24,760	100.00	Total	4,39,840	100.00	Total	55,830	100.00

This Table, while presenting the use of different types of vehicles in Delhi, clearly points out that cycle trips are the maximum. In formulating any safety measures it is thus essential that the needs of cycle traffic should be given the highest priority. It may be pointed out that recent study of road accidents in Delhi has shown that cyclists are involved in most of the road accidents.

6.8. Mode of Conveyance versus Distance

Table 3 has been prepared with a view to study the average distance per trip performed by different types of passenger transport vehicles in Delhi.

TABLE 3

Percentage of trips classified by distance and mode of conveyance

Length of trip	Mode of conveyance			
	Cycle	Private car	Motor cycle rickshaw	Taxi
Up to 1 mile	0.49	0.21	0.36	0.29
1-2 ,,	5.82	8.19	7.74	7.24
2-3 ,,	18.81	19.13	26.79	28.42
3-4 ,,	23.17	28.09	25.86	25.31
4-5 ,,	14.14	13.29	16.46	16.49
5-6 ,,	9.84	8.44	6.18	6.07
6-7 ,,	8.40	9.65	6.39	6.65
7-8 ,,	8.39	5.31	4.58	4.19
8-9 ,,	4.71	2.95	1.97	1.52
9-10 ,,	3.62	2.20	2.54	2.10
More than 10 miles	2.61	2.54	1.13	1.72
Total	100.00	100.00	100.00	100.00

The 'modal' or the most frequent distance for a cycle trip is 3.5 miles, indicating that upto this distance, cyclists find convenient to travel. The Table, however, shows that more than 50 per cent of the cyclists are forced to cover a distance more than 4 miles and upto 10 miles. This is perhaps due to high transport charges and poor bus frequency. In case of motor vehicles, i.e., private cars, motor cycle rickshaws and taxis, the average trip is of a distance of 4 miles.

As the average travel distance per trip in case of cycle and motor vehicle is the same, i.e., about 4 miles, it may be stated that the residential areas and working centres of persons using these types of transport are on an average at the same distance apart.

6.9. Occupations of Persons and Frequency of Trips

Table 4 has been prepared to study the distribution of trips performed by persons engaged in different vocations. Occupations have been classified by major industry-wise, such as agriculture, mining and quarrying, manufacturing, construction, electricity, trade & commerce, transport, services, government, etc.

TABLE 4

Percentage of trips analysed by occupation

Occupation	Percentage
Agriculture	1.18
Mining & quarrying	0.62
Manufacturing - foodstuffs and textiles	2.79
Other manufacturing	3.41
Construction	5.63
Electricity (gas, water, etc.)	3.27
Trade & commerce	15.43
Transport, etc.	8.44
Service - Government	31.88
Others	27.35
Total	100.00 (See Table 5 and Table 2-total of col. 2 and 3.)

The Table shows that the maximum number of trips, i.e., about 32 per cent, are made by persons employed in Government services. This confirms that Delhi is mostly inhabited by people in Government services. About 15 per cent of the trips are made by persons in trade and commerce, indicating that Delhi is also developing now as a commercial city. Persons serving transport industry made about 8 per cent of the total trips as compared to 6 per cent of the trips performed by people engaged in construction work. Very few trips are undertaken for agriculture and mining and quarrying.

6.10. Occupation versus Mode of Conveyance

The previous Table has shown that nearly 32 per cent of the trips are performed by Government servants. Table 5 now provides the details of these trips as per mode of conveyance.

TABLE 5

Percentage of trips classified by occupation and mode of conveyance

Occupation	Mode of conveyance							
	Private car	Motor cycle rickshaw	Taxi	Motor cycle	Tonga	Cycle rickshaw	Cycle	Total
Agriculture	6.73	2.48	3.34	1.08	6.84	0.75	78.78	100
Mining & quarrying	18.31	1.65	1.34	5.25	1.95	0.21	71.29	100
Manufacturing-Foodstuffs & textile	8.16	3.77	2.86	3.73	3.31	0.27	77.90	100
Other manufacturing	13.12	5.84	3.32	3.53	2.95	0.52	70.72	100
Construction	7.12	1.90	1.70	3.65	1.82	0.25	83.56	100
Electricity (gas, water, etc.)	5.62	1.46	1.07	3.22	1.44	0.06	87.13	100
Trade & commerce	15.84	5.83	3.51	5.07	7.15	1.03	61.57	100
Transport etc.	7.90	11.08	14.44	2.70	10.35	2.79	50.74	100
Service—Government	29.67	10.38	8.37	9.67	7.35	1.60	32.96	100
Others	8.62	4.19	2.50	2.77	4.38	0.84	76.70	100

The Table shows that cycle is the chief mode of conveyance in almost all the cases. Private cars are more used by persons employed in Government services followed closely by people engaged in mining and quarrying and trade & commerce together. Tonga trips which are mostly in Old Delhi and its nearabout, as pointed out earlier, are made by Government servants and by people engaged in trade and commerce.

6.11. Purpose of Trip

Table 6 gives the distribution of trips according to the purpose for which they were undertaken. A broad classification of purpose has been made as work, shopping, training, recreation, health, etc.

TABLE 6

Percentage of trips classified by purpose

Purpose	Per cent
Work	76.86
Shopping - wholesale	3.29
Shopping - retail	2.30
Training	3.59
Recreation	2.93
Health	1.11
Others	9.92
Total	100.00

It is seen that 77 per cent of the total trips are made by persons for work. About 6 per cent of the trips are made for shopping purposes whereas about 3 per cent for recreation and 1 per cent for health purposes. The Table further shows that about 85 per cent of the trips performed have inelastic demand for making the trips. These trips include purposes such as work, wholesale shopping, training and health. The remaining trips are for purposes which have elastic demand.

6.12. Purpose of Trip and Period of the Day

Table 7 gives the distribution of the trips over different periods during which they were undertaken. About 30 per cent of the trips with elastic demand are made during the morning and evening peak hours.

TABLE 7

Percentage of trips classified by purpose and periods of the day

Period	Purpose						
	Work (76.86)	Wholesale (3.29)	Retail (2.30)	Training (3.59)	Recreation (2.93)	Health (1.11)	Other (9.92) = 100 percent
1. 8 to 9.45 A.M.	20.88	16.91	11.68	19.91	8.18	14.94	11.66
2. 5 to 6.45 P.M.	21.54	14.57	16.63	14.50	21.36	26.57	25.67
3. 9 P.M. to 5.45 A.M.	5.41	3.21	5.59	4.02	10.35	7.76	6.51
4. Other hours	52.17	65.31	66.10	61.57	60.11	50.73	56.16
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

As pointed out in reference to earlier Tables, the majority of the trips in Delhi are undertaken for work. Table 7 shows that 42 per cent of the work trips are performed during morning and evening peak hours covering 3½ hours of the day. 5 per cent of the work trips are made during night hours and the remaining are distributed over other hours. It is, in fact, these work-trips which create heavy rush during peak hours. If the demand for these work trips could be staggered, it will be very helpful in relieving congestion during these hours.

During off peak hours there are relatively more number of shopping trips than other periods of the day. Retail shopping is mostly done during the evening hours.

Recreation trips are mostly performed during evening hours. Next to work, the night trips are performed mostly for recreation purposes. Trips performed for health purposes are evenly distributed on peak and non-peak hours.

6.13. Purpose and Mode of Conveyance

Table 8 has been prepared with a view to study the relationship between mode of conveyance and purpose of the trips. Table 9 further gives classification of the trips by different conveyances according to purpose.

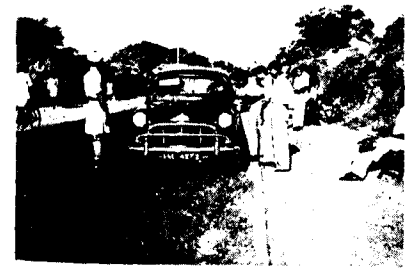

Photo 1.

Shows a motorist being interviewed

Photo 2.

Shows interviewers recording an interview with the passenger in the motor-cycle rickshaw

Photo 3.

Shows a motor cyclist being interviewed

Photo 4.

A cyclist is being interviewed on the roadside

Photo 5.

Traffic congestion in Subzi-mandi area is mostly due to the big volume of slow moving vehicles which occupy most of the carriage-way on a broad road

Photo 6.

Shows a heavy cycle traffic along with fast traffic on Shanker Road

Photo 7.

Rush of cycle traffic on Punch-kuin road during peak period

Photo 8.

Kerb parking of motor vehicles on both sides of the road takes away much of the effective road width

TABLE 8

Percentage of trips classified by purpose and mode of conveyance

Purpose	Conveyance							
	Private car	Motor cycle rick-shaw	Taxi	Motor cycle	Tonga	Cycle rickshaw	Cycle	Total
Work	7.29	3.09	2.40	2.53	2.96	0.66	80.98	100
Shopping wholesale	9.74	4.22	3.39	2.74	4.74	0.42	73.75	100
Shopping retail	4.62	2.08	1.15	1.73	3.74	0.37	86.31	100
Training	3.97	2.21	3.05	1.66	1.32	0.37	87.42	100
Recreation	21.16	7.39	4.11	4.96	4.28	0.28	57.82	100
Health	10.79	3.65	3.79	1.25	2.86	—	77.66	100
Others	10.19	3.91	3.20	2.95	1.69	0.33	77.73	100

TABLE 9

Percentage of trips classified by mode of conveyance and purpose

Mode of conveyance	Purpose							
	Work	Shopping wholesale	Shopping retail	Training	Recreation	Health	Others	Total
Private car	70.71	4.05	1.34	1.80	7.83	1.51	12.76	100
Motor cycle rickshaw	72.24	4.24	1.46	2.42	6.60	1.23	11.81	100
Taxi	72.47	4.24	1.01	4.14	4.56	1.58	12.00	100
Motor cycle	74.28	4.70	1.52	2.27	5.54	0.52	11.17	100
Tonga	78.76	5.40	2.98	1.64	4.34	1.09	5.79	100
Cycle rickshaw	86.89	2.36	1.45	2.26	1.40	...	5.64	100
Cycle	77.75	3.04	2.48	3.92	2.12	1.07	9.62	100

Table 8 shows that cycle remains the predominant mode of conveyance for all purposes. Private car is utilized more for recreation and health purposes. The hire vehicles perform almost the same number of trips as private vehicles for almost all purposes. But this Table fails to provide the distribution of cycle trips, for instance, over different purposes. Table 9 shows that among cycle trips about 78 per cent are performed for work purposes. Similarly, in the case of private car trips, about 71 per cent are performed for work purposes. The Table further shows that more than 2/3rd of the total trips in Delhi performed by different types of vehicles are for work purposes. Marketing trips are performed mostly on cycles, private cars and tongas.

6.14. Income and Mode of Conveyance

Table 10 classifies trips according to income of the person making the trip and the mode of conveyance employed.

TABLE 10

Percentage of trips classified by income and mode of conveyance

Income group	Private car	Motor cycle rickshaw	Taxi	Motor cycle	Tonga	Cycle rickshaw	Cycle	Total
Less than Rs 75	—	—	—	—	3.76	1.44	94.80	100
Rs 75 — 99	—	—	—	—	2.45	0.61	96.94	100
Rs 100 — 149	—	—	—	—	3.22	0.55	96.23	100
Rs 150 — 249	—	5.38	—	4.99	4.09	0.41	85.13	100
Rs 250 — 499	—	9.42	—	10.89	3.32	0.26	76.01	100
Rs 500 — 749	30.43	11.99	9.54	13.28	2.34	0.16	32.26	100
Rs 750 — 999	54.24	7.98	7.21	11.19	1.15	0.21	18.02	100
Rs 1,000 — 1,499	86.76	6.02	9.24	7.07	1.57	0.02	7.32	100
Rs 1500 — and more	74.92	5.13	7.23	4.55	1.60	0.21	6.36	100

From the Table, there seem three broad classifications of persons according to their income as far as their mode of conveyance is concerned, viz., (a) persons having income upto Rs 150, (b) with income from Rs 150 to Rs 500, and (c) persons with income more than Rs 500 p.m.

The chief mode of conveyance of persons falling in category (a) is cycle. About 96 per cent of the trips are made by cycle. Rest of the trips are mostly made by tongas.

Persons falling in 2nd category also use motor vehicles like motor-cycle and motor cycle rickshaw as their mode of conveyance whereas usage of slow moving vehicles is comparatively less. But in this case also, the chief mode of conveyance is cycle. Nearly 80 per cent of the trips are made by cycle.

Utility of motor vehicles is more for persons with income more than rupees five hundred per month. Private car is the predominant mode of conveyance of this class of people. In case of persons with income ranging from Rs 750 to Rs 999, nearly 50 per cent of the trips are performed on private cars and with income between Rs 1,000 to Rs 1,500 it rises to about 70 per cent.

7. CONCLUSIONS AND RECOMMENDATIONS*

7.1. The desire line map for cycles, Fig. 7 (Plate II), shows that there is a maximum demand of a straight road between zone 4 and 11, i.e., Subzimandi area and Chandni Chowk. Nowadays, the traffic along these zones moves via Tis Hazari, Dufferin Bridge and Queens Road. As these roads are already heavily congested, it would be proper to reserve a route exclusively for the use of slow-moving vehicles which predominate in this area as indicated in Fig. 6 (Plate II) showing desire line map for slow-moving vehicles. These slow-moving vehicles mostly originate from vegetable market area in Subzimandi and may be diverted to Boulevard Road and allowed to enter Chandni Chowk via Dufferin Bridge. The fast-moving vehicles and cyclists may continue to use the existing route and join Queens Road from Pull Mathai. This will segregate the slow moving traffic from the other types of vehicular traffic in this most congested area.

7.2. Cyclists' desire line map, Fig. 7 (Plate II), also shows that there is a heavy cycle traffic from Vinay Nagar side coming up to Najafgarh Road area via Shanker Road. In order to relieve the area of congestion, it is suggested that a separate cycle track called an "expressway" preferably with covered top for providing protection against sun and rain, exclusively for the use of cyclists may be developed as shown in the travel line chart for cycles, Fig. 10 (Plate III), by dots.

* It is recommended that a field survey be made with a view to look into the possibility of implementing the suggested improvements made in this Paper and making minor changes here and there to completely fit in with the field conditions.

7.3. The third route of cycle traffic congestion is from trans-Jamuna to Chandni Chowk area. The suggestion of providing another bridge over the Jamuna River made in latter paragraphs will greatly help to relieve this congestion.

7.4. The desire line map for fast moving vehicles, Fig. 5 (Plate I), indicates the following routes as heavily congested :

(i) Chandni Chowk—Subzimandi.

(ii) Chandni Chowk—Connaught Place.

(iii) Connaught Place—Karol Bagh.

Situation (i) has already been discussed while discussing cyclists desire lines in para 7.1. and an appropriate measure has been recommended. As regards (ii), there is a strong need to have a direct link between Chandni Chowk and Connaught Place besides the existing Minto Bridge. Perhaps it may be possible to develop a route from Chandni Chowk—Jamma Masjid—Turkman Gate—Mata Sundri Road joining Barakhamba Road and Connaught Place. This will necessitate providing an overhead railway bridge near Rouse Avenue.

As regards situation (iii), Panchkuin Road exists as a direct travel road between Karol Bagh and Connaught Place. As this road carries a heavy volume of fast and cycle traffic, it is recommended that a continuous cycle track on both sides of this road should be provided and cycle traffic at intersections should be controlled with additional phase in signals for cycles only.

7.5. The desire line chart for trans-Jamuna traffic, Fig. 8 (Plate II), shows that there is quite a heavy volume of traffic crossing the present Jamuna Bridge. The analysis shows that there is a need to provide another bridge over Jamuna River in order to reduce congestion on the present bridge. Based on the present Origin-Destination traffic data according to moment area method, it is found that the location of the bridge should be nearabout the present bridge. But keeping in view the developments taking place in the southern parts of Delhi, it may perhaps be more advantageous to provide a bridge near Nizamuddin.

7.6. The travel line charts given in the Paper also show that cycle traffic as well as motor traffic is very heavy on Faiz Bazaar Road and deserves immediate attention.

Provision for a separate cycle route between Red Fort and Delhi Gate should be made. The cycle traffic may come on a separate route from Red Fort to Daryaganj corner and then take a diversion towards Ansari Road to join the main stream of traffic at Delhi Gate only.

7.7. 'Pie' charts, Figs. 11 to 18 (Plate IV), show that there is a heavy flow of traffic from residential areas like Kingsway Camp, Shaktinagar, Patel Nagar, Diplomatic Enclave, Jungpura, Lodi Colony and from trans-Jamuna zones towards office and business areas such as Central Secretariat, Connaught Place, Daryaganj and Chandni Chowk during the morning peak hours. Analysis of traffic into fast, slow and cyclists, as shown in the 'pie' charts clearly confirms the earlier conclusion that cycle is the chief mode of conveyance in every case. There is a maximum flow of cyclists from Vinay Nagar, Lodi Colony, Kingsway Camp and from colonies situated across the River Jamuna.

From the desire line chart for cyclists it is seen that most of the cycle traffic from Vinay Nagar, Lodi Colony and Patel Nagar comes over to Central Secretariat and adjoining areas; whereas for most of the cyclists coming from Kingsway Camp, Shaktinagar and trans-Jumuna area, the destination zone is Chandni Chowk and its surrounding areas. Similarly, it is found that there is a heavy flow of fast moving vehicles from Patel Nagar, Lodi Colony, Jangpura and Diplomatic Enclave which comes over to Central Secretariat, Connaught Place and Chandni Chowk.

From the above data and charts, it should be clear that the inner cordon zones comprising office and business areas become crowded during the morning peak hours and this congestion is more or less of longer duration. Proper parking facilities in this area should be developed to meet this heavy demand. Comparing the inbound traffic with the total parking space available in a particular zone, it is observed that there is a glaring need for off street parking in areas such as Chandni Chowk, Naya Bazaar, Karol Bagh and Connaught Place. Proper re-arrangement of parking is also necessary in areas like Daryaganj, Connaught Place, Kashmere Gate and Naya Bazaar.

7.8. In order to relieve congestion in the inner cordon area traffic with origin and destination both outside the inner cordon zones should bypass the inner cordon area. Such divertible traffic which passes through the inner cordon zones enroute comprises the following three movements, viz.,

(i) traffic with origin and destination both outside the outer cordon ;

(ii) traffic with origin outside the outer cordon and destination in the mid cordon zones and vise versa; and

(iii) traffic with origin and destination both in the mid-cordon zones.

Such divertible traffic is 19.23 per cent of the total inbound traffic, showing thereby that a considerable amount of congestion can be relieved simply by re-routing the inbound traffic which has origin as well as destination zones outside the inner cordon areas but which passes through the inner zones enroute.

7.9. At present there exists a ring road round Delhi, as shown in Plate V, which almost coincides with the boundary of the outer cordon zones. This by-pass is useful mostly to traffic with origin-destination outside the outer zone, but is of little use to other movements of traffic listed above. At present a major portion of this traffic has to pass through the inner congested zones enroute to their destination.

7.10. In order to save the inner congested areas, another suitable loop road has been suggested as shown in Plate V. This road will lie in the mid cordon area and will divert the above mentioned traffic from going to the central areas.

For example, with the existence of such a road, traffic between Kingsway Camp and Patel Nagar instead of passing through the inner cordon congested area can move along the proposed road. This will not only avoid congestion in the inner cordon area but will provide a free route for divertible traffic. Similarly, traffic from areas situated near Humayun Tomb, Jangpura and Lodi Colony coming to Patel Nagar and Karol Bagh can avoid entering Connaught Place or Central Vista by using the proposed loop road.

7.11. It has been observed that congestion on certain roads can be reduced to a marked degree by segregating traffic of different movements with the provision of new by-passes. Traffic coming from Qutab Road and Mathura Road and going to trans-Jamuna side can cross the river Jamuna near Humayun Tomb via proposed Inner Ring Road, as shown in Plate V and can thus avoid coming to Mathura Road, Faiz Bazaar and Elgin Road, which are already heavily congested. This necessitates the construction of an overhead Jumuna Bridge and also a railway bridge near Humayun Tomb as shown in the same Plate.

7.12. In order to relieve congestion on Mathura Road and Faiz Bazaar, a separate link road has been marked out, connecting Chandni Chowk, Turkman Gate, Mata Sundri Road with Lytton Road and Pandara Road. This link road meets the Inner Ring Road (proposed) near Lodi Colony.

The road will carry most of the traffic coming from and going to old Delhi and South Delhi colonies. This will necessitate the constuction of a new railway bridge near Rouse Avenue, shown in Plate V.

In order to save Connaught Place area from over-congestion, traffic coming from Old Delhi to Central Secretariat should be diverted towards Ferozeshah Road after crossing the proposed overhead bridge near Rouse Avenue.

This will also relieve congestion on various approach roads to Connaught Place, Central Secretariat and especially at Minto Bridge.

8. SUMMARY OF RECOMMENDATIONS

The various recommendations and suggestions given at relevant situations have been listed below:

(i) The transport facilities in Delhi in general are inadequate, with the result that persons have to cycle for as long a distance as 10 miles. D.T.U. should take up investigations to find ways and means for providing cheap and adequate transport facilities for citizens of Delhi.

(ii) As most of the trips in Delhi performed for work purposes are during the peak hours, it is recommended that the demand for such trips should be staggered in order to relieve congestion on roads.

(iii) In order to provide a by-pass for the inner cordon area comprising Government offices and business centres, it is suggested that a new Inner Ring Road should be developed. This measure will help to relieve about 20 per cent congestion in the inner cordon zones.

(iv) The suggestion given in (iii) above also necessitates the construction of a new bridge over the Jamuna River near Nizamuddin at the junction of the proposed ring road. This new bridge will not only help to provide a passage on the other side of the Jamuna Bridge to the traffic coming from the inner ring road, but will also allow the traffic from the whole of South Delhi to cross the Jamuna at this point.

(v) As the roads in inner cordon area are highly congested, an alternative route connecting Old Delhi with colonies in South Delhi by-passing Connaught Place has been suggested via Chandni Chowk, Turkman Gate, Mata Sundri Road, Lytton Road, Pandara Road and Lodi Road. This route will necessitate the construction of an overhead railway bridge near Babar Lane where at present a pedestrian bridge exists.

This link road will reduce traffic on approach roads to Connaught Place from Old Delhi side especially at Minto Bridge.

(vi) A separate cycle track exclusively for the use of cycles, called an "express cycleway", with covered top, in order to provide protection against sun and rain, may be constructed connecting Vinay Nagar, Shankar Road and Najafgarh area.

(vii) There is a strong need to develop a continuous cycle track on both sides of Punchkuin Road which provides a major link between Connaught Place and Karol Bagh. Cycle traffic at intersections should be controlled with additional phase in signals for cycles only.

(viii) As the traffic between Subzimandi and Chandni Chowk is quite heavy, it is found that the existing routes are not adequate to handle the mixed traffic efficiently. As most of the slow moving traffic originates from Subzimandi Market, it is suggested that the slow moving traffic may be diverted towards Boulevard Road and should enter Chandni Chowk via Dufferin Bridge. Fast traffic and cyclists may use the existing route via Tis Hazari, Pull Mathai and Queens Road to enter Chandni Chowk.

This measure will help relieve congestion by segregating slow moving traffic from the main stream.

(ix) Since traffic on Faiz Baazar Road is very heavy, it is suggested that a cycle route should be developed between Red Fort and Delhi Gate as mentioned earlier. This will segregate the fast and cyclicts' traffic.

(x) As office areas and business centres like Chandni Chowk, Naya Bazaar and Connaught Place become crowded during the morning peak period and since this congestion is of long duration, it is highly recommended that proper arrangements for off-street parking should be made at Connaught Place, Chandni Chowk and Naya Bazaar area for smooth flow of traffic. Rearrangement of parking is also required in Faiz Bazaar, Kashmere Gate and Connaught Place areas.

9. SUGGESTIONS FOR FUTURE ORIGIN–DESTINATION SURVEYS

9.1. Before conducting an O—D Survey, a thorough study of natural phases in the topography, bridges, tunnels and other funneling points of traffic flow is most essential. The city under study should be divided into major areas, such as :

(i) Business-cum-shopping area.

(ii) Areas comprising Government and private offices.

(iii) Educational and university areas.

(iv) Residential areas, and

(v) Suburban areas.

9.2. For roadside interviews, suitable locations for survey stations should be made on the boundary line of these areas. A movement from one area to another should only be recorded as a trip, because in the present case it has been observed that movements by vehicles with origin and destination in the same area but passing through other areas enroute have also been recorded.

9.3. In order to speed up the interview, the amount of information should be held to a minimum. On heavy thoroughfares, a multi-lane arrangement is necessary to avoid accumulation of traffic during peak periods. One lane should be used for interviewing and the excess traffic is to be by-passed in the extra lanes.

9.4. The interviewers should be given thorough instructions about the information to be furnished in the proforma. In case of commercial passenger vehicles, it should be noted that it is the passenger and not the driver who is to be interviewed and any information to be filled should be furnished from the passenger hiring the vehicle or from any one of the passengers, in case there is more than one. If possible, a pilot survey for a day should be conducted just to train the interviewers and to ensure efficiency and accuracy.

9.5. In order to minimise the office work, information should directly be recorded in a precoded card. This is feasible on survey stations situated at points where major roads enter urban areas.

9.6. Hollerith Punch carding technique should only be employed in case the number of interviews is very large, say, more than fifty thousand. In other cases, this can be profitably avoided by employing enumerators for sorting purposes.

Appendix I (Form No. 1)

ORIGIN-DESTINATION SURVEY OF TRAFFIC—GREATER DELHI 1957

Name.....

Time.....

Direction In Out

Station No.....

S. No.	MODE					Loading factor	ORIGIN			DESTINATION			PURPOSE							FREQUENCY			OCCUPATION										INCOME								
	P	Tr	Mr	T	Mc		Locality	Street	Nearest intersection	Locality	Street	Nearest intersection	W	SW	SP	T	R	H	O	D	W	M	Agr.	M.Q.	Mfg. (A)	Mfg. (B)	Con.	Ele.	T.C.	Tr.	Ser.	Oth.	A	B	C	D	E	F	G	H	I
1																																							
2																																							
3																																							

(Form No. 2)

ORIGIN-DESTINATION SURVEY OF TRAFFIC—GREATER DELHI 1957

Name.....

Time.....

Direction In Out

Station No.....

S. No.	MODE			Loading factor	ORIGIN			DESTINATION			PURPOSE							FREQUENCY			OCCUPATION										INCOME								
	TO	B	H		Locality	Street	Nearest intersection	Locality	Street	Nearest intersection	W	SW	SP	T	R	H	O	D	W	M	Agr.	M.Q.	Mfg. (A)	Mfg. (B)	Con.	Ele.	T.C.	Tr.	Ser.	Oth.	A	B	C	D	E	F	G	H	I
1																																							
2																																							
3																																							

ACKNOWLEDGMENT

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Appendix I *(contd.)* **(Form No. 4)**

Origin-Destination Survey of Traffic — Greater Delhi - October, 1957

ENUMERATOR :

STATION NO :

DIRECTION : IN OUT

TIME :

	MOTOR VEHICLES						ANIMAL-DRAWN VEHICLES		
	P	TR	MR	T	MC	BU	TO	B	H
1.									
2.									
3.									

(Form No. 5)

Origin-Destination Survey of Traffic — Greater Delhi - October, 1957

ENUMERATOR :

STATION NO :

DIRECTION : IN OUT

TIME :

	CYCLES				CYCLES			
	1	2	3	4	1	2	3	4
1.								
2.								
3.								

Appendix II

Origin-Destination Survey of Traffic—Greater Delhi October, 1957

List of survey stations

Inner cordon survey stations

(a) Shankar Road
(b) Reading Road
(c) Deshbandhu Gupta Road
(d) Rohtak Road
(e) Old Rohtak Road
(f) Roshanara Road
(g) G. T. Road
(h) Malkaganj Road
(i) Tis Hazari
(j) Dufferin Bridge
(k) Kashmere Gate
(l) Faiz Bazaar
(m) Hardinge Bridge
(n) Wellesly Road
(o) Pandara Road
(p) Humayun Road
(q) Lodi Estate Road
(r) Lodi Tomb
(s) Qutab Road
(t) Club Road
(u) Tin Murti
(v) Kitchner Road

Outer cordon survey stations

(a) Najafgarh Road
(b) Rohtak Road
(c) Grand Trunk Road
(d) Timarpur
(e) Jamuna Bridge
(f) Mathura Road
(g) Kailash Colony
(h) Qutab Road
(i) Gurgaon Road

Appendix–III—'A'

Origin & Destination Survey of Traffic - Greater Delhi

CODE SHEET

Col No.	1 & 2	3	4	5 & 6	7 & 8	9	10	11	12 & 13	14 & 15	16 & 17	18 & 19	20	21 & 22	23	24
S. No.	Time ½ hour	Time period	Direction	Station	Station group	Mode of vehicle	Vehicle groups	Loading factor	Origin zone	Origin group zones	Destination zone	Destination group zones	Purpose	Frequency per month	Occupation	Income
1.																
2.																
3.																
4.																
5.																
6.																
7.																
8.																
9.																
10.																
11.																

Appendix III 'B'

Origin-Destination Survey of Traffic Greater Delhi, 1957

CODING SCHEME

1. Time

Time has been coded in quarter hour frequencies, 1 to 96, starting at 12 midnight.

2. Time Period

Morning peak period	8.00 – 9.45 A.M.	1.
Evening peak period	5.00 – 6.45 P.M.	2.
Night peak period	9.00 P.M. – 5.45 A.M.	3.
Off peak period	All others	

3. Direction

In bound	1
Out bound	2

4. Stations

Outer cordon stations Nos. 1 to 9 have been coded as such. The inner stations, labeled a to v, have been coded with two digits running from 10 to 31.

5. Station Group

Group	Basic station code	Station group code
Northern	15, 16, 17, 18	40
Southern	24, 25, 26, 27, 28, 29, 30	41
Western	10, 11, 12, 13, 14	42
Minto Road	19	19
Kashmere Gate	20	20
Delhi Gate	21	21
Hardinge Road	22	22
Mathura Road	23	23
Kitchner Road	31	31

6. Mode of Vehicle

P - Private car	1
TR - Truck	2
MR - Motor cycle rickshaw	3
T - Taxi	4
MC - Motor cycle	5
TO - Tonga	6
B - Bullock cart & rehra	7
CR - Cycle rickshaw	8
C - Cycle	9
H - Thelas	0

7. Vehicle Groups

Fast moving vehicles	1
Slow moving vehicles	2
Cycles	3

8. Loading Factor

Vacant	0
Half - full	2
Full	4

9. Origin Zones

All the labelled forty eight origin zones have been accordiingly coded from 1 to 48.

10. Origin Group Zones

Outer cordon zones

Group	Basic Zoning Code	Group Zoning Code
North	47	01
East	40, 41, 48	02
South East	36, 37	03
South	38, 39	04
South West	24, 43	05
West	6, 23, 44, & 45	06
North West	46	07

Mid cordon zones

North	1, 2, 3. 4	10
South East	29, 30, 35	11
South	31, 32, 33, 34	12
South West	21, 25	13
West	7, 8, 9, 22	14
North West	5	15

Inside inner cordon zones

Connaught Circle	16	16
Government Offices	20	20
North East	11, 12, 13	21
South East	17, 18, 28	22
South	19, 26, 27	23
West	15	24
North West	10, 14	25

11. Destination Zones and Group Zones

Same procedure followed as in case of origin zone and group zones.

12. Purpose of Trip

W - Work	1
SW - Shopping, wholesale	2
SP - Shopping, retail	3
T - Training	4
R - Recreation	5
H - Health	6
O - Other	7

13. Frequency

D - Daily	24
W - Weekly	04
M - Monthly	01

14. Occupation

Agr.	–	Agriculture, etc.	1
M.Q.	–	Mining & quarrying	2
Mfg. (a)	–	Manufacturing - foodstuffs and textiles	3
Mfg. (b)	–	Other manufacturing	4
Con.	–	Construction	5
Ele.	–	Electricity, gas, water and sanitary	6
T. C.	–	Trade & commerce	7
Tr.	–	Transport, etc.	8
Ser.	–	Service Government	9

15. Income Groups

		Rupees per month	
A	–	Less than 75	1
B	–	75 - 99	2
C	–	100 - 149	3
D	–	150 - 249	4
E	–	250 - 499	5
F	–	500 - 749	6
G	–	750 - 999	
H	–	1000 - 1499	8
I	–	1500 & more	9

Appendix IV

Zone No.	*Name*		*Zone No.*	*Name*	
1.	Kingsway Camp	Area	25.	Moti Bagh	Area
2.	Timarpur	,,	26.	Teen Murti	
3.	Civil Line	,,		South Avenue	,,
4.	Subzimandi	,,	27.	Aurangzeb Road.	,,
5.	Bharatpur	,,	28.	Shahjahan Road.	,,
6.	Shakur Basti	,,	29.	Pandara Road.	,,
7.	Zakhera	,,	30.	Nizamuddin,	
8.	Rajinder Nagar	,,		Jangpura, etc.	,,
9.	Karol Bagh	,,	31.	Lodi Colony	,,
10.	Sadar Bazaar	,,	32.	Safder Jung	,,
11.	Chandni Chowk	,,	33.	Vinay Nagar	,,
12.	Daryaganj	,,	34.	Kotla, Sewa Nagar	,,
13.	Rouse Avenue &	,,	35.	Lajpat Nagar	,,
	Tagore Road, etc.	,,	36.	Okhla	,,
14.	Pahar Ganj	,,	37.	Kalka Ji	,,
15.	Panchkuian Road	,,	38.	Chirag Delhi	,,
16.	Connaught Circus	,,	39.	Mehrauli	,,
17.	Hardinge Avenue	,,	40.	Shahadra	,,
18.	Baroda House	,,	41.	Shakarpur Khas	,,
19.	Queensway	,,	42.	Khan Pur	,,
20.	Central Sect.	,,	43.	Mehpal Pur	,,
21.	Dhola Kuian	,,	44.	Dabni	,,
22.	Pusa Institue,		45.	Bahadurgarh	,,
	Inder Puri, etc.	,,	46.	Narela	,,
23.	Najafgarh Road.	,,	47.	Azad Pur	,,
24.	Delhi Cantt.	,,	48.	Gadhri	,,

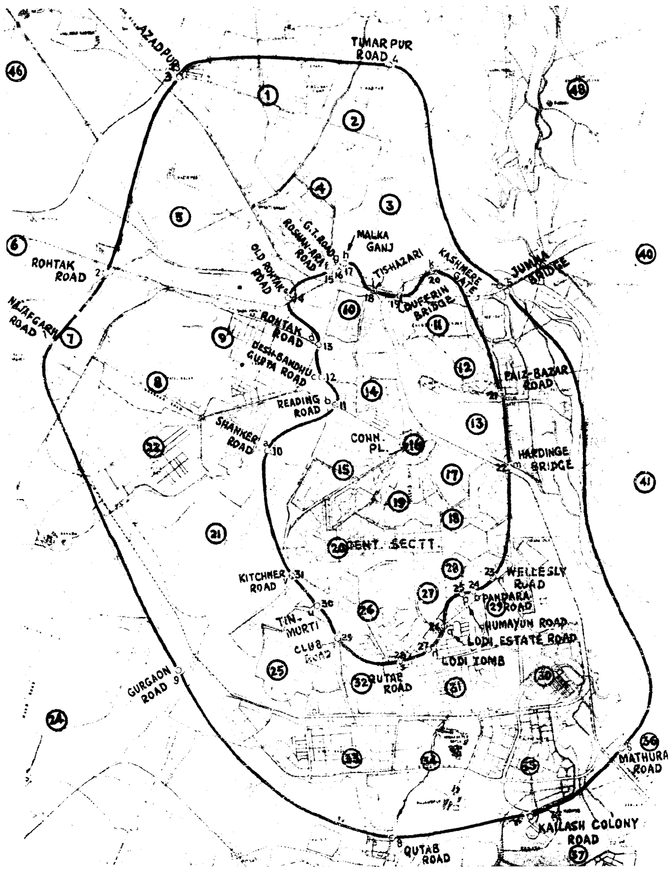


Fig. 3. Map showing the 48 zones, the principal areas and the cordon lines

TYPE % WORK
TIME PERIOD
DIRECTION
STATION
STATION GROUP
NUMBER OF VEHICLES
VEHICLE FACTOR
ORIGIN ZONE
ORIGIN GROUP
DESTINATION ZONE
DESTINATION GROUP
PURPOSE
PURPOSE OF TRIP
OCCUPATION
INCOME

Fig. 4. Punch card design for the origin-destination traffic study of Greater Delhi 1957

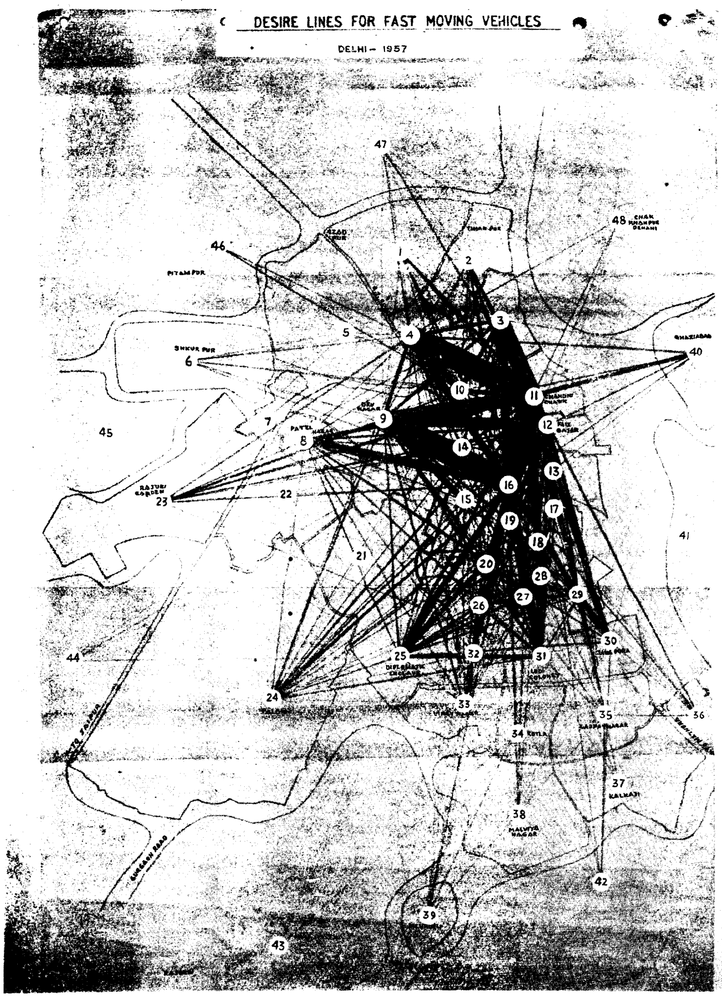


Fig. 5. Map showing desire lines for fast moving vehicles, Delhi 1957

Fig. 6. Map showing desire lines for slow moving vehicles, Delhi 1957

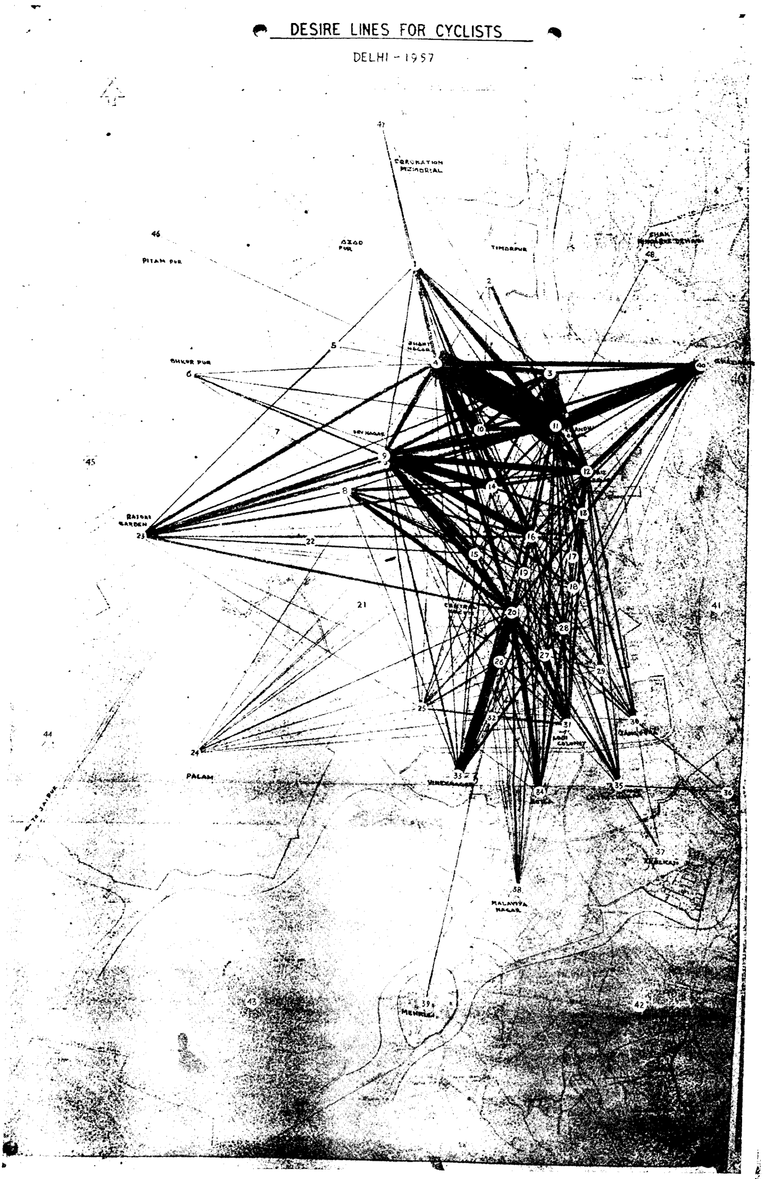


Fig. 7. **Map showing desire lines for cyclists, Delhi 1957**

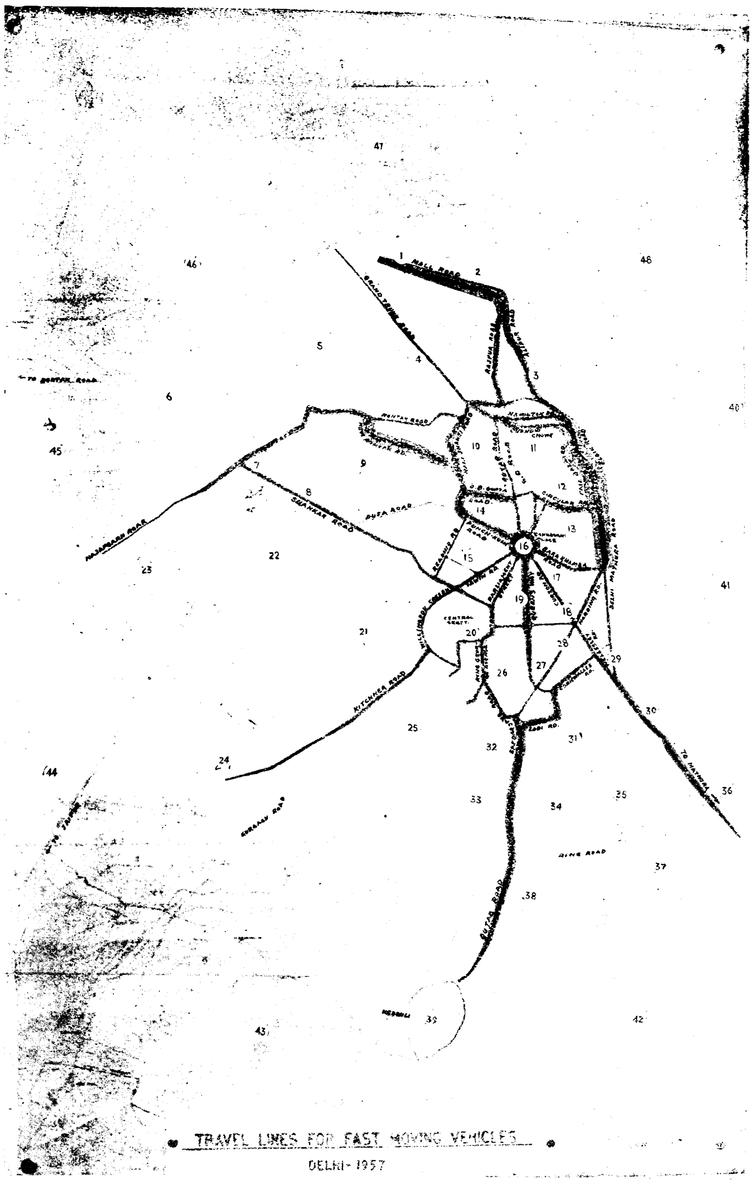


Fig. 9. Map showing travel lines for fast moving vehicles, Delhi 1957

PLATE IV

OUT-BOUND TRAFFIC

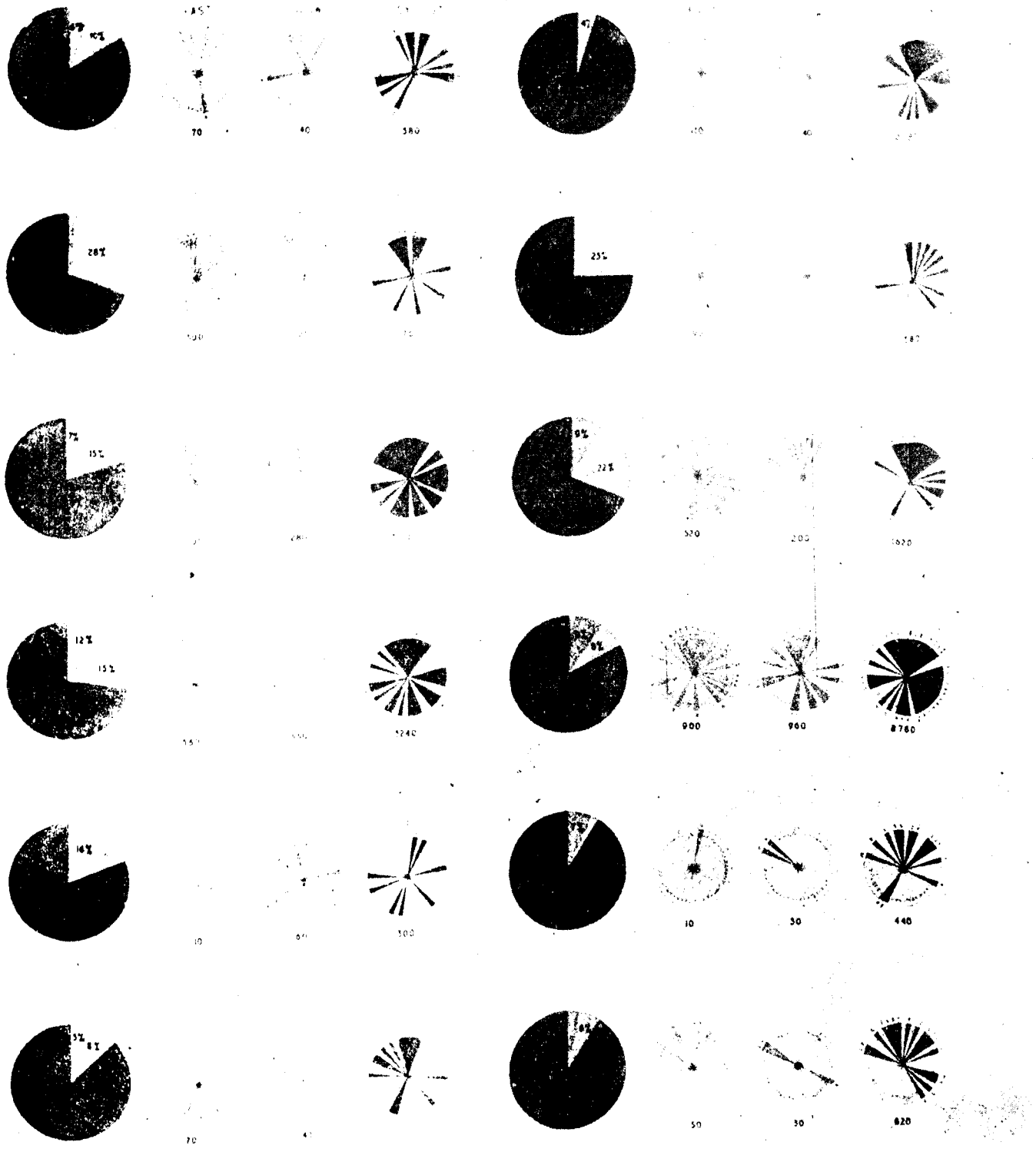
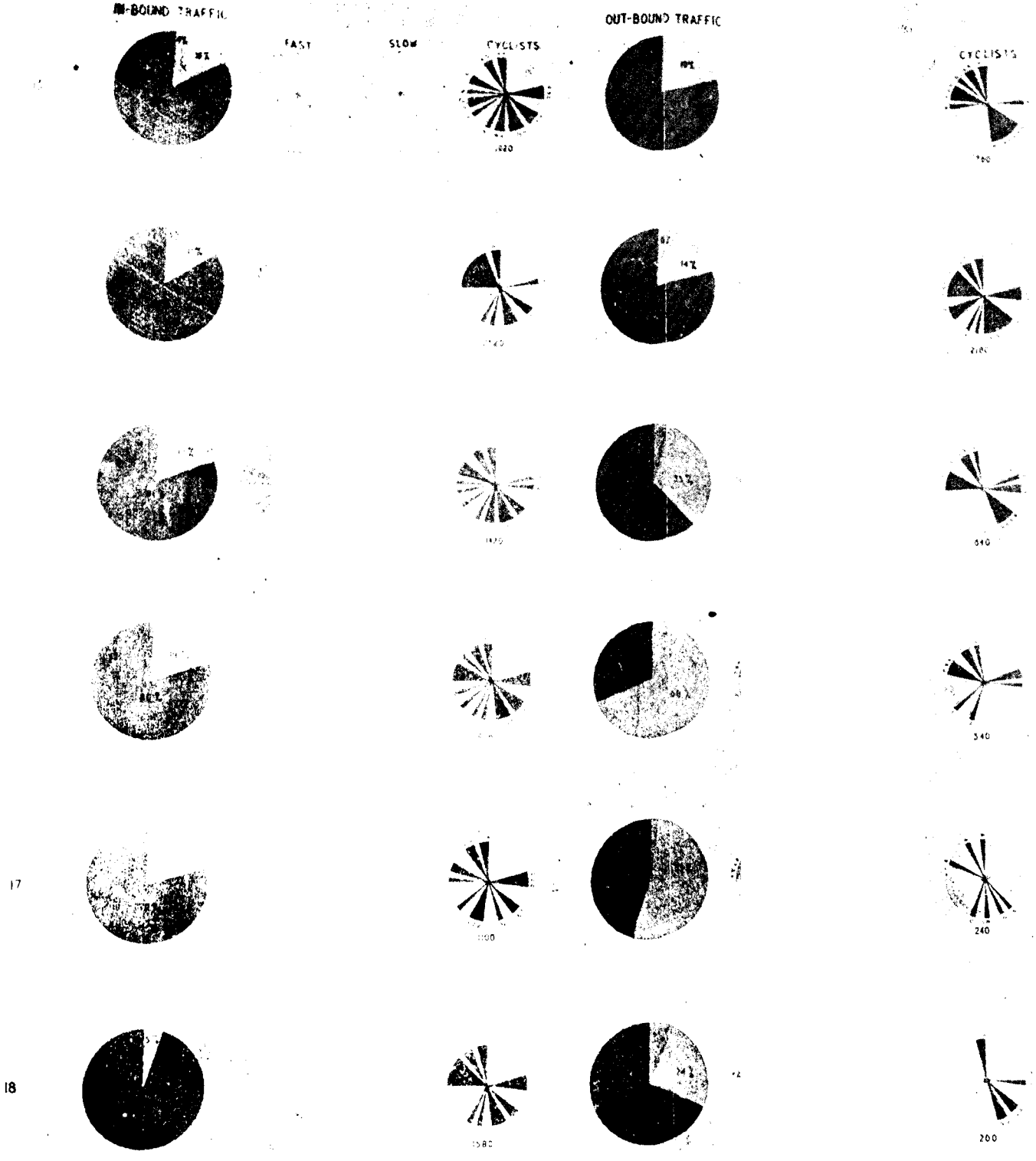


PLATE IV
(contd.)



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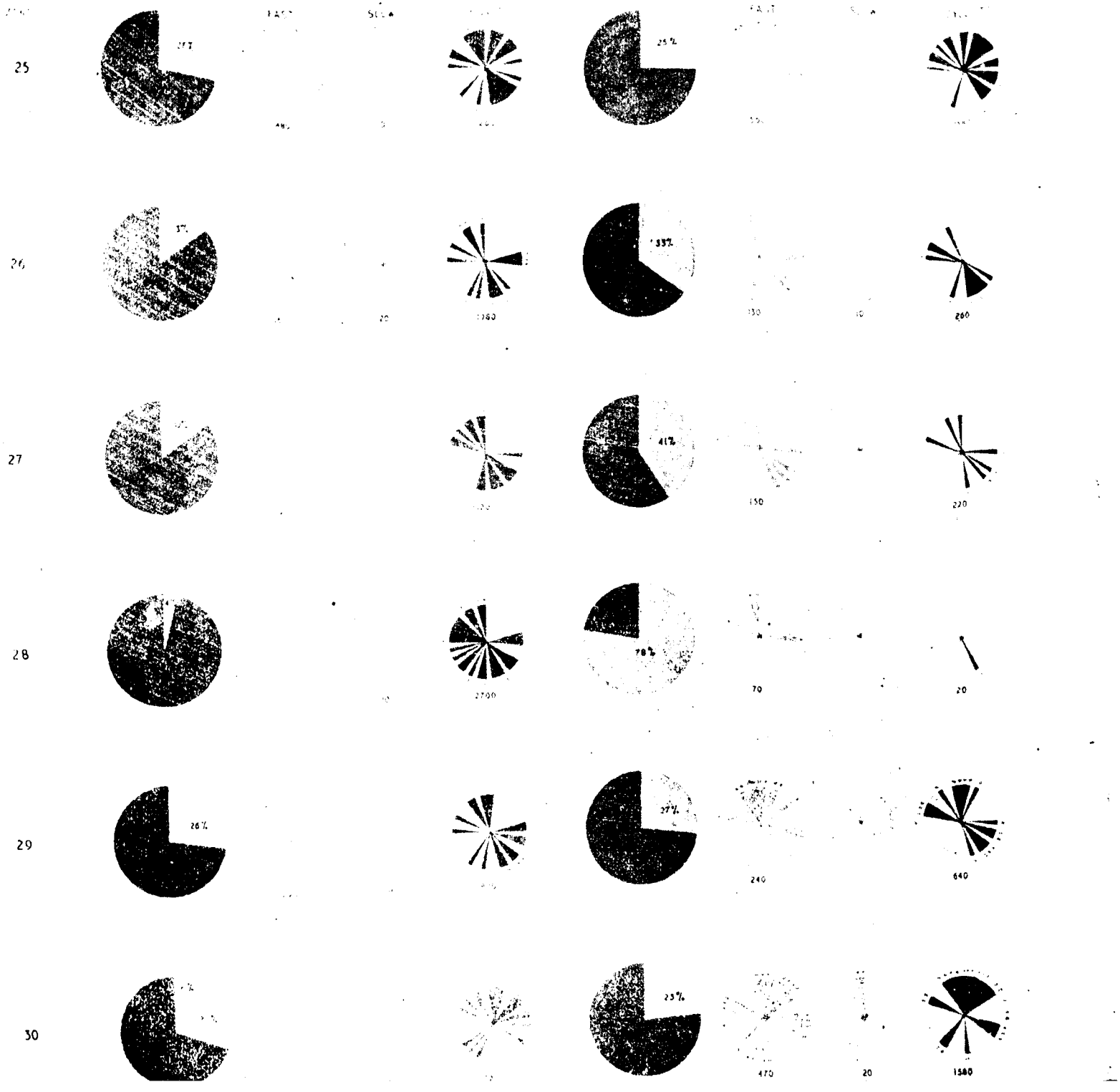

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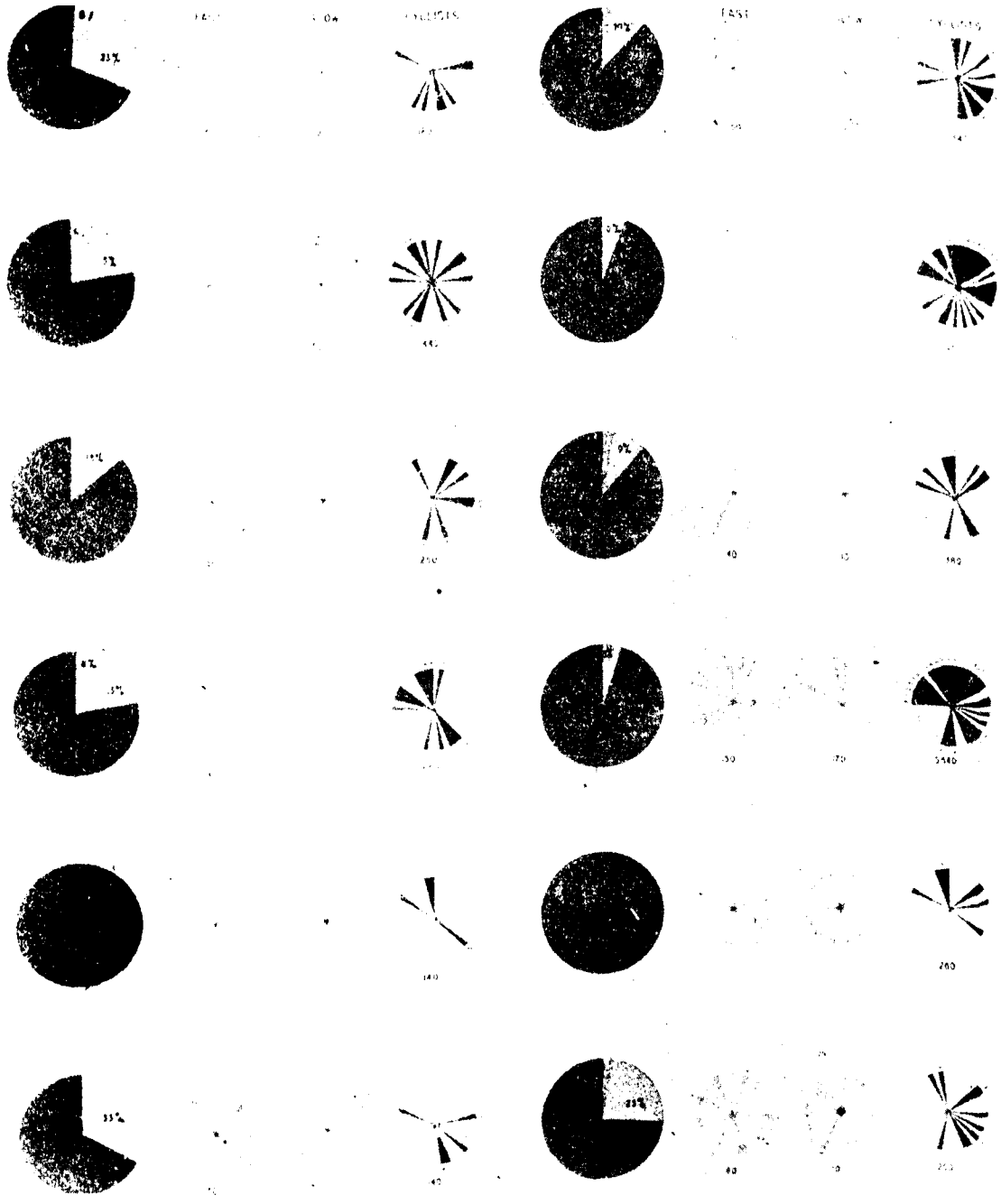
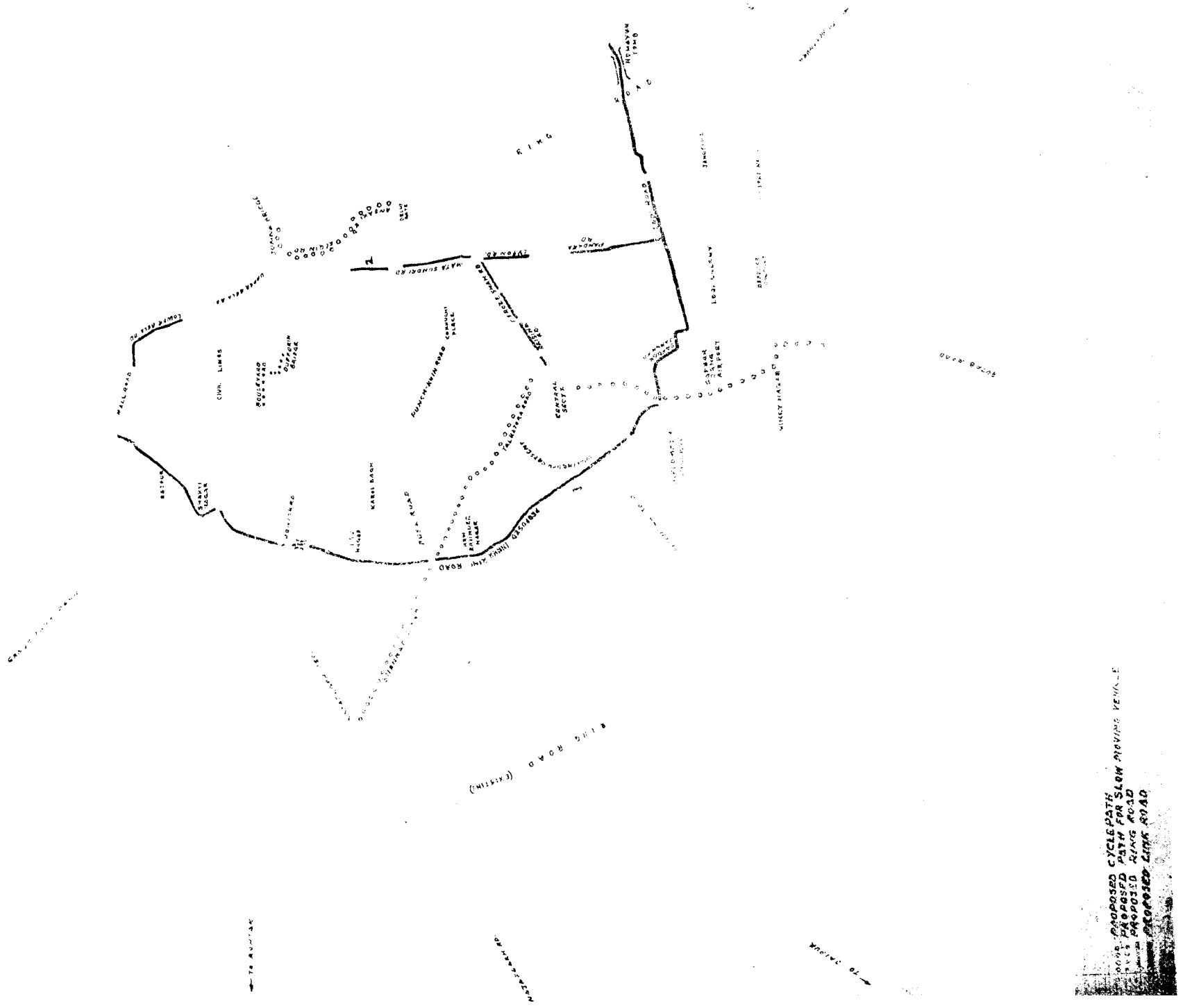


● PIE CHARTS SHOWING ... OUTBOUND AND INBOUND TRAFFIC FOR EACH ZONE ●

PLATE V


RING
PROPOSED INDIRA KIWI ROAD
PROPOSED CYCLE PATH
PROPOSED PATH FOR SLOW MOVING VEHICLES
PROPOSED RING ROAD
PROPOSED LINK ROAD

Paper No. 222

"REGIONAL CONCEPT FOR HIGHWAY PLANNING— THE WEB AND LATTICE PATTERN"

By

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CONTENTS

SYNOPSIS

The Paper stresses the need for adequate and balanced planning of the road system both for urban and rural areas.

It develops the concept of regional units for purposes of planning of the highway network. It proceeds to describe the road fabric which would be suitable for the trend of development in the country. The Web and Lattice pattern is recommended for agricultural and developed areas.

An illustrative highway plan is also described showing its applicability for a particular district.

1. INTRODUCTION

1.1. The road development of this country until recently was scanty and had more or less local significance, and the roads

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mainly satisfied the requirements of slow bullock-cart traffic and pack animals moving in caravans. The distances in India are tremendous and have many obstacles along them. Trunk roads built during the earlier periods were few and inadequate, and with passage of time most of them got into disrepair. During the last century, prior to the introduction of Railways, some of the old trunks were improved and maintained through the Military administrators, but with the coming in of Railways, attention was concentrated on the construction of feeder roads to Railways, allowing the trunk roads to get into a state of disrepair.

1.2. After the end of World War I, the motor transport received a great impetus, necessitating a bold approach to the question of road development, and the first unified attempt to give an all-India complex to the highway system in the country was initiated with the Nagpur Plan in 1943, when, with the adoption of Grid and Star principle, roads were envisaged on a broad pattern and traversed the length and breadth of the country. Since the formulation of the Nagpur Plan, the conditions have further altered substantially. There has been a pronounced change in the character of highway transportation involving long distance hauls, increasing speeds, greater traffic volumes, heavier type of vehicles, etc. The urge for economic, cultural and social integration between urban and rural areas has considerably increased, and roads are now looked upon as vital links for promotion and strengthening of these contacts. Increasing dependence between marketing centres and the farms, industrial centres and the supply zones of raw materials, and similar supply and demand requisites have made the role of highways an indispensable factor in forging the overall developmental fabric of the country.

1.3. Amongst all the modes of transport at present available, the road is the only one where no specified places like stations, etc., are needed, unlike other means, such as, railways, water traffic and air transport where stations, wharfs and terminal buildings have necessarily to be provided and the entrance and exit points particularly specified. The important and vital role played by roads in the development of the economy of the country is thus fully established.

1.4. Fully realising that the time had come to take a fresh stock of the country's needs, the Chief Engineers prepared during 1958, a Report on Road Development Plan for India for the period 1961-81 for consideration of the Government. This Report, like its predecessor, the Nagpur Plan, follows the same bold pattern of stabilizing and expanding the highway system of the country

in relation to the anticipated traffic as well as the economic and functional needs.

1.5. With such a background, the future road system has necessarily to be planned in a manner as to provide maximum accessibility benefits without, as far as possible, involving overlapping or unbalanced concentration of milages.

The relative requirements necessitated by the varying population dispersions, travel habits, various types of vehicles, traffic modes and patterns, location of habitations, etc., have to be correlated and an overall integrated system of road layout developed.

2. THE PRESENT PATTERN

2.1. The Nagpur Plan envisaged the "Grid and Star" pattern and enunciated two formulae for working out the total milages under the two categories.

Category I, consisting of National Highways, State Highways and Major District Roads, was generally intended to provide 'grids' traversing the country, with big cities and towns standing out as 'stars' attracting traffic to these focal centres, while category II roads comprising Other District Roads and Village Roads were, by and large, to provide approach roads to outlying places and connecting them with the main road system.

2.2. Following this idea, some States based their road development plans on the conception that villages with population of 500 or more should have direct approach to the main roads. This system had a very good advantage of providing intimate links connecting villages and towns with trading centres, and thereby establishing a feeling of cohesion between them. This approach was particularly necessary at that stage as the country had a poor and deficient road system.

2.3. The wide gap between the towns and villages was substantially narrowed, and the Nagpur Plan increased the overall milage intensity to 26 miles per 100 sq. miles. The Plan envisaged the following targets:

(1) Villages in highly developed areas to be within 5 miles of the main road (average distance being less than 2 miles in most cases) and within 20 miles of a main road in non-agricultural area (average distance between 6 to 10 miles in most areas), and

(2) Villages in highly populated areas to be within 2 miles of an all-weather District Road and for other areas within 5 miles of a District Road.

2.4. This conception was, however, affected to some extent due to the deduction of the railway milage from the overall road milage. Even after ignoring this deduction factor, the Grid and Star formulae give, on the basis of present area figures and assuming a uniform layout of the road system, the following broad picture:

(i) 53.8 miles per 100 sq. miles in case of fully developed agricultural area involving an average maximum distance of 1.86 miles from any road and 3.8 miles from a metalled road; and

(ii) 10.80 miles per 100 sq. miles in case of non-agricultural area with a maximum distance of 9.2 miles from any road and 17 miles from a metalled road.

2.5. The milage targets set out in the Nagpur Plan were actually achieved by the year 1958 and, at the conclusion of the Second Five-Year Plan (1960–61), the road milage in the country is expected to reach a total of 279,000. The Road Development Plan (1961–81) doubles the road milage in relation to that proposed in the Nagpur Report, thereby increasing the gross intensity to 52 miles per 100 sq. miles. It sets out total milages, on the basis of formulae for each class of road, and broadly lays down the following "accessibility" milage targets:

Description of area	Maximum distance (miles) of any place		Milage intensity per 100 sq. miles of area
	From a metalled road	From any road	
Developed and agricultural area	4	1.5	70
Semi-developed area	8	3.0	30
Undeveloped and uncultivable area	12	5.0	19

The gross milage intensity = 52 miles per 100 sq. miles

2.6. The report has thus specifically laid down both the milage and accessibility targets and it is obvious that, within that framework, the most suitable road fabric would be one which would adequately meet not only the country's present requirements and the anticipated future material and physical needs but also simultaneously fit in with the nation's cultural and social heritage. The latter finds expression in decentralised community administration in the form of Panchayats.

2.7. Looking to the rapid and multi-directional developmental progress, it is not quite easy to assess the future pattern of the country's development with a mathematical precision, but a prudent and judicious appreciation of the country's requirement will have to be done if the future road structure has to function in its proper role. This can largely be effected by an analytical study of the manner of the country's development pattern in recent times and the tendencies for future development, and extending the curves to depict the shape likely to be obtained in the future.

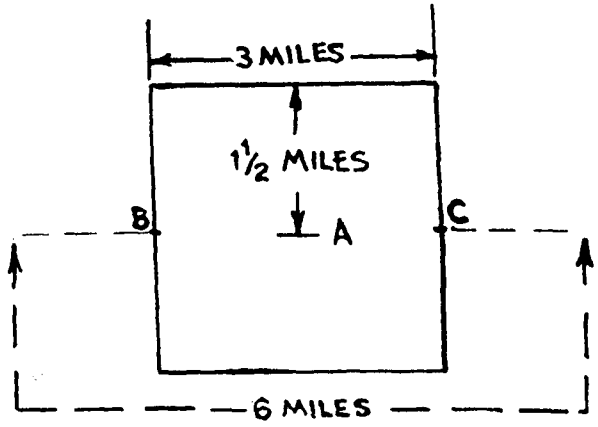
2.8. It will, therefore, be interesting to visualise the trends of development in respect of the various elements affecting the functioning of roads. This has been attempted in the succeeding chapters.

3. ACCESSIBILITY DISTANCE

3.1. With the total milage for an area determined in accordance with specific formulae, the term "accessibility distance" assumes a rather difficult bearing when it is associated simultaneously with rural and urban roads. In the case of Star and Grid pattern, too many rays from a "star" (town) will seriously affect the spread-out of the road system in the rural area. Conversely, providing insufficient number of converging roads to a town will also unbalance the composite highway structure. A practical and rational integration within the urban and rural milage pattern is, therefore, an essential element.

3.2. Normally, assuming a uniform spread out of an overall road milage, as calculated from a formula for a specific area, a square grid would provide the most efficient layout; each side of the square being equal to twice the "accessibility" distance. The centre of such a square will have the required accessibility distance from a road and, at the same time, the maximum distance between any two places lying anywhere along the sides of the square, when measured along the roads, will not be more than 4 times the accessibility distance. For instance, with the accessibility distance of 1.5 miles, if the road system is planned with a grid of 3 miles square, any place 'A' within the square will not be more than 1.5 miles from a road and, for intercommunications, any two places 'B' and 'C', extremely situated

within the area or along the road system, will not be more than 6 miles apart as shown in the sketch below:



Excepting a circle, any other mathematical pattern either rectangular or oblong will exceed the proportioning between the minimum accessibility distance and the maximum measured distance along a road proper of 1 : 4 given above.

3.3. It is true that the minimum accessibility distance in any road layout will be affected by the radial roads of towns; but, for all practical purposes, it would not be impracticable to work out this distance for any area by dividing the area in square miles by the road milage. In actual practice, in any rational composite road system, the variation from the target calculated as above will not affect more than 10 per cent of the area even in extreme cases. On this basis, for accessibility distance of 1.5 miles, adopted in the 1961–81 Report, a milage of 66.6 will be needed for an area of 100 sq. miles.

3.4. The "accessibility" distance in case of arterial roads having higher grade specifications has, however, relatively deeper significance as high financial cost is involved, and a more detailed approach is necessary for determining these distances. For this purpose, it will be necessary to correlate the optimum spacing of these arterial roads with their functionary and economic characteristics as related to the twin objective of demand for services and supply of capacities for efficient transport. A balancing equilibrium between the two requisites is likely to give a workable solution and the following criteria may be applied with advantage in that respect:

(1) Travel costs in relation to saving in time, driving, accidents, operations and other transport charges;

(2) Construction and maintenance costs including costs of land acquisition;

(3) Equilibrium between capacity to carry vehicles and the demand for travel;

(4) Innate design requirements of the roads and their functional values;

(5) Land planning requirements.

It may, however, be stated that with the country's present inadequate road structure and the under-developed transport system, such a detailed study is not called for. This might become necessary later after a reasonable sufficiency has been attained in the developmental stages of both roads and transport.

4. CONCEPTS FOR HIGHWAY PLANNING

4.1. The Present Concept

Planning has two aspects, the spatial or geographic and biological or demographic. The road development pattern, since we know it, has generally revolved round villages, towns and cities as individual nuclear centres. The modern urbanised society is based on the fact of mobility and the highest grade of city serves as an outstanding centre of human affairs, an economic metropolis, an independent centre of trade and finance and a cultural and administrative unit.

4.2. The rural culture has been profoundly affected by impact of urban life. The centralised amenities in respect of services and social activities and greater opportunities for fruitful occupations available in towns and cities become magnets of attraction. As such, there has, of late, been an active tendency on the part of people to gravitate towards bigger towns, with the result that the rural sector of the country is getting listless and stunted.

4.3. India's population was estimated at 36.24 crores in 1950. Residents of cities with population of over 1,00,000 totalled 2.36 crores (roughly 6.5 per cent), while cities with population of 20,000 and over contained a total population of 4.3 crores (roughly 12 per cent), Table 1 showing the comparative figures of percentage of population in towns and villages of different categories during the last four Census Reports reveals that —

TABLE 1

Percentage of population living in towns and villages of different sizes

Village or town with population	1921	1931	1941	1951
	Actual figures (from census reports)			
Under 500	30.3	27.8	24.4	21.9
500 to 1,000	23.0	22.6	22.5	20.4
1,000 to 2,000	20.4	21.1	20.5	19.5
2,000 to 5,000	14.2	15.4	16.4	16.6
5,000 to 10,000	3.9	4.4	5.4	5.8
10,000 to 20,000	2.4	2.4	2.6	3.8
20,000 to 50,000	1.9	2.3	2.5	3.3
50,000 to 1,00,000	1.2	1.3	1.6	2.1
1,00,000 and over	2.7	2.7	4.1	6.6

(1) The percentage of population living in villages of less than 2,000 people has been progressively getting reduced, the rate being very much marked in case of villages with population of under 500;

(2) Population intensities in case of towns with population more than 2,000 have been gradually increasing, the rate being more pronounced in case of towns with population of over 20,000.

4.4. It would not, therefore, be wrong to attribute thinning out of the villages to the lack of normal amenities in the villages, and deficiency and inadequacy of road communications could be one of the main causes responsible for this.

4.5. **The Proposed "Regional" concept**

A "region" would be an area homogeneous in respect of some associate characteristics whether of land or people. The criteria for recognition of such units would depend upon the structure of the society in association with geography of the area and would cover:

(i) Local unit, large and homogeneous enough to form a compact society having common and corporate interests;

(ii) Defined boundaries to take account of natural, geographic and historic features;

(iii) Sufficiency in respect of its economic and financial sustenance; and

(iv) Social units, not too large to destroy personal contacts and not too small to fail to provide variety and diversity.

4.6. Economics is fundamentally regional. It will be impossible to make every village by itself a self-sustained centre both from economic and administrative considerations. For stabilising and preserving the economic set up of the rural areas, it would therefore become necessary to promote a system of "grouping" or "bunching" of villages and link the villages together by a proper communication system. Each cluster of villages should form a workable and fairly self-sufficient community unit on a cooperative basis, and it should be provided with essential facilities like roads, health, education, water supply and other social amenities. A small town in such a cluster may serve as a nucleus with nearby villages drawing on it for various services and sending their own surplus of agricultural produce for disposal. By this way, it should be possible to develop the village centres on region-wise group basis, avoiding the tendency towards migration to bigger towns.

4.7. In regard to the urban centres, the main functions devolving on a city comprising a geographic, economic social and political unit involve a two fold approach—

(i) assessment of the efforts and the character of the region, its resources and economic production;

(ii) examination of the impact produced by its organizational and social activities on the character of its tributary areas.

The growth of cities results in rural depopulation but the economic factors of accessibility would introduce a close tie-up between the great city with its environs and the tributary areas.

A tributary "regionl" of an urban centre would normally be an integrated pattern consisting of—

(i) Compact and continuous urban core area with less compact marginal 'satellite' settlements, chiefly governed by considerations of rapid accessibility and amenities.

(ii) "Suburban" area with rural-urban complex supplying the normal daily necessities and be reachable within about an hour. This would generally mean an area of about 20.0 miles radius.

(iii) "Circulation" or influence area as determined by the accessibility range and its comparative significance in relation to the similar areas of the adjoining cities of equivalent status.

In India, where distances are great, the trade areas are extensive and fairly well defined and the population concentrates in the pivotal centres having generally historical and cultural background. Some areas grow to modern greatness with industry and commerce as the chief gravitation magnets. The overall effect obtained is a broad regional arrangement focussed on the hub, the city proper with its life and organisation.

The circulation features of a city usually follow either (i) a grid plan with a diagonal arrangement of roads converging to a centre, or (ii) a radial-concentric pattern with radiating roads from the centre to outskirts in a star like formation along main roads and one or more peripheral roads forming wide thoroughfares. The development pattern in the U.S.A. broadly follows the former, while the general trend on the Continent and elsewhere is in accordance with the latter.

4.8. Regional Units for Planning

4.8.1. Spheres of influence: tributary areas

Appendix I shows the usage of land and the dispersion of population of India. The agricultural and developed land accounts for 60 per cent of the total area while the semi-developed and undeveloped areas are practically equal in extent, each being about 20 per cent of the total area. In regard to the spread out of the towns and villages, the following assumptions have been made:

	Developed area (Per cent)	Semi-developed area (Per cent)	Undeveloped area (Per cent)
Distribution of towns and villages with population of 2,000 and above	90	7	3
Distribution of towns and villages with population of less than 2,000	85	10	5

On this basis, taking only the agricultural and developed area into consideration, and assuming a uniform spread out of various towns and villages of different gradings, the spacings between them broadly work out as under:

Population	Distance apart
Over 1,00,000	100 miles
Between 1,00,000 and 20,000	50 ,,
,, 20,000 and 10,000	35 ,,
,, 10,000 and 5,000	27 ,,
,, 5,000 and 2,000	6.0 ,,
,, 2,000 and 1,000	4.0 ,,
,, 1,000 and 500	3.0 ,,
Below 500	1.5 ,,

4.8.2. Urban and suburban regions

In broad reckoning, the spacings given in para 4.8.1 above generally conform in practice to the dimensions of the influence areas of the various groups. Thus, places with population of more than 20,000 would occur at the rate of 1 in 1,640 sq. miles or, say, 40 miles apart; of these, every fifth place comes under the category of metropolitan city having population of more than 1,00,000. From the hypothetical dispersions of the towns and villages, given in Plate I, it is seen that:

(a) the tributary area of a metropolitan city extends to 45 miles radius covering about 6,500 sq. miles of area;

(b) other towns with population range from 20,000 to 1,00,000 will have varying influence areas, the maximum going to a 20 miles radius zone covering 1,250 sq. miles of area.

4.8.3. From the considerations of urban planning, it is desirable that for a big centre, having a hard core serving as the main nerve centre, and self-sufficient neighbourhood or "satellite" towns skirting round it, the latter should be connected to the city proper by suitable wide and radial road system, and these again should be linked with each other by one or more boundary or ring roads, depending upon the geography and economic importance of each place and the nature, size, and spread out of its neighbourhood. The road pattern will resemble more like a

"spider's web". The number of satellite towns for a big town or city will be dictated by the importance of the place and the rate of its development, but it may be assumed that a town or city with a population of:

(a) higher range of 1,00,000 will have a suburban area of 15 to 20 miles radius;

(b) lower range of 20,000 population, 8 miles radius.

4.8.4. In regard to the road pattern, apart from the radial roads emanating from the urban centre, a circular road with 6 miles diameter bonding an area of about 25 sq. miles might be taken to enclose "core" area for each such place. All local roads and streets coming within the heart core or within the satellite towns proper for local circulation are, however, left out from consideration as these would primarily be the direct responsibility of the municipality concerned.

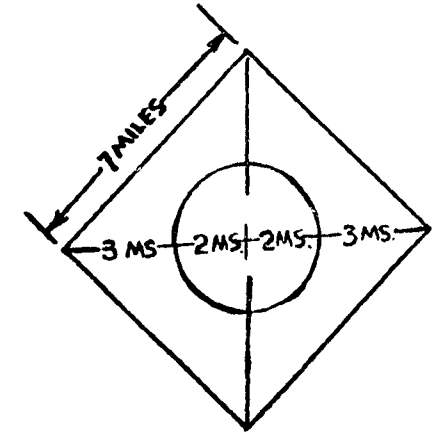
4.9. Rural Regions

4.9.1. It is rather difficult to correctly assess the exact dimensions of a self-contained "regional" unit in rural areas as this will largely be governed by the type of land and its use, nature, quantity and quality of production materials, professional habits, etc. Broadly speaking, the 'regional' community unit within its geographical area should have a considerable measure of unity in its economic set up, service, organisation and surroundings and include settlements in which the services can, as far as possible, be integrated. The means of transport should be quick and well established so that any two places should be accessible to each other within about an hour.

4.9.2. As seen from para 4.8.1, villages (with population of less than 500) are situated, on an average, 1.5 miles apart and from sufficiency requirements enough number of these should be "grouped" together to form a composite and co-operative unit and should be linked by means of "bonding" road, taking into consideration that no place within the "bonded" area should be more than 1.5 miles from a road. Judging from the fact that there will be other higher categories of roads also traversing the rural areas, it would seem practical to have a primary "bonding" road with a radius of about 2 miles. Such a road will enclose an area of about 12.5 sq. miles and, on the assumption of a uniform spread out of the population, would serve a population of about 5,000. The area: population ratio has actually a very wide range from considerations of economic sufficiency depending upon the development pattern of an area,

but the proposed "primary unit" would seem to be of rational dimensions.

4.9.3. Next may come the "rural centre" having a size of about 50 sq. miles and serving a population of about 20,000. This would seem to be a small self-sufficient regional unit having fairly balanced socio-economic requisites for the foundations of its community life. The road system for this area may consist of a circular bonding road mentioned above, and an outlying road system of, say, 7 miles square, as shown in the sketch below:

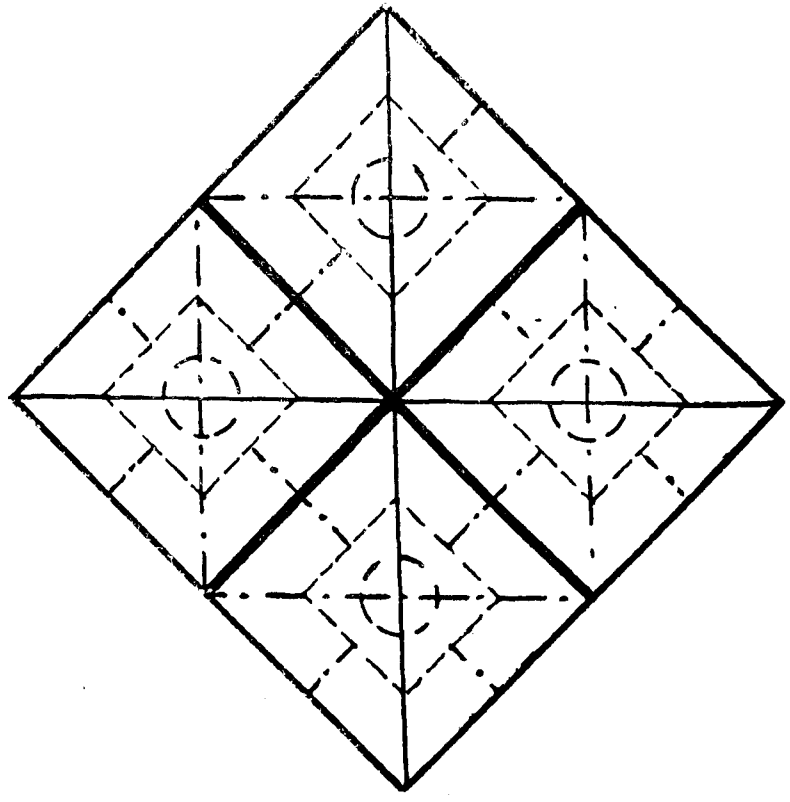


4.9.4. By enlarging the concept of a regional set up with the basic structure as indicated above, 4 rural units may be combined to make a "block" and 4 blocks combined to make a "zone". For attainment of cohesion and unity, the focal service and marketing institutions in the larger units should be located centrally and the main highways should serve the area efficiently. The overall rural set-up would, therefore, broadly consist of the following constituents:

Regional unit	Area (sq. miles)	"Nodal" centres with population of	Total population covered
(i) Primary unit	12.5	500–1,000	5,000
(ii) Rural centre	50	2,000-5,000	20,000
(iii) Block area	200	5,000	80,000
(iv) Zone	800	10,000	3,25,000

4.9.5. A hypothetical pattern of an internal road system for such a rural set-up may be envisaged on the following lines. The primary unit to have a road circulatory system connecting various villages of the unit and it may broadly be in the form of a circle with a radius of 2 miles. This may have an outlying

road system of, say, 7.0 miles square, for the "rural centres". Roads for these two regions may be of classified Village Road standard as they will have an exclusively local utility of providing inter-village communications. The rural centres forming a "block" should be interlinked by O.D. Rs., the next higher category of roads. Each block should also have a circulatory system consisting of all-weather and upgraded type of roads and these should integrate with the main highway system of the country. A symbolic representation of a road system for a block is shown below:



5. OTHER TRENDS IN PLANNING

5.1. Traffic Aspect

5.1.1. In the old set-up, the bullock-cart and pack animals were the chief forms of transport and long distance through running roads did not have a prominent significance. All roads leading to any important marketing centre had necessarily to

enter the interior of the place. Even where through carriage of goods was intended by means of caravans, these centres had to serve as halting places. All the traffic, therefore, centred towards the "heart" of the place and as the road system was intended to cater for this type of traffic, the roads in the habited area did not have adequate attention paid to the geometry of the alignments.

5.1.2. The era of the bullock-cart which has hitherto been a predominant feature of the rural economy of the country is, with the advent of motor vehicles, fast dwindling particularly in towns and urban areas. There has been a steady increase in the number of motor vehicles plying in the country and, with the manufacture of vehicles in India, the rate of increase is bound to accelerate rapidly. The future traffic pattern will, as such, show a steep rise in the use of road by motor vehicles. Even today, it is not uncommon to find that traffic volume in the neighbourhood of important industrial and capital towns has increased very significantly and this has already made the traffic control measures more complicated. In the rural areas, the bullock-cart is, however, likely to remain for a long time as a predominant farm—to—market vehicle. At present, there are about 102 lakh bullock carts plying in the country. Besides, with the increasing use of cycles and auto-rickshaws, a stage has come when adequate provision has to be made in planning of highways to meet the requirements of widely varying mixed traffic.

5.1.3. The growth of towns has relatively been going on in a very haphazard manner. The streets are narrow and congested and their alignments are usually winding. Ribbon development even along the main routes in a town thrives vigorously and encroachments and unauthorised occupation of road land provide serious bottlenecks to the free and through flow of traffic. Experience has shown that in most of the inhabited areas and marketing centres, it is almost impossible to obtain a through link with satisfactory geometrics and bypasses have to be provided in most of the towns and even large villages for the convenience of through traffic.

5.2. Economic Aspect

The study of the present economic set up, particularly in the rural areas, indicates that—

(a) most of the concentration of villages occurs along roads, railways, canals and such distinctive features as provide facilities for communications and transport, the pucca roads particularly attracting denser concentrations.

(b) Villages mostly lie in a strip of 2 to 3 miles on either side of a pucca road. This characteristic is evidently linked with the haulage capacity of the bullocks as bullocks can conveniently pull the maximum load for about 2 to 3 miles before coming on a pucca road and a greater haulage on a kutcha road would tire them out.

(c) Marketing and commercial centres with population of, say, up to about 10,000, are generally spaced at about 20 to 25 miles distances. This is obviously related to the bullock-cart performance, as usually about 20–25 miles is the normal workable journey per day for a bullock-cart.

(d) The distribution of population amongst towns and villages does not follow a set pattern. For instance, in U.P., 51.69 per cent of the population lives in villages with population of less than 1,000, while in Madras, only 15 per cent of the population lives in villages of this category.

(e) For economic returns through savings in time and vehicle life, efficient transport will involve long distance running, high speeds and avoidance of congested areas through towns and villages.

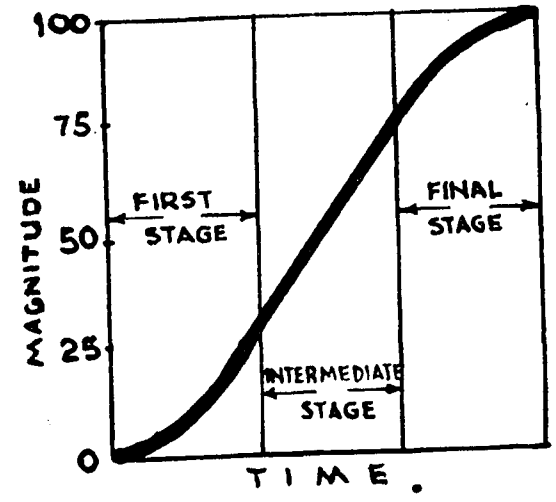
5.3. Geographical Aspect

5.3.1. Semi-developed or undeveloped areas have till now received inadeqate attention in respect of providing easy and quick means of access and they must be given due consideration and sufficient weightage allowed in working out milage targets.

5.3.2. Topographical features of areas will also affect lengths of roads. In highlands, comprising mountainous and hilly regions, the actual lengths will roughly be doubled, thereby necessitating a 100 per cent increase in the direct milage worked out by any empirical formula for such areas.

5.4. Developmental Aspect

According to the concept of general growth, a slow but constantly accelerated rate in early years is followed by a period of rapid and steady growth, then by a decelerating rate until the curve continues on to a very minimum growth when a saturation point is reached. The general trend is indicated in the graph given below.



(TAKEN FROM: HIGHWAY RESEARCH BOARD Bulletin 194)

The length of time required to pass through each of the periods varies considerably for different regions, in fact, it varies even in the components from which the trend is derived. The chief component would be the "population factor."

The other components would depend upon the object for which the developmental trend is to be determined. For example, for "travel trends", the other components would relate to traffic capacity, number of vehicles, vehicle miles run, etc.

6. CATEGORISATION OF THE ROAD SYSTEM

6.1. Both the Nagpur Plan and the 1961–81 Report have adopted the same classification of roads, viz., National Highways, State Highways, M.D.Rs., O.D.Rs. and V.Rs. for the road system in the country. An additional category of 'Expressway' for ensuring an uninterrupted flow of heavy and fast traffic on certain important and heavily trafficked routes has also been introduced in the 1961–81 Report. This is, however, not expected to be a separate entity as it is primarily associated with the functional characteristics of a road and the latter, where necessary, would only need to be designed accordingly.

6.2. The roads have also been grouped under two categories, —category I roads comprising National Highways, State High-

ways and M.D.Rs. will generally be metalled and surfaced, while category II, consisting of O.D.Rs. and Village Roads, will mostly be un-metalled. The categorisation is thus chiefly related to the type of construction of a road.

6.3. So far as the "classification" is concerned, the system so far adopted seems to be quite appropriate for the conditions obtaining in this country but it is suggested that the "categorisation" should depend upon the functional characteristics rather than on crust capacities. It is seen that—

(1) National Highways and State Highways have almost similar performance characteristics and have common specifications. They chiefly form the main arterial system of the country without any narrow considerations of boundaries of States or other local aspects, and the chief distinction between the two is mainly in respect of the manner of financing. It may, therefore, be suggested that the classification of the two may remain, in relation to each other, as it is at present, but from overall considerations the two classes may be grouped together under "Inter-State Highway System". As per 1961–81 Report, the two together would, in case of agricultural and developed areas, give a milage of 9.22 per 100 sq. miles or roughly 13 per cent of the total road milage. It would probably be possible to bring most of the places with population of over 20,000 on this system.

(2) The M.D.Rs. and O.D.Rs. have again similar characteristics of satisfying the regional requirements and will form the internal circulation system serving the interior of each district or similar units or areas, linking centres of importance and functioning as main branches of the Inter-State Highway System. The difference between the two classes will, however, mainly relate to their functional ability to withstand the local needs of traffic, climatic severities and their relative importance. The more important roads carrying heavier densities of traffic will have higher grade of specifications in respect of crusts, drainage crossings, geometric sufficiencies in alignment and grades, etc., and will come under the classification of major roads. The O.D.Rs., on the other hand, will have comparatively low cost specifications but their basic engineering features would be such that they could easily be upgraded to higher category without involving any infructuous expenditure. These two classes of roads may, therefore, be grouped under the category of "Regional Road System".

The above two categories will form the main fabric of the country's road pattern.

(3) The Village Roads have a distinct rural bias and they would essentially provide:

(i) "boundary" roads and interlinks connecting various villages to form self-contained rural centres, and

(ii) approach roads "bonding" the village community units with the inter-State or regional system.

6.4. With greater urge and stimulus displayed by rural areas to be associated with the nation building activities of the country, in which road construction and maintenance form the most appropriate means of mobilising local materials and human resources on the basis of self-help and self-reliance, the village roads can easily be associated intimately with local effort.

It may be emphasised that these village roads should be built to the approved traffic-worthy standards and not be mixed with cart tracks and irregular paths. In order to distinguish them from the latter, the village road as envisaged in the system may be called "classified village roads."

6.5. The road fabric may, therefore, contain –

(1) "Inter-State" system consisting of National Highways, State Highways and Expressways;

(2) "Regional" system consisting of M.D.Rs. and O.D. Rs.; and

(3) "Village" road system consisting of classified village roads.

7. ROAD FABRIC

7.1. Agricultural and Developed Areas

7.1.1. Analysing the Grid and Star formulae adopted in the Nagpur Plan, it is seen that after excluding the allowance for further development, the nett milage in the agricultural and developed areas works out to a length of 46 miles per 100 sq. miles allowing nearly 17 miles on area basis and the balance 29 miles for towns and villages, roughly giving a proportion of approximately 1 : 1.7 or 4 : 7. The deduction due to rail-

ways has been considered under the area milage. This gives rather a heavier weightage for towns and villages and during actual planning greater attention has been given in providing access roads to villages without a planned co-ordination to establish continuous links with a view to ensure inter-village contacts.

7.1.2. The 1961-81 Report envisages an aggregate total of 70 miles per 100 sq. miles of aggricultural and developed areas, thereby giving a maximum accessibility distance of 1.43 miles or, say, in practice, a maximum lead of 1.5 miles for any place. Of these, 42 miles are worked out on area basis and 28 miles for towns and villages giving a proportion of 3 : 2. This seems to be a more balanced arrangement.

The Plan contains the following milage targets:

Main roads		
National Highways	32,000 miles	
State Highways	70,000 ,,	
Major District Roads	1,50,000 ,,	2,52,000 miles
Other roads		
Other District Roads	1,80,000 ,,	
Village Roads	2,25,000 ,,	4,05,000 ,,
		6,57,000 miles

7.1.3. Planning of the future should, within the milages and accessibility targets set out in the 1961-81 Report, aim at reducing the size of the great urban conglomeration while improving and making more widely accessible the amenities of city civilization in towns and country alike.

The road system has, therefore, to be balanced and properly conceived so as to satisfy industrial (both heavy and medium industries), commercial, agricultural, mineral, economic, social and cultural development of the country and adequate provision has to be made for future expansion in the various sectors. Sufficiency of communications in rural areas and adequacy features to satisfy the growing urban requirements would have to be the fundamental bases for any future planning. A substantial new milage will have to be constructed and it is, therefore, all the more desirable to evolve a proper basis for the formulation of a pattern for the road system.

7.1.4. As discussed earlier, a "spider-web" pattern consisting of a radial and concentric road system has been found appropriate for urban centres. In regard to the rural areas, a "lattice" pattern comprising bonding and inter-circulatory roads on "regional" basis would seem to be the most feasible. A balanced and composite urban-rural association must be achieved and this can be brought about effectively by a rational and properly planned system. The composite fabric for the road system may, therefore, consist of—

(a) Diagonals representing the inter-State highway system, i.e., National Highways, State Highways and Expressways, forming the main arterial highway framework and having the characteristics of through highways.

(b) Grids in different directions in alternate layouts of major and minor roads providing the internal regional system and feeding the inter-State system.

(c) "Boundary" roads providing for—

  (i) grouping of villages and providing inter-village links in rural areas, or

  (ii) bypasses or circular roads in urban areas avoiding the congested centres and linking various satellite towns along the periphery of a major centre.

7.1.5. An attempt has been made to prepare a symbolic representation of the proposed composite highway system within the milage and accessibility targets set out in the 1961-81 Report and to suit the proposed "regional" concepts for urban and rural areas. Such a pattern has been given in Plate I A. Broadly speaking, it comprises the "Web" pattern for the urban centres and "Lattice" pattern consisting of diagonals, grids and inter-village links for the rural areas. The "Web and Lattice" pattern generally satisfies the necessary concepts of planning on "regional basis" and it also offers grids in square dimensions which has been considered to be efficient from the considerations of easy accessibility.

7.1.6. The milage, as per suggested pattern, would on measment be on the direct and shortest line, but in actual practice, the lengths of roads are likely to increase due to various local conditions owing to diversions, crossings, etc., apart from the topographical features, and an additional allowance of 10 per cent would not be unjustified. The milage on this pattern works out

quite consistently with that set out in the 1961-81 Report as shown below:

Category	As per formula (excluding 5 per cent) allowed for future development	As per pattern (actual plus 10 per cent)
N. H. & S. H.	8.78	7.93 + 0.8 = 8.73
M. D. Rs		
O. D. Rs	35.00	15. 5 + 1.6 = 17.10
Village Roads	23.70	17. 0 + 1.7 = 18.70
Total	67.48	20. 3 + 2.0 = 22.30
		60. 7 + 6.1 = 66.83

The millage is thus comparable.

7.1.7. The milage of 60.7 should mathematically give accessibility target of $\frac{100}{60.7} = 1.64$. The chart shows that hardly about one per cent of the total area would lie outside this range, while only about 3 per cent would be outside the accessibility limit of 1.5 miles. This is not of any practical significance. With the addition of extra 10 per cent in milage, the deviation will still be narrower.

7.1.8. The web and lattice system when interposed on the uniform spread-out arrangement of the country's cities, towns and villages for various grades, gives a pattern as shown in Plate II, and it is seen therefrom that:

(i) the accessibility targets are obtained quite satisfactorily;

(ii) bonding of villages and formation of regional units in rural areas are well achieved;

(iii) the tributary area of a metropolitan city extends to 85 miles square giving an area of 7,200 sq. miles and its suburban character covers an area of 28 miles square or about 800 sq. miles;

(iv) other towns with population range of 20,000 to 1,00,000 will have varying influence areas, the maximum giving 28 miles square or about 800 sq. miles of area and the minimum restricted to the web area of 6.0 miles radius or, say, 100 sq. miles; and

(v) the urban and suburban area for cities up to 1,00,000 population may be taken on an average as 14.0 miles square or 200 sq. miles. The influence areas have been indicated hypothetically in the map in Plate II.

7.1.9. The above extents of influence areas for various centres closely conform to the standard pattern obtained from the dispersal of population centres when assumed on uniform basis as shown in para 4.8.1. above, and the suggested web and lattice system may be said to be practically satisfying the developmental concepts discussed in the preceding pages.

7.1.10. A road normally serves strips of catchment areas situated along its both sides, but while working out the influence areas this principle has not been followed rigidly as the roads have been generally taken as boundaries of the influence areas. This has been done mainly for simplifying the approach.

7.1.11. It may be emphasised that the pattern shown in Plate II is purely symbolic and hypothetical and will be capable of adoption in actual practice only if a new system of roads were to be formulated and all towns and villages were dispersed in strictly uniform pattern. But this is never obtained in practice. In any planning, the existing system of the roads cannot be ignored and, by and large, with the exception of some isolated roads, the existing road system will have to be retained and incorporated in the future planning system. Besides, the alignments of roads will very largely be governed by actual dispersion of towns and villages, topographical features, river crossings, layouts of irrigation channels and railway systems, retention of the existing canals and drainage structures and similar obligatory considerations. The proposed system only focusses the salient features and objectives which have to be taken care of in planning of a road system, and at best it can only serve as a guide. It is not by any means intended that the existing road system should be scrapped. It will, however, be realised that with the doubling of the Nagpur road milage, as envisaged in the 1961–81 Report, a substantial road milage will consist of new roads, and it is very necessary that for planning to be done on sound and practical basis, the missing links in the existing system must necessarily be supplied judiciously and its extension conceived on rational lines. A bold and sturdy outlook has, therefore, to be brought into play, and the broad principles underlying the suggested system adopted as far as possible.

7.2. Semi and Undeveloped Areas

7.2.1. There are vast undeveloped and semi-developed areas in the country aggregating to nearly one-third of the total area where the suggested web and lattice pattern will be neither satisfying nor economical. This pattern primarily emphasises development on self-sustained regional basis and these statistics can be obtained only in developed areas.

7.2.2. The main problem in undeveloped and semi-developed areas, on the other hand, is to provide very quick means of transport to bring the agriculture and farm produce or any other locally manufactured goods to the nearby markets as expeditiously as possible. Any approach towards creating self-supporting regional units in these areas will be unworkable as such units, even if capable of formation, will be both economically and administratively unwieldy and inefficient. The inter-village links will be disproportionate in length and will be even unnecessary as the marketing centres will invariably form the central hubs to which the various villages will individually be drawn for their social, cultural, economic and trade attributes.

7.2.3. The highway fabric for these areas will, therefore, chiefly consist of:

(i) inter-State routes traversing the areas because of their intrinsic characteristics of through movement irrespective of locality consideration;

(ii) regional routes on a broad grid for providing access to the region; and

(iii) feeder roads linking the various places of habitation either individually or collectively, where feasible, in suitable clusters to the framework of roads under (i) and (ii).

The highway arrangement for these areas would, therefore, generally follow the grid and star concept and each area will have to be provided with a layout of the road system to suit its geographical, historical and habitation pattern. Each case will, therefore, have to be considered on its merits depending upon the conditions actually obtained.

8. ILLUSTRATIVE HIGHWAY PLAN

8.1. For preparation of development plans, a district would be the basic unit for obvious reasons. Though the inter-State system would have to be defined on a panoramic scale in relation to the country as a whole in an integrated manner, the internal system will have to suit the regional requirements. An attempt has been made to work out on a broad basis a developmental framework of a road system for a district unit on the web and lattice pattern and Agra District has been taken for that purpose. It generally represents overall averages for proportioning of areas and disposition of population amongst the various centres as are obtained for India as a whole. It would, therefore, give a fairly practical portrayal of the application in actual practice of the principles discussed in this Paper. The road development map of this district has been given in Plate III.

8.2. It might be emphasised that the plan shows only a skeleton development pattern but for a detailed map it will be necessary to carry out proper traffic, economic, geographic and engineering surveys. The existing conditions in all aspects having bearing on the functionary and engineering values of both the existing road system and the future pattern will have to be ascertained in proper perspective before a final picture can be drawn. The present attempt only gives an indication of the manner of approach to the problem.

8.3. The milages of various classes of roads as actually obtained by scalar measurement and those obtained on the basis of the formula suggested in the 1961-81 Report compare as follows:

Class of road	As per formula	As per pattern (Plate I A)	Remarks
Inter-State system			
National Highways	70	92	The difference in milages in these 2 classes is not unexpected as the N.Hs. are envisaged on country-wide basis
State Highways	124	110	
Total	194	202	
Regional system			
M. D. Rs.	387	384	
O. D. Rs.	497	870	
Village road system	372		
Grand total	1,450	1,456	

The milages are fairly comparable. The Other District Roads and Village Roads have not been shown separately on the plan as a proper idea of the exact locations of the various villages and small towns in the rural area and their tributary extents will be necessary before this can be finalised. Broadly speaking, however, the bonding circular roads and some of the linking roads will come under the category of village roads while the roads having characteristics of continuity and long lengths will belong to the category of Other District Roads.

9. CONCLUSION

9.1. With increasing technical and scientific strides made in various fields of the country's developmental activities, the awareness of the role of motor vehicle has come to stay. The urge for long distance haul and use of heavy carriers operating at high speeds have been increasing rapidly and, coupled with the advantages accruing from the use of roads for transport purposes, the need for an adequate and methodically planned road system both for urban and rural areas has become imminent.

9.2. The Chief Engineers have formulated a 1961-81 plan for road development of India and it sets out the milage and the accessibility targets for different conditions of land use. It doubles the Nagpur Plan milage from 3,31,000 to 6,57,000 and has laid down "accessibility" distances of 1.5 miles, 3 miles and 5 miles for fully developed, semi-developed and non-developed areas respectively.

9.3. There has been a pronounced tendency towards migration from villages to towns and cities; lack of amenities and communication facilities and meagre means for social contacts in the rural areas have largely been responsible for their denudation. The present pattern of highway planning largely aims at providing links to the rural habitation centres from the main roads, thereby giving direct means of access to the neighbouring urban centres. This approach brings rural and urban areas together but it does not foster or strengthen the rural set-up. In the modern age, a village of small dimensions cannot survive by itself as a healthy organism and a regional community unit providing an area of economic sufficiency and common living will be an effective means of stabilising the rural areas. Similarly, an urban centre forms a geographical, economical, social and political unit and its development integrating its compact and concentrated core and its suburban dispersions and wider tributary areas is also essential. Thus, for an overall vigorous and healthy

growth of the country, both the urban and rural economies have to be properly dovetailed and integrated.

9.4. The concept of "region" in case of rural areas has been proposed to encompass areas of influence commencing with a primary unit of about 12.5 sq. miles (covering a population of about 5,000), having about one hour walking distance between any two places within its orbit and enlarging into bigger units, viz., rural centre, a block and finally a zone covering 50,200 and 800 sq. miles respectively. A regional unit in urban centres would contain a composite unit comprising the nerve centre in the core area and the inter-related neighbourhoods or satellite towns situated in the periphery within easily reached distances. Rapid communication system is also necessary for linking the city with its tributary or influence area on which it depends for economical and social stability. A territorial socio-economic homogeneity is thus established and, for such a region, a radial-concentric pattern of circulation system of the spider-web type would seem feasible.

9.5. The highway mosaic has, therefore, to suit the inches of the subgrade soil at optimum moisture to a density of 1.75 gms/c.c. This is followed by 8 inches of soil with 5 per "regionalisation" concept for both the rural and urban areas and also to satisfy the through and local needs of transport within the framework of the milage and accessibility targets laid down in the 1961-81 Report. The composite fabric of the road system on "Web and Lattice" pattern is, therefore, suggested. It consists of diagonals depicting National Highways and State Highways comprising roads of inter-State importance, grids in different directions consisting of Major and Other District Roads to form the regional circulatory system, and boundary roads providing bypasses and periphery roads in the urban areas and interlinks between villages and regional units in rural areas. It combines the "Web" system for urban areas and "Lattice" system for rural areas.

9.6. It may, however, be stated that this pattern will be suitable only for agricultural and developed areas where the concept of self-sustaining "regions" can be worked to in practice. In thinly populated semi-agricultural and non-agricultural areas, this pattern will not be workable as regionalisation will be unbalanced physically and economically. Direct links between towns and villages, as far as possible, would be necessary for these areas and the Star and Grid pattern would seem to be more suitable.

9.7. A district will, for many reasons, be an appropriate unit for planning of highways and an attempt has been made to prepare on the "regional" concept a highway plan for the

Agra District in U.P. as shown Plate III. This map is only an effort to broadly illustrate the features of the "Web and Lattice" pattern. For a detailed plan, it will be necessary to carry out proper economic, engineering and traffic surveys before the picture can be finalised.

9.8. It may, in conclusion, be emphasised that the suggested "Web and Lattice" pattern shown is only symbolic. The actual pattern in the field will depend upon the economic conditions, topography, existing road system of the area and the present and anticipated traffic patterns, and these will have to be determined first. The proposed system, therefore, only focusses the salient features and objects which have to be satisfied by a properly planned road system and it can at best serve only as a guide.

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Appendix I

Land Usage and Distribution of Population

1. Distrubution of areas by land usage

		Sq. miles	Per 100 sq. miles
(i)	Agricultural and developed areas	7,60,700	60.5 sq. miles say 3/5th
(ii)	Semi-developed areas, forests, etc.	2,59,600	20.5 sq. miles say 1/5th
(iii)	Undeveloped and uncultivable areas	2,46,600	19.0 sq. miles say 1/5 th
		12,66,900	100.0

2. Number of towns and villages of different populations (1951 census)

Size of towns and villages (population)		Total No.
Over 1,00,000		71
Between	50,000 & 1,00,000	93
,,	20,000 & 50,000	352
,,	10,000 & 20,000	652
,,	5,000 & 10,000	1,176
,,	2,000 & 5,000	20,508
,,	1,000 & 2,000	51,769
,,	500 & 1,000	1,04,26
Below 500		3,80,019

PLATE I

MAP SHOWING HYPOTHETICAL — UNIFORMLY SPACED DISPERSION — OF — TOWNS & VILLAGES IN INDIA

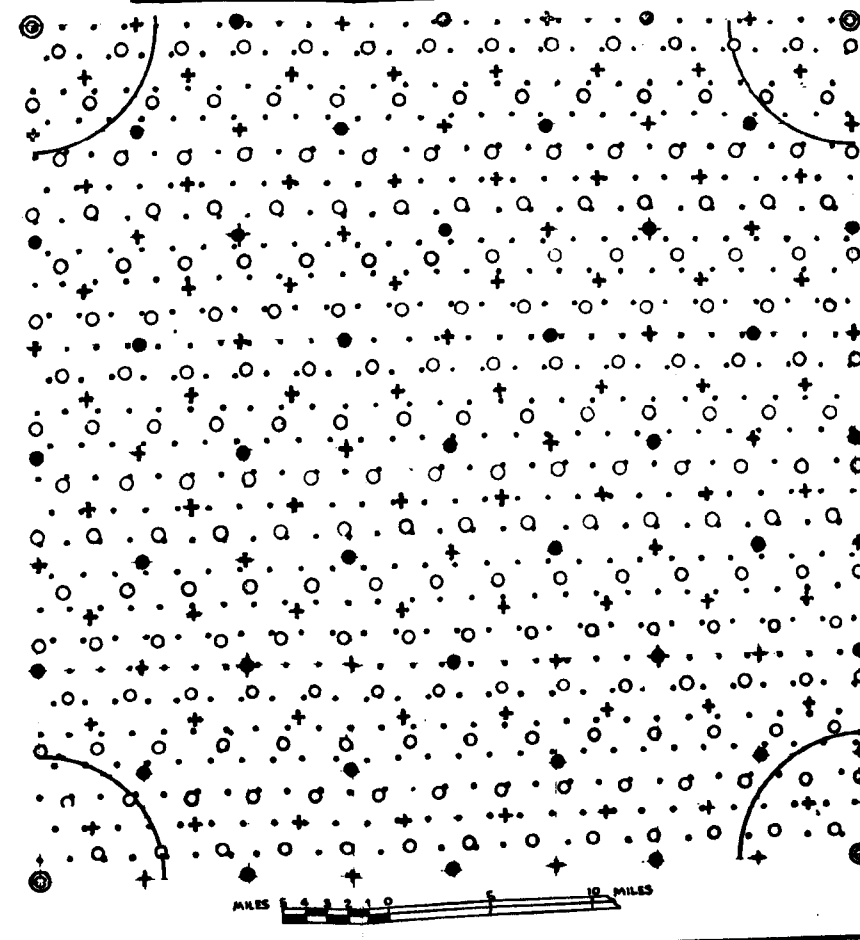
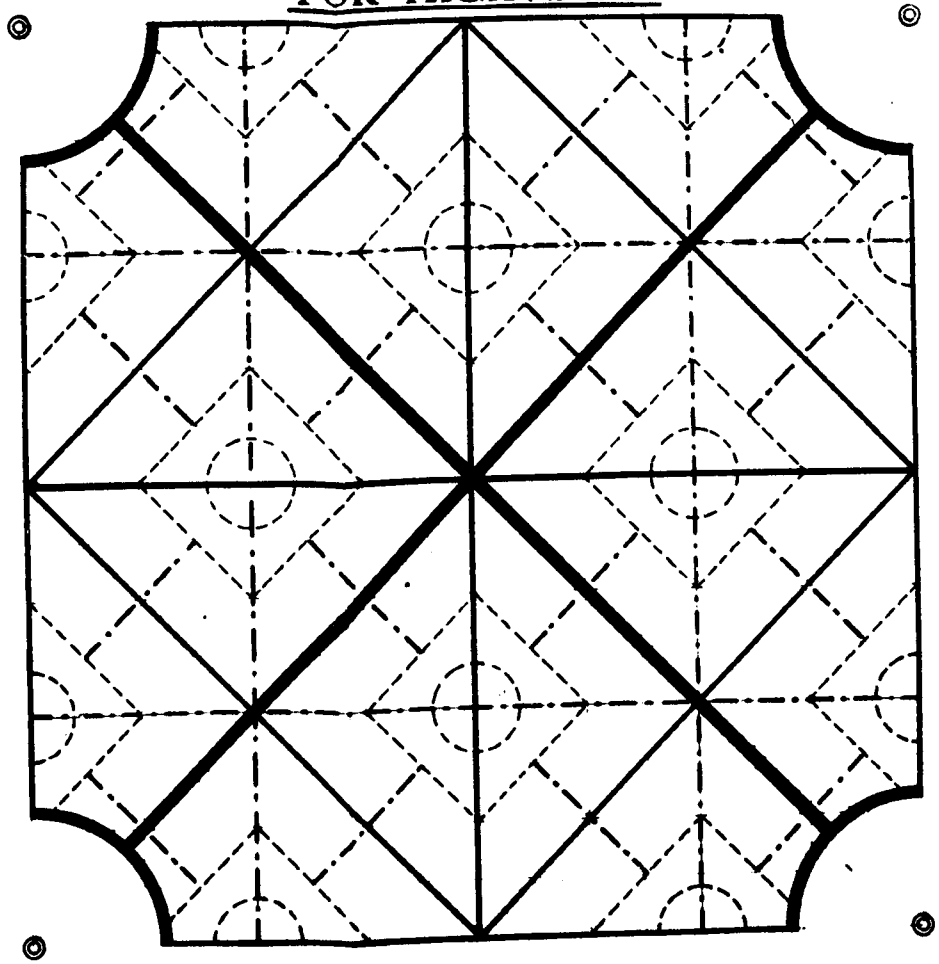


PLATE I-A

SYMBOLIC REPRESETATION
—OF THE—
WEB AND LATTICE PATTERN
—FOR HIGHWAYS—



LEGEND

NATIONAL HIGHWAYS & STATE HIGHWAYS
MAJOR DISTRICT ROADS
OTHER DISTRICT ROADS
VILLAGE ROADS

PLATE II

HYPOTHETICAL REPRESENTATION OF INFLUENCED AREAS OF THE
— TOWNS AND CITIES WITH POPULATION —
— OF 20,000 AND ABOVE, ON WEB & LATTICE PATTERN —

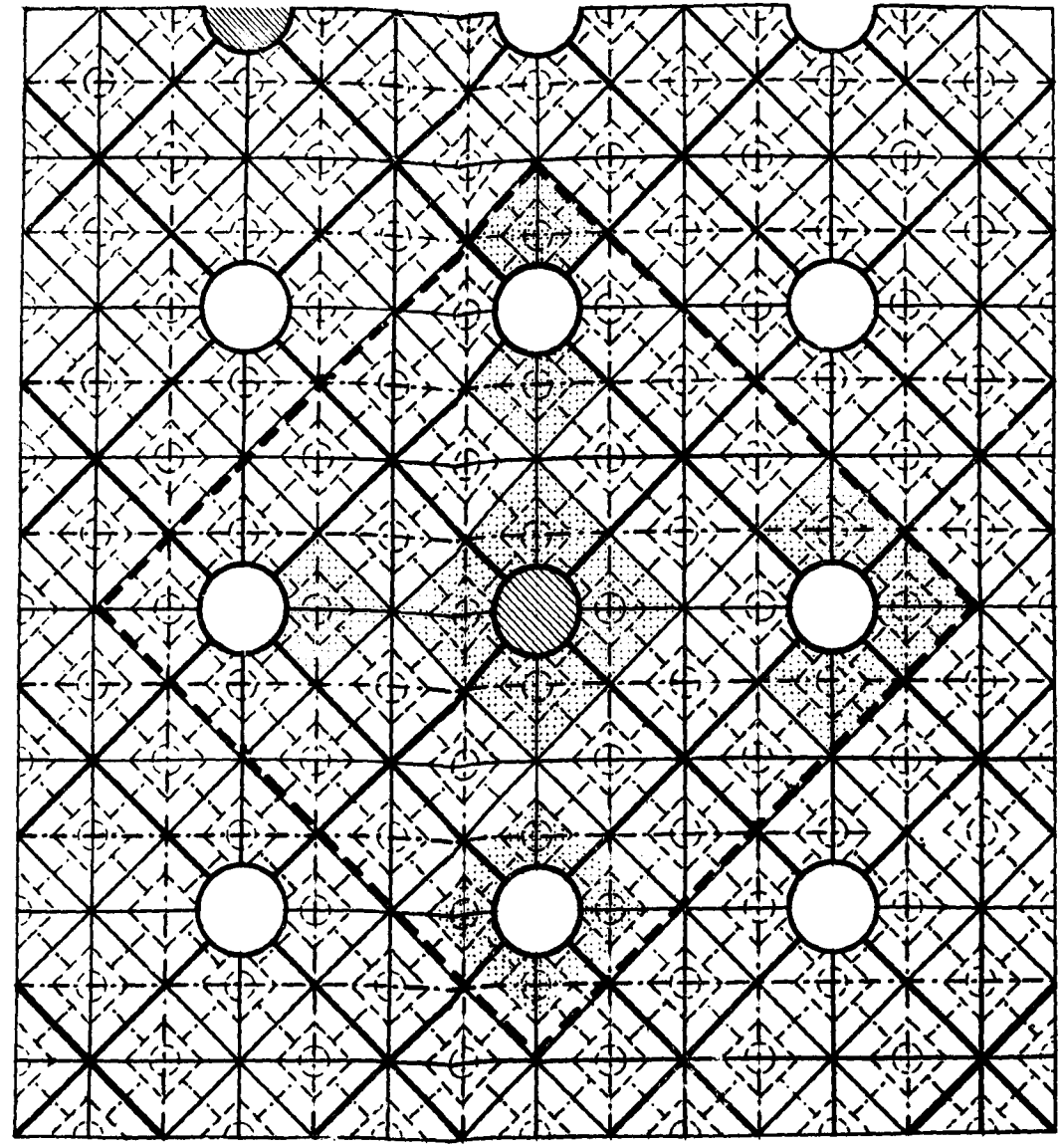
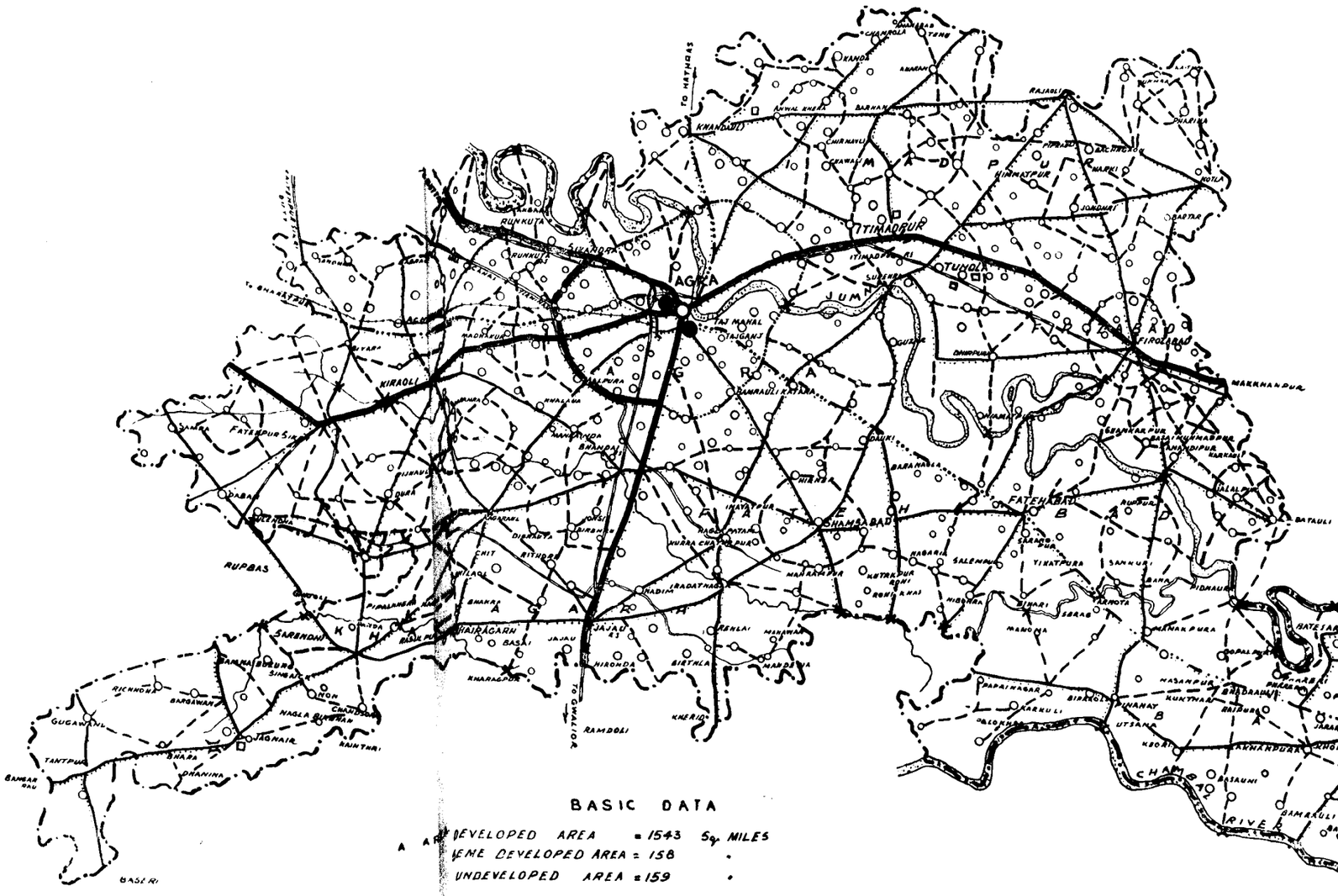


PLATE III



REFERENCES

CATEGORIES	SYMBOL: EXISTING ROADS	SYMBOL: NEW ROADS	MILAGES: AS MEASURED	MILAGES: AS PER FORMULA
N.H			92	70 *
S.H			110	124 *
M.D.R			384	387
O.D.R			870	869
V.R				
			TOTAL 1456	1450

* THIS DIFFERNCE IS DUE TO THE ALL INDIA COMPLEX OF NATIONAL HIGHWAYS.

BASIC DATA

A. AREA:
- DEVELOPED AREA = 1543 Sq. MILES
- SEMI DEVELOPED AREA = 158 "
- UNDEVELOPED AREA = 159 "
- TOTAL = 1860 "

B. POPULATION:

VILLAGES WITH POPULATION BELOW		NUMBER	SYMBOL
500		500	·
500	1000	364	o
1000	2000	223	O
2000	5000	100	O
5000	10000	11	□
10000	20000	—	
20000	50000	1	●
50000	100000	1	●
ABOVE 100000		1	●

MAP OF AGRA DISTRICT
SHOWING ROAD DEVELOPMENT ON "WEB AND LATTICE" (REGIONAL) PATTERN

MILES 5 4 3 2 1 0 5 10 MILES

A Note for Panel Discussion

"THE USE OF LOW GRADE AGGREGATES IN ROAD CONSTRUCTION"

By

CENTRAL ROAD RESEARCH INSTITUTE

CONTENTS

1. INTRODUCTION

In the future road development programme of the country, construction of a few thousand miles of road is envisaged. The specifications for the common type of road consist in providing stone soling or burnt brick, whichever is cheaply available, in the base course, and stone metal in the upper course. It is possible to attain the desired target in areas where stone is readily available but at places where stone is not available at economical distance the cost of road construction goes up very high and at places may even be prohibitive. At such places, attempts have been made in the past to use some other inferior type of aggregates which may be available at site.

The strength of such aggregates varies not only from quarry to quarry but also within the same quarry. Consequently, their use has resulted in widely varying and unpredictable behaviour, which in turn has shaken the faith of the road engineer in their use for permanent road construction. The present position is that such aggregates are avoided as far as possible.

As a result of systematic study carried out, it has been shown that there are large deposits of the low grade aggregate

fairly well spread out throughout the country which can be made use of economically even where the cost of the stone metal is not very high, provided a scientific control on usage is exercised.

The natural low grade aggregate can be broadly classified into the following categories :

(i) Kankar (nodular or calcareous),

(ii) Moorum (light or dark red coloured gravel),

(iii) Laterite,

(iv) Slate.

A few hundreds of samples were collected from different parts of India and their general location is shown in the map given in Plate I.

These soft aggregates when quarried consist of coarse material mixed up with fine material in varying proportions. The fine fraction may again vary widely in plasticity from very sandy to very clayey and influence to a large extent the behaviour of such aggregate during wet weather. The suitability of these materials would, therefore, depend to a great extent on the percentage of coarse fraction which can be separated from the mixture.

For purposes of the present discussion only the aggregate free from fine material has been considered.

2. TESTS

A number of laboratory tests have been adopted in the various countries to assess the value of an aggregate in actual road usage. Important amongst these are : Los Angeles Abrasion Test, the Deval's test, the Crushing Strength Test and the Aggregate Impact Test. It is found that the American Los Angeles abrasion test is the most informative but the British Crushing Strength Test gives fairly comparative values and being simpler is adopted in most of the countries. Since the crushing strength test requires expensive machinery, the aggregate impact test which gives fairly concordant values and is very simple in technique has recently begun to be used in field laboratories. The same test has, therefore, been used in the study referred to above as a single test for determining the aggregate value of the large number of soft aggregates collected from various parts of India. The aggregate impact values of kankar, laterite and moorum are given in Table 1.

It will appear from the results that the impact value generally varies from 15-50 with a large majority of samples having aggregate impact value ranging between 30 and 40. The lower values of 15-20, which some of the nodular kankars have, are comparable with that of good hard stone. The higher values of 40-50 correspond to those of well burnt brick. It can, therefore, be seen that almost all these materials can confidently replace burnt brick in the soling and some of these can even be used in the upper course in place of stone metal.

Resistance to softening effect of water

There are certain types of soft aggregates such as laterites and shales which vary widely in strength in the dry and saturated states. Some of these which have an aggregate impact value of more than 35 show a tendency to get soft when they come in contact with water. These materials are, therefore, not suitable to be used in the upper course of unsurfaced roads, as in the presence of water they get soft and wear quickly causing a slushy condition of the road. However, they have a definite place in the base courses of the roads and the depth below the road surface at which these can be safely used, can be determined from the soaked C.B.R. test.

In the background of latest accepted practices elsewhere and as a result of laboratory studies, combined with whatever reports on field behaviour are forthcoming, tentative suggestions for the increased use of low grade aggregates on a scientific basis have been made.

3. TENTATIVE SPECIFICATIONS FOR USE OF LOW GRADE AGGREGATE* IN ROAD PAVEMENT

Note : As a result of testing a large number of soft aggregates it was found that aggregate impact test values bear a good correlation with the Los Angeles abrasion test value, which has already been found to give good correlation with field behaviour. The aggregate impact value test has, therefore, been referred to for soft aggregate in the tentative specifications.

These specifications can be split up into the following sections :

(i) Surface-treated water-bound macadam and soling courses in areas of low water table (water level deeper than 6 ft from the subgrade).

* Laterite, kankar, moorum, shale, brick bat etc.

(ii) Surface-treated water-bound macadam and soling courses in case of high water table.

(iii) Unsurfaced water-bound macadam and soling courses in areas of low water table.

(iv) Unsurfaced water-bound macadam and soling courses in areas of high water table.

(1) Surface-treated water-bound macadam and soling courses in areas of low water table

(i) Low grade aggregate with dry aggregate impact value of not more than 35 shall be used as metal in the surface-treated water-bound macadam road carrying medium traffic of about 1,000 tons per day.

(ii) The aggregate with dry aggregate impact value of not more than 60 shall be used as soling in the surface-treated water-bound macadam road for all traffic intensities.

(2) Surface-treated water-bound macadam and soling courses in areas of high water table

Aggregate with dry aggregate impact value of not more than 35 shall be used as a metal in the surface-treated water-bound macadam road carrying medium traffic of about 1,000 tons per day.

(3) Unsurfaced water-bound macadam and soling courses in areas of low water table

(i) Aggregate with dry aggregate impact value of not more than 35 shall be used as metal in the unsurfaced water-bound macadam road carrying very light traffic of about 200 tons per day.

(ii) Aggregate with wet aggregate impact value of not more than 60 shall be used as soling in the unsurfaced water-bound macadam road for all traffic intensities.

(4) Unsurfaced water-bound macadam and soling courses in areas of high water table

(i) Aggregate with dry aggregate impact value of not more than 35 shall be used as metal in the unsurfaced water-bound macadam road carrying very light traffic of about 200 tons per day.

(ii) Aggregate with wet aggregate impact value of not more than 60 shall be used as soling in the surface-treated water-bound macadam road for all traffic intensities.

Note: (1) In the case of aggregates with dry or wet aggregate impact value exceeding 60, they could be used in sub-bases, provided the total thickness of the crust above is determined scientifically, say, by the standard C.B.R. method.

(2) In the case of calcareous aggregates which have cementitious properties, the aggregate should first be compacted in the laboratory in the presence of water and then allowed to cure for a week or so. The sample should then be saturated and its C.B.R. determined. From this, the thickness of inert aggregate required over it for the local traffiic conditions should be determined. This is necessary so as to give due credit to the cementitious properties of the material.

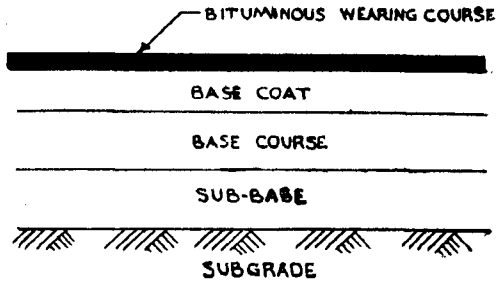
Before the tentative recommendations are adopted, it would be useful to exchange information between various regions as to the manner in which low grade aggregates have been used so far and the results that have been achieved along with economic implications.

A questionnaire has been framed with a view to assist in the collection of such information and to keep the discussions within the scope of the subject.

4. QUESTIONNAIRE FOR DISCUSSION ON THE USE OF SOFT AGGREGATES IN ROAD CONSTRUCTION

Since soft aggregates can be used in different layers of the road structure for purposes of discussion, it is essential that the exact nomenclature of the various layers should be defined. The terms used in the questionnaire have been taken out from the

Indian Roads Congress Journal, Vol. XXII-3, December 1957, pp. 545 to 548. For ready reference, a rough sketch is given below:



GENERAL

(1) (a) What are the different types of soft aggregates (kankar, moorum, laterite, slate, etc.) available in your State?

(b) Are the deposits substantial or petty?

(c) What is the maximum and minimum size of such aggregates?

(2) (a) Do you use soft aggregates in road construction either as a sub-base, base course or base coat?

(b) If so, what is the length of such roads constructed in your State?

(c) How does the cost of such roads compare with other types of conventional roads?

(3) (a) If used in the base coat, are such roads given bituminous treatment or not?

(b) If so, what length?

(4) (a) What is the type and intensity of traffic on such roads?

(b) If bullock carts ply, what is the usual load and weight?

(5) **Compaction**

(a) What thickness of loose layer is generally laid for compaction at a time for sub-base, base course and base coat?

(b) What is the compacting unit, whether a heavy or light roller, and how do you find its performance?

(6) **Specifications**

(a) What are the specifications for the material used in (i) sub-base (ii) base course (iii) base coat (iv) wearing coat?

(b) Are admixtures such as sand and clay added to the soft aggregates? if so, how?

(c) Do you follow soil-gravel road system while proportioning the admixtures?

(7) (a) What is the climatic condition of the area where such roads have been laid such as rainfall and position of the water table?

(b) How are the roads behaving where soft aggregates have been used with and without bituminous wearing coat in (i) wet weather (ii) dry weather?

(8) (a) Has any attempt been made to replace stone soling or metalling with such soft aggregates in water-bound macadam roads?

(b) If so, what is the behaviour of such roads during (i) wet weather (ii) dry weather?

(c) What is the cost of soft aggregates at quarry as compared to the cost of stone boulders or stone metal?

(9) **Surfacing**

(a) What is your experience of the performance of bituminous wearing coat over a base coat where soft aggregates have been used?

(b) In such cases, do you find a priming coat necessary ? If so, at what rate of application ?

(10) **Design of pavement**

What criterion do you adopt for determining pavement thickness ?

(11) How can the scientific use of low grade aggregates be made popular ?

TABLE 1

Test results on inferior aggregates

S. No.	Type of aggregate	Lab. sample No.	Los Angeles abrasion value per cent	Bulk density in lb per cu. ft.	Aggregate impact value	Absorption after 24 hours per cent	Sp. gravity passing No. 10 B.S.
1.	L	1771	40.28	93.0	35.10	3.33	2.71
2.	L	1772	36.04	94.5	29.60	4.24	3.42
3.	L	1778 S	77.60	85.0	52.50	4.00	3.03
4.	L	1779	37.60	77.4	29.40	3.31	2.78
5.	L	1780	36.60	75.0	31.00	4.50	2.86
6.	L	1781	40.10	77.0	30.60	4.00	2.75
7.	L	1782 S	50.00	74.0	36.50	5.26	2.90
8.	L	1785	26.76	90.0	22.90	5.52	3.30
9.	L	1786	27.20	91.5	26.40	6.33	3.38
10.	L	1787 S	48.48	87.5	42.30	3.33	2.86
11.	L	1788	32.60	98.0	24.05	3.36	3.41
12.	L	1792	40.80	78.7	47.30	4.29	3.08
13.	L	1794 S	46.00	70.5	47.45	4.42	3.05
14.	L	1807	37.00	90.5	32.10	3.42	3.50
15.	L	1823	41.20	81.5	41.40	5.50	3.03
16.	L	1824	42.40	80.5	44.90	5.90	2.75
17.	L	1826	43.60	80.0	52.70	6.00	3.09
18.	L	1827 S	41.00	79.0	46.30	6.39	3.29
19.	L	1828	42.70	80.5	45.30	5.92	3.20
20.	L	1829 S	46.60	76.3	53.00	3.34	3.14
21.	L	1834 S	57.00	72.0	56.15	4.87	2.83
22.	L	1836 S	53.00	76.0	50.60	4.70	2.97
23.	L	1837	38.80	101.0	39.50	4.66	3.58
24.	L	1838 S	40.20	96.5	31.70	4.17	3.90
25.	L	1839 S	33.20	100.0	31.70	4.85	3.54
26.	L	1848	31.00	82.0	32.30	5.51	3.05
27.	L	1851	23.60	77.8	30.06	6.60	3.08
28.	L	1852	33.70	78.5	30.40	4.65	3.42
29.	L	1853	37.30	82.5	38.30	2.80	3.33
30.	L	1854 S	40.00	80.0	30.20	3.47	2.78
31.	L	1855	37.40	84.5	34.10	3.72	3.38
32.	L	1856	25.00	79.0	30.80	2.99	2.77
33.	L	1858	37.60	80.5	36.20	4.53	3.30
34.	L	1867 A	37.60	85.0	34.90	3.03	2.98
35.	L	1867	37.60	82.0	33.55	2.88	2.92
36.	L	1868 S	64.00	84.0	41.00	6.34	2.98
37.	L	1861	33.00	79.0	31.15	3.97	2.93
38.	L	1873 S	60.80	77.0	50.30	6.05	3.09
39.	L	1875 S	53.60	63.5	47.70	3.89	3.29
40.	L	1876 S	50.00	65.0	30.70	7.10	2.98
41.	L	1877 S	27.80	80.0	26.60	6.80	3.48
42.	L	1878 S	54.00	76.0	46.05	4.02	3.02
43.	L	1879	32.00	82.5	33.30	4.90	3.06
44.	L	1871 S	43.20	85.0	37.50	4.20	3.33
45.	L	1883 S	41.00	101.0	32.45	3.04	3.18

TABLE 1—(*Contd.*)

S. No.	Type of aggregate	Lab. sample No.	Los Angeles abrasion value per cent	Bulk density in lb per cu. ft.	Aggregate impact value	Absorption after 24 hours per cent	Sp. gravity passing No. 10 B.S.
46.	L	1881 S	42.20	76.50	39.50	6.20	3.34
47.	L	1894	26.80	89.50	25.70	3.90	3.33
48.	L	1905	22.00	80.00	23.95	4.33	3.16
49.	L	1907	34.67	81.50	29.60	6.40	3.21
50.	L	1908 S	47.00	81.00	36.00	2.85	2.94
51.	L	1900 S	45.80	77.00	36.30	4.52	3.04
52.	L	1911 S	44.00	85.50	41.90	5.52	3.38
53.	L	1912 S	47.60	81.80	39.50	4.53	2.97
54.	L	1935	37.60	85.98	32.10	5.72	2.82
55.	L	1939	30.60	82.67	27.10	6.00	3.03
56.	L	1949	47.20	85.98	30.85	5.3	3.12
57.	L	1950 S	40.00	85.98	31.09	5.70	3.24
58.	L	1951	33.80	85.98	25.05	7.75	3.41
59.	L	1957	27.80	78.04	29.35	7.90	3.13
60.	L	1964	49.00	72.75	52.50	4.90	3.16
61.	L	1966	37.00	43.41	47.45	5.35	3.23
62.	L	1968	32.80	72.75	41.00	6.25	3.37
63.	L	1980 S	42.60	83.33	36.00	3.45	2.86
64.	L	1982 S	43.00	79.37	41.50	3.54	3.99
65.	L	1988	36.67	79.37	34.50	3.79	3.16
66.	L	1990	33.00	83.33	35.15	4.33	3.19
67.	L	1991	34.90	81.35	33.40	3.37	2.99
68.	L	1992	37.80	79.37	37.40	4.51	3.06
69.	L	1993	31.50	84.66	32.75	2.80	3.08
70.	L	2146	34.00	88.62	32.90	2.32	3.32
71.	L	2147	33.40	86.64	31.05	2.74	3.39
72.	L	2169	46.60	77.38	48.70	4.45	3.41
73.	L	2170	50.00	81.35	38.40	2.34	3.17
74.	L	2187	32.00	89.95	38.40	3.27	3.33
75.	L	2188	27.60	92.59	28.25	2.59	3.34
76.	L	2190 S	41.90	78.04	39.70	4.69	3.25
77.	L	1869	34.10	173.30	23.70	4.00	2.83
78.	L	1930	48.10	156.20	26.80	5.30	2.89
79.	L	1754	28.40	118.10	47.70	9.20	3.32
80.	L	1789	33.30	132.90	38.60	7.40	3.32
81.	L	1790	33.40	122.00	31.00	10.40	2.85
82.	L	1791	33.40	121.60	28.20	10.00	3.10
83.	L	1865 S	96.50	130.80	76.80	7.20	2.67
84.	L	1866 S	96.70	128.50	73.60	7.30	2.60
85.	L	1903	45.20	121.10	31.60	22.80	3.88
86.	L	1850	41.80	143.60	30.70	5.20	2.85
87.	L	1917 S	43.70	124.90	41.80	14.00	2.85
88.	L	1965	41.00	126.50	41.80	9.80	2.20
89.	L	1989	28.90	140.70	35.70	8.60	2.82
90.	L	1806	47.00	178.30	34.60	4.30	3.73

TABLE 1—(*Contd.*)

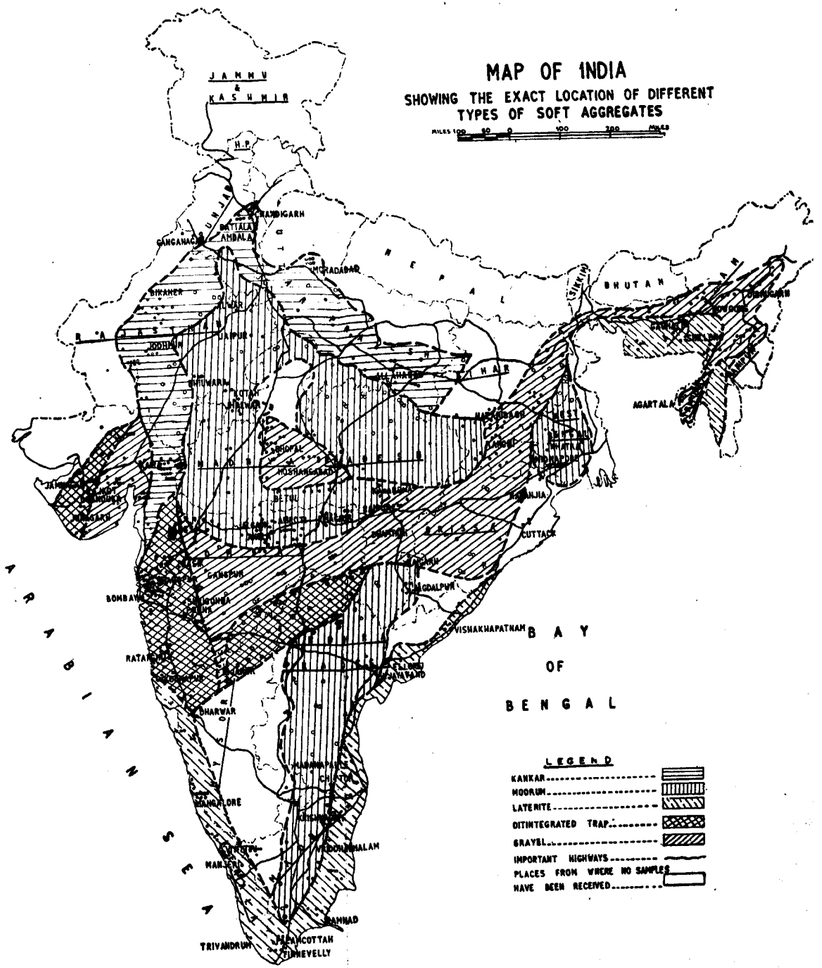
S. No.	Type of aggregate	Lab. sample No.	Los Angeles abrasion value per cent	Bulk density in lb per cu. ft.	Aggregate impact value	Absorption after 24 hours per cent	Sp. gravity passing No. 10 B.S.
91.	L	1808 S	39.00	182.82	33.40	4.80	3.59
92.	L	1857	31.50	116.10	37.00	16.90	4.60
93.	L	1859 S	34.00	159.10	37.80	6.60	4.11
94.	L	1793 S	44.60	130.00	42.40	9.60	2.81
95.	L	1882 S	42.20	166.00	33.40	5.70	2.79
96.	L	1906 S	41.50	147.60	39.70	10.00	2.69
97.	L	1981 S	43.20	138.80	40.60	7.80	2.57
98.	L	1795 S	64.20	136.60	47.00	7.60	2.38
99.	L	1948 S	37.00	145.30	24.20	6.20	2.48
100.	L	1833		121.30	45.70	13.20	2.63
101.	L	1847	31.30	148.60	26.10	6.30	2.79
102.	L	1872	24.20	130.10	23.20	10.70	2.82
103.	L	1874	62.10	125.80	50.80	12.90	2.75
104.	L	1896	69.80	114.90	45.50	16.00	2.95
105.	L	1897	25.60	142.50	24.10	7.10	2.48
106.	L	1940	24.10	138.70	21.50	9.00	2.77
107	L	1880	—	161.10	28.60	7.10	2.10
108.	L	1821 S	79.90	182.40	64.40	23.60	2.63
109.	L	1832 S	58.80	114.80	37.30	14.10	2.27
110.	L	1825 S	40.80	129.10	33.00	10.80	2.64
111.	L	1916	19.30	163.70	15.90	6.40	3.34
112.	L	385 S	35.90	96.19	31.9	1.93	2.80
113.	M	394 S	43.43	92.18	38.9	3.99	2.77
114.	M	471 S	43.43	84.33	38.9	6.67	2.78
115.	M	280	31.48	91.85	27.8	2.22	2.95
116.	U	285	29.34	85.76	35.1	18.13	2.79
117.	U	286	26.21	105.13	22.9	2.32	3.10
118.	U	288 S	45.15	104.81	40.5	3.29	3.00
119.	U	304 S	33.53	97.59	29.7	4.77	3.00
120.	U	329	36.86	82.42	32.8	6.36	2.77
121.	U	338 S	39.77	84.31	35.5	3.75	2.75
122.	U	347	21.59	93.54	18.6	1.56	2.72
123.	U	348	21.47	97.64	25.0	3.10	2.73
124.	M	360	26.86	82.94	23.5	6.27	2.78
125.	M	367 S	70.64	110.76	64.1	1.97	2.73
126.	M	396 S	54.61	93.98	49.3	2.18	2.76
127.	M	693 S	62.14	100.85	47.0	1.94	2.74
128.	M	451	41.81	81.94	37.4	6.26	2.80
129.	U	431 S	50.42	90.72	45.4	1.60	2.86
130.	U	622 S	45.36	93.87	40.70	1.91	2.74
131.	U	306	30.41	96.03	26.8	3.06	2.95
132.	U	307	30.52	83.66	26.9	3.20	2.74
133.	M	334	33.85	99.07	30.0	1.38	2.91
134.	U	374	40.95	—	36.6	—	2.70
135.	M	378	30.84	99.66	27.2	3.63	2.88

TABLE 1—(*Contd.*)

S. No.	Type of aggregate	Lab. sample No.	Los Angeles abrasion value per cent	Bulk density in lb. per cu. ft.	Aggregate impact value	Absorption after 24 hours per cent	Sp. gravity passing No. 10 B.S.
136.	K	387	26.75	88.24	23.4	3.46	3.17
137.	U	417	20.40	103.97	17.5	1.66	2.91
138.	U	418	23.63	101.95	20.5	1.45	3.03
139.	U	419 S	44.63	102.81	39.9	3.38	2.98
140.	U	420	14.38	106.88	11.9	1.46	3.04
141.	U	421	30.30	98.40	26.7	2.56	2.82
142.	U	384 S	33.64	89.26	29.8	3.00	2.79
143.	U	439 S	29.98	90.64	26.4	2.66	2.93
144.	U	443 S	30.09	83.42	26.5	7.63	2.85
145.	U	444	19.01	100.00	16.2	1.03	2.93
146.	U	446 S	49.01	90.64	34.8	2.32	3.26
147.	U	448	26.24	88.82	22.0	3.99	2.88
148.	U	449	22.02	92.18	39.0	3.00	3.00
149.	M	465	30.84	89.85	27.2	2.75	2.84
150.	U	488 S	44.72	—	40.1	—	2.70
151.	U	491 S	41.27	82.67	38.9	6.78	2.82
152.	U	505	23.65	82.77	20.5	8.39	2.65
153.	U	508	22.56	104.40	19.5	2.58	2.95
154.	K	511 S	40.31	83.07	36.0	5.52	2.61
155.	K	512	25.14	85.58	21.9	6.24	2.57
156.	K	513	25.03	89.83	21.8	4.80	2.50
157.	M	574 S	43.75	109.60	39.2	6.16	2.65
158.	M	575	35.36	87.22	31.4	5.59	2.76
159.	U	592	20.94	96.32	18.0	2.33	2.87
160.	K	609	31.59	86.30	27.9	2.95	2.43
161.	U	611 S	32.24	96.32	28.5	4.93	2.57
162.	U	612	27.07	94.25	23.7	1.61	2.74
163.	U	624	26.54	84.66	23.2	8.15	2.91
164.	U	626 S	22.77	102.81	19.7	1.57	2.73
165.	U	626	38.37	83.82	34.2	4.60	2.81
166.	U	628	30.41	86.92	26.8	2.97	2.87
167.	U	629 S	38.37	80.40	34.2	7.45	2.71
168.	U	638 S	41.81	72.03	37.4	10.29	3.26
169.	U	445 S	34.39	91.34	30.5	7.12	2.77
170.	U	625	59.59	82.99	53.0	3.3	3.05

Note : X Interpolated value.
L Laterite.
M Moorum.
K Kankar.
U Undifferentiated.
S Softens under water.

PLATE I



GENERAL REPORT
ON
ROAD RESEARCH IN INDIA
1958-59

GENERAL REPORT ON ROAD RESEARCH IN INDIA 1958-59*

CONTENTS

INTRODUCTION

With this report, the Indian Roads Congress would have so far published four reports on Road Research in India. Year after year more and more engineers are taking part in the general discussion on road research and it could be justifiably stated that this forum is serving the purpose of co-ordinating the work of the different laboratories as well as bringing the field engineer in touch with the research man.

Reports received this year bring out the fact that construction engineers are consulting the laboratory wing in many States for problems connected with construction of new highways, use of local materials in road construction and for studying pavement failure problems. This is a very encouraging trend.

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* Compiled by the Director, Central Road Research Institute, New Delhi.

Another significant development worthy of mention is the taking up of co-operative research projects by several research laboratories in this country.

As in the previous years, this general report was prepared on the basis of reports received from the following Road Research Institutes of the country and where it was possible to have access to other reports, advantage was taken of them too though full reports had not been received:

1. Central Road Research Institute, New Delhi.
2. Engineer Research Wing of the College of Military Engineering, Kirkee.
3. Highways Research Station, Madras.
4. P. W. D. Research Institute, U. P., Lucknow.
5. Soil Research Division of Bihar P.W.D., Patna.
6. R. & B. Research Institute, West Bengal.
7. B. & R. Research Laboratory, Karnal.

It is quite likely that there might be a few omissions due to some of the reports not being received in time for the compilation of the report. All such omissions may be brought up during discussions, so that they are not lost sight of.

After briefly reviewing the work done, salient points are given at the end of each section for the sake of discussion in the open session.

I. DESIGN, CONSTRUCTION AND MAINTENANCE

1. RIGID PAVEMENTS

1.1. Design

One of the points of interest, for the present, in the field of rigid pavement design is the work that is being continued by the Central Road Research Institute in connection with the measuring of temperature differentials in concrete pavements with a view to have better idea on the order of thermal stresses in these pavements. Similar work is being taken up by the Madras Highway Research Station also.

1.2. Construction and maintenance

1.2.1. General

In the present stage of industrial development of the country, thick concrete pavements are being constructed,

particularly in heavy factory areas. For factory roads at Heavy Electricals, Bhopal, 12 in. thick concrete pavement is laid in single pour and constructed as a monolith. To achieve proper compaction in such cases, internal vibration is employed in the absence of heavy modern machinery.

1.2.2. Field experiments

Pavement for tracked vehicles

In continuation of what has been reported in previous years, work was continued on this problem in the College of Military Engineering, Kirkee[1]. Based on field trials on concrete pavements topped with materials like ironite and carborundum powder and on stone-sett pavements, the trend of results reported indicates the following: (i) The resistance to wear is dependent on the strength of concrete. It was observed that 1 : 2 : 4 concrete having strength of 2,500 lb per sq. in. gets abraded much faster than concrete having higher strength. (ii) Performance of stone-sett pavements was reported to be very satisfactory as compared to concrete pavements and that stone-sett pavements withstand the load and abrasive action of the tracked vehicles. (iii) The only disadvantage pointed out in regard to this kind of pavement is the jarring and rattling effect produced on the vehicle and its crew when the vehicles move fast, due to the unevenness of the pavements.

Grouted Cement Concrete Experiments

The field experiments on grouted concrete reported last year are being continued.

1.3. Laboratory Research

1.3.1. Use of admixtures in concrete

The work [2] carried out at the Highways Research Station, Madras, has shown that with the use of Febmix Admix, (5 fluid ozs/cwt of cement), the setting time of the cement was decreased, the yield of mortar increased and the tensile strength and compressive strength of mortar of different W/C ratios were increased. Similarly, the addition of Melgan A decreased the setting time of cement, affected reduction of mixing water for the same consistency and improved the workability. However, the use of Melgan A resulted in reduction of both the compressive and tensile strengths to the extent of about 20 per cent.

The experiments conducted at the U.P., P.W.D. Research Institute, Lucknow[3], have also shown that the use of Febmix in concrete increased its workability as well as tensile and compressive strengths.

The work done at the same Institute on the use of Feberete, claimed to be an air-entraining agent, indicated increase in the workability of concrete and reduction in its strength.

The work[4] carried out at the Central Road Research Institute has shown that entrainment of 4.5 per cent of air in concrete with the use of vinsol resin, by suitably adjusting the W/C ratio and S/A ratio of the air-entrained concrete, resulted in higher compressive and flexural strengths and higher resistance to abrasion of concrete as compared with parallel plain concrete. Such air-entrained concrete also showed better workability and reduced bleeding compared to plain concrete. The experiments on the effect of entrainment of air on the resistance of concrete to sulphate attack and to weathering action, consisting of heating and cooling and wetting and drying, have shown that there is a marked increase in the resistance of concrete to sulphate attack and about 50 per cent increase in weathering durability.

1.3.2. Use of pozzolanas in concrete

Work[5] at the Central Road Research Institute, on partial replacement of cement by surkhi in concrete, has revealed that the type of surkhi and its mode of preparation may be different for the different properties sought to be attained. The workability and bleeding characteristics of the surkhi concrete are greatly influenced by the fineness of the surkhi. With a highly reactive surkhi, replacement upto 25 per cent of cement in concrete is possible with very little loss in strength and somewhat increased resistance to abrasion. A number of surkhis have been found to give high resistance to alkali aggregate reaction in concrete, while some surkhis burnt at higher temperature give increased resistance to sulphate attack also.

Experiments conducted in the C.R.R.I., to study the effect of fineness of surkhi on its reactivity, have shown that the pozzolanic reactivity increased with the increase in fineness of surkhi.

The work of the U.P., P.W.D. Research Station in connection with use of surkhi and shale as pozzolana as mentioned in earlier reports is continuing.

1.3.3. Tests on cement and concrete

Mix proportions

The method recommended by the C.R.R.I. to determine the mix proportions of hardened mortar and concrete has been used in analysing a large number of samples at the U.P., P.W.D. Research Institute, Lucknow. It has been observed that if the loss on ignition is taken into account, the chances of error in this method could be reduced.

Vibration compaction

Based on the laboratory experiments conducted in C.R.R.I., it is suggested that vibratory method of compacting cement-sand mortar briquettes for tensile test is to be preferred to other existing methods since the personal factor is eliminated in this method. It is found that this method gives more uniform results.

Relationship between W/C and compressive strength of concrete made with Indian cements

This relationship is basis for all concrete mix designs. The C.R.R.I. has completed work to find out the relation between W/C ratio and compressive strength of concrete with two more Indian cements.

1.3.4. Membrane curing of concrete

The work carried out in the P.W.D. Research Institute, U.P.,[3] has revealed that S. V. Ceremul, a product of Standard Vacuum Company, could be used in place of water curing in places where there is scarcity of water. The institute has recommended field trials with this product in arid regions of India.

The experiments conducted at the Highways Research Station, Madras [2], have shown that the alkathene film can be used for curing of concrete in places where there is acute scarcity of water.

1.3.5. Alkali aggregate reaction

The research work conducted at the C. R. R. I., to further verify the pessimum ratio concept, has shown that for several types of reactive minerals, there is a certain level of alkali in the cement which gives maximum expansion. Below and above this alkali content, the expansion is reduced. The work has indicated the possibility of harmful expansion even with low alkali cements when the percentage of reactive minerals in aggregate is also low. It has also been shown that there is a certain minimum percentage of alkali content which is required for each

type of mineral for the reaction to take place. Minerals like opal and pyrex glass have been found to require less alkali for reaction, while certain less reactive minerals like Rhyolites and Volcanic glasses required comparatively higher percentages of alkali for the reaction. Experiments have further shown that sodium oxide gives higher expansion of mortar bars as compared with that given by an equivalent amount of potassium oxide in the cement.

Further studies on the preventive measures for alkali aggregate reaction, carried out in the C. R. R. I., have shown that montmorillonitic and kaolinitic clays require burning temperatures of 800°C. while illitic clays require a temperature of 1000°C. to give maximum benefit against alkali aggregate reaction.

1.3.6. Abrasive resistance of cement and mortars

The investigations carried out at the C. R. R. I. have shown that the introduction of gaps in the sand grading in different size fractions does not materially affect the compressive and flexural strength if the surface areas, water/cement ratio and cement/sand ratio are kept constant. On the other hand, the introduction of gaps in the finer fractions of sand, viz., sieve size BS No. 25-52, No. 52-100 and No. 25-100, appreciably improved the abrasive resistance of mortars. However, the introduction of gaps in coarser fractions such as sieve size BS No. 7-14 and No. 14-25 did not result in any improvement in the abrasive resistance.

1.3.7. Joint sealing compounds

CME Kirkee continued the work on joint sealing compounds for airfields using jet aircraft. It was mentioned in previous years' report that these compounds developed blisters on mere exposure to sun. Experiments conducted so far indicate that "the blisters are caused due to entrapped air and moisture in concrete".

Laboratory investigations by the College of Military Engineering, Kirkee [1], have shown that joint sealing compounds having a softening point higher than 90°C. do not develop blisters but that such compounds failed in the extension test at low temperatures. Addition of rubber improved the elastic properties of the compounds.

In the C.R.R.I. different types of fibre boards are being impregnated with bitumen to study their use for joint fillers.

1.4. Overlays

As some of the existing pavements are unable to stand the present increasing traffic loads, with a view to have better understanding on stregthening the pavements, experiments are in progress for both rigid and flexible overlays.

1.5. Prestressed Concrete

Research on prestressed concrete, being one of the sponsored research schemes, is taken up by the Madras Highways Research Station. Work is just being started on the use of prestressed slabs and blocks in the strengthening of culverts and small span bridges.

In this series of tests it is proposed to try out prototype members both for culverts and small span bridges. The primary objectives for the experimental observations are stated to be :

1. Evolving a design for a pretensioning bed.
2. Evolving suitable designs for the structural members.
3. Behaviour of pretensioned member during manufacture.
4. (a) Behaviour under static load.
   (b) Pattern of cracking and mode of failures under super loads.
   (c) Load-deflection characteristics.
   (d) Ultimate load investigation.
5. Behaviour of pretensioned member subject to repeated loads.

Laboratory investigations are in progress in C.R.R.I. to find out ways and means of reducing subgrade friction in prestressed concrete pavement during construction.

Salient points

1. Feasibility of using air-entrained concrete for pavement construction.
2. Use of reactive pozzolanas in concrete for roads.
3. Joint sealing compounds.
4. Strengthening of existing concrete pavements.
5. Reinforcement in slabs.

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2. FLEXIBLE PAVEMENTS

2.1. Bituminous Pavements

2.1.1. Design

(i) Pavement thickness

The work on evolving an empirical method for design of flexible pavements is being continued in the Central Road Research Institute. Pavement evaluation studies for both sound and failed portions on roads around Karnal, taken up in this connection, were completed.

Based on the work conducted in the same Institute, a design curve for determining pavement thicknesses required over different types of subgrades for bullock-cart traffic is proposed. This design curve was evolved by extrapolating existing C. B. R. design curve with the aid of elastic theories.

(ii) Pavement performance

Most of the research organisations have reported several investigations on performance of pavements. All these investigations were directed to find causes of road failures and to suggest remedies. This trend is very encouraging because only by such an approach can a realistic design method be worked out.

(iii) Design of dense graded mixtures

The work on design of dense mixtures with the object of obtaining suitable mixtures for Indian traffic and climatic conditions, was continued in the Central Road Research Institute. It was noticed that the same proportion of the aggregates as is obtained from the crusher plants together with the crusher run dust can be employed to get an acceptably dense mixture and a specification based on this has also been laid on one of the national highways.

In order to estimate the absorption of water and the possible swelling of dense carpets in areas subjected to heavy rainfall, a test was developed using a pressure chamber in which the mixture samples were kept under varying temperatures, vacuum pressures and duration. Based on a series of tests conducted, it was found that a test temperature of 140°C. with a vacuum of 10 in. and duration of 30 minutes gives satisfactory conditions.

The compressive strength of bituminous mixtures as given in the A. S. T. M. standards was modified by using a temperature

of 5°C., and based on a series of tests, it was found that the compressive strength of a bituminous mixture at 5°C. is as high as three times that at 25°C. The reproducibility of the results was found to be quite good. Also, the strength value at low temperature was found to be quite sensitive to the variations in binder content which factor is of significant importance in the design of bituminous mixtures.

In order to reduce the cost of asphaltic concrete mixtures, fillers such as silty soil, clayey soil and industrial ash were used in a series of mixtures with varying percentages of binder content and the efficiency of these fillers is being studied with Marshall stability tests, etc.

2.1.2. Construction and Maintenance

(i) Field experiments

Surface dressings: In the Central Road Research Institute an experimental length of test track was designed and laid with the following objectives in view :

1. To determine the correct grade of binder for a single coat surface dressing.
2. To determine the correct quantity of binder required.
3. To determine the quantity and size of aggregates to be employed.
4. To study the efficiency or otherwise of primers.

The entire experimental stretch was laid over a new water-bound macadam carrying about 4,000 tons of traffic per day. The experimental stretch is under observation.

Based on the work in the Research Station of the U. P. P. W. D., it was found that bitumen is more suitable for surface dressing for brick pavements than tar and also that bitumen primer is better than low viscosity road tars. It was also found that simultaneous painting with tar and bitumen using tar for the first coat and bitumen for the second coat was found better than two coat painting with tar alone.

Prefabricated bituminous surfacings: The prefabricated bituminous surfacings as per their new specifications were given a trial on a test track in the CME at Kirkee. As mentioned in the previous year's report, the C. B. R. of the subgrade and its moisture content were determined before and after laying the P. B. S. It was observed that the moisture content rose in the subgrade after monsoons. In the area under the P. B. S.

when tested after two months, there was no reduction in the moisture content, but in the surrounding uncovered area there was a drop in the moisture content. So it is considered essential that for any P. B. S. road, it should be on an embankment of 2-3 feet higher than the surrounding ground level. Also, a side drain of 2-3 ft deep should be provided and linked with P. B. S. to prevent ingress of moisture.

2.1.3. Laboratory research

(i) Open graded premix carpets

Based on laboratory investigations so far conducted on binder aggregate relationship for open graded premixes in the C.R.R.I., it is found that about 4 per cent of bitumen is required for a $\frac{3}{4}$ in. size aggregate. It was also noticed that the increase in quantity of aggregates to be laid per unit area only increases the overall thickness of the carpet and does not materially improve the stability within the carpet. It appeared that the optimum quantity of aggregate per 100 sq. ft. is $1\frac{1}{2}$-2 times the quantity required for shoulder to shoulder coverage, that is, about 9 cu. ft. for $\frac{3}{4}$ in. size.

The work done in the Research Station of the U.P., P.W.D.,[1] indicates that in the case of brick pavements, precoated chippings is definitely advantageous to surface dressing and even better than a two-coat surface dressing.

(ii) Bituminous penetration macadam

In the Central Road Research Institute, an attempt was made to determine the optimum quantity of binder required for a full grout penetration macadam of 2 in. and 3 in. thickness using hot binder. Based on a stability test fabricated in the Institute, and noting the maximum load sustained by the specimens under the plunger, the quantities of aggregates and the optimum quantity of binder required were obtained as being 20 cu. ft. of $1\frac{1}{2}$ in. aggregates with 110 lb of binder for 2 in. macadam and 30 cu. ft. of 2 in. metal with 150 lb of binder for 3 in. macadam. It was also observed that either asphaltic bitumen or tars can be used in equal quantities by weight to give a satisfactory performance.

Work has been done in the Research Station of the U.P. P.W.D.[1] for built up spray grout using brick ballast. It was reported that the surface was excellent even though brick ballast only was used and the cost was the same as for the conventional water-bound macadam with brick ballast and two-coat surface dressing.

(iii) Stripping of bituminous binders under wet conditions

The work of adhesion and stripping is being continued in the Central Road Research Institute, Madras Highways Research Station[2] and also at the Research Station of the U.P., P.W.D.[1] It is reported both by Madras Highways Research Station and by the U.P., P.W.D. Research Station, that use of adhesive agents definitely improves adhesion between wet stone and binder and as such it can be used for construction during rains or during monsoon periods. Adhesive agents tried were adhevia T, Doumeen T, Wet fix, etc. Various other adhesive agents like white lime, etc., were also being tried. According to the U.P. P.W.D. Research Station, it was found that for a surface painting during wet weather, based on experimental strips, the surface with white lime behaved the best.

(iv) Bituminous stabilization of soils

The work in the Madras Highways Research Station[2] indicates that road tar 3 does not act as a good primer over stabilised soil base and that the bituminous wearing course gets separated from the base. Also, effect of binder prepared by blending kerosene oil and napthalinic acid with bitumen RC 3, with and without hydrated lime, for stabilized sand was tried at the Madras Highways Research Station and the results indicate that the strength does not increase very much. The work in the U.P. Research Station indicates that stabilized soil and fine sand mixed with bitumen emulsion disintegrate soon after immersion in water whileas it is not so with coarse sand. It is also observed that soils with emulsion can withstand high loads while dry and as such the use of local soil with emulsion can effectively prevent the dislodgement of stones in a water-bound macadam.

(v) Weathering and oxidation of road tars

In the C.R.R.I., an initial attempt was made to draw up an evaluation test for the effect of oxidation of tars using sand tar mixtures and obtaining their compressive strength, etc. In the second stage, tests were conducted to standardise the procedure for evaporation after noting the effect to thickness of the binder film, using RT-3 which is a popularly used binder. Viscosity tests using micro-viscometer on various binders were conducted and the tests indicate that the viscosity index is much more sensitive than the E.V.T. or the Frass Brittle point for purposes of evaluation.

(vi) Low temperature tar

Samples of tars prepared from low temperature crude tars so as to conform to the specification of RT-4 were subjected to a series of physical tests and also for weathering index in the C.R.R.I. It was found that though from the point of view of viscosity, e.v.t., etc., the samples conform to the specifications of RT-4, the tar acids contained were still at a high level. An attempt to use these tars with straight run bitumen proved a failure but the mixture of the crude low temperature tar itself with an equal quantity of bitumen gave a satisfactory mixture. Further work is being done.

(vii) Analysis of bitumens

In order to study the role played by the phenols in affecting the properties of the road tar, investigations were continued in the C.R.R.I., using tars containing a high quantity of volatile oils. As most of the phenols even in RT-1 are of the middle oil group, crude tar samples obtained from high temperature corbonisation plants, which have a high phenol content, are being analysed.

The U.P., P.W.D. Research Station[1], continues to work with an electro-photometer for studying the effect of over-heating of tar, and bitumen by observing the percentages of light transmitted through a low concentration solution of bitumen in benzene, similar to the work on absorptiometer conducted by the C.R.R.I.

(viii) Analysis of road stones

Road aggregates from different parts of the country are being studied in the C.R.R.I., and the data regarding physical and petrological properties are being collected. Similar work is also being done in U.P., P.W.D. Research Station as well as in the Madras Highways Research Station.

Salient points

1. Criteria for the design of dense carpets.
2. Necessity for mechanisation of bituminous work.
3. Tar bitumen mixtures.
4. Manufacture and use of emulsions.

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2.2. Water-Bound Macadam and Brick Pavements

Extensive work in the laboratory as well as in the field has been conducted by the U.P., P.W.D. Research Station[1], in connection with water-bound macadam and brick pavements.

As regards water-bound macadam, a dilute emulsion has been employed on an experimental strip, using H.R.M. (60 per cent bitumen) emulsion to maintain the water-bound macadam in case the surface painting over it is delayed. It was observed that the surface wherein the emulsion was mixed with local stone before laying and then spreading it evenly was satisfactory. A similar attempt using kankar stone was made and the surface is under observation.

Based on extensive work on brick pavements, some of the salient results claimed by the U.P., P.W.D. Research Station, are as under:

1. Brick pavements can suitably be used for road construction if reasonable quality of bricks is available.
2. Provision of 1-½ in. of sand cushion reduces the wear of bricks under traffic.
3. The life of the pavement is less without surface treatment and use of bitumen premix carpet is better than surface dressing and bitumen is more suitable.
4. Brick pavement in cement sand mortar cannot be used for road construction without surface treatment, and concrete overlay of 1½ in. is not satisfactory.
5. Brick pavement with sand cushion over an existing hard base is not satisfactory.

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2.3. Soil Roads including Stabilization

2.3.1. General

A review of the work for the year under report indicates a general recognition of the use of soil as a construction material on the part of the various State P.W.Ds. etc., resulting in the setting up of new labortories. The technique of stabilised soil construction as such, has been adopted in the construction of runways. The use of locally avilable gravel has also been undertaken for the construction of low cost roads in the State of Bihar[1].

Another noteworthy feature has been the work on the Eastern Express Highway undertaken by the Bombay P.W.D., in collaboration with the C.R.R.I., involving some new techniques of building highway fills across swamp deposits, including the use of vertical sand drains for expediting consolidation of the soft clay subsoil.

2.3.2. Stabilization of black cotton soil

Laboratory experiments on the treatment of black cotton soil with lime, details of which were reported last year were continued in C.R.R.I. These tests have indicated encouraging results in the laboratory, namely, that the C.B.R. value increases from as low as 3 to about 80 with the addition of 5 per cent lime.

Work on the use of lime for stabilization of highly plastic soils resembling black cotton soil has been undertaken by the West Bengal Roads & Buildings Research Institute[2], adding 1 per cent, 2.5 per cent, and 5 per cent lime to black cotton soils. With the addition of 2.5 per cent lime, an increase of the field C.B.R. to 36.2 has been reported as compared to 3.7 in the case of untreated soil. In another length, the addition of 3 per cent lime had given a field C.B.R. of 54 compared to about 2 in the original state. The results are encouraging and indicate large scale trials in the field.

In the Madras Highways Research Station[3], stabilization work under field scale has been done by adding sand to black cotton soil, thus considerably bringing down the plasticity index.

Other experiments concerning the swell pressure of black cotton soils were undertaken in the C.R.R.I. this year. The results indicate that the swell pressure depends very much on the density of the soil, increasing with the increase in dry bulk density. For low densities upto 1.5 gms./c.c. the swell pressure

is very small but as the degree of compaction is increased there is an abrupt rise in swell pressure. Swell pressure of a soil is found to depend also on the initial and final moisture contents of the soil. The swell pressure of a soil from the dry state to shrinkage limit seems to be more or less the same but above the shrinkage limit, swell pressure decreases, as the initial moisture increases and after saturation, no swell pressure is observed.

The effect of height of the specimens and of confinement of swell pressure have also been investigated. The results indicate that the swell pressure increases as the area of confinement increases.

2.3.3. Mechanical stabilization

A number of full scale field trials applying the conventional specifications to stabilized soil road construction were in progress during this year also.

In Bihar, major work on the soil-gravel road construction has been undertaken on a large scale, using scientific methods, in collaboration with the C.R.R.I. in the districts of Hazaribagh, Bhagalpur, etc. The normal specification adopted, consists of 6 in. thick uncompacted layer of soil-gravel mixture, with a plasticity index varying between 8-11, compacted to 4½ in. at optimum moisture content. As the traffic on these roads is expected to be rather low, no surface dressing has been given. The State P.W.D. has also reported that these roads are behaving satisfactorily on the whole.

In the West Bengal soil-sand stabilized base courses are being used in place of conventional double brick (flat) soling.

A number of road lengths have also been taken up by the Punjab & Madras P.W.Ds. using mechanical stabilization applying the existing specifications.

3.3.4. Chemical stabilization

The work on chemical stabilization of soils has not yet found favour with the research workers on account of high cost. Except for spreading chemicals on the surface, no systematic work seems to have been done so far.

2.3.5. Cement stabilization

The use of soil cement on a large scale has been adopted by the Engineer-in Chief's branch of the Army Headquarters, New Delhi, in collaboration with the C.R.R.I., in the construction of

taxi track of an airfield. The pavement is designed for a wheel load of 60,000 lb and a contact pressure of 100 p.s.i. The total thickness provided on the subgrade which has a C.B.R. value of 3 per cent is 34 in. This thickness is built up by compacting 12 inches of the subgrade soil at optimum moisture to a density of 1.75 gms/c.c. This is followed by 8 inches of soil with 5 per cent cement, another layer of 5 in. of soil with 7.5 per cent cement and still another layer of 4.5 inches of soil with 10 per cent cement. The surface carpet is provided by 3 inches of bituminous macadam followed by 1.5 inches of dense bituminous carpet. This process, apart from reduction in cost in certain cases gives a high outturn and can be used with advantage even in cases of emergency.

Some initial trials with stabilization of soil with cement for village roads have shown that even when soil is stabilized with 5 per cent cement, it does not develop as such or even after stone grafting, enough strength to take up the abrasion of light traffic.

The West Bengal Roads & Building Research Institute in collaboration with the C.R.R.I., is constructing a 5½ mile length of soil-cement road near about Calcutta, using 2½ in. cement in the base course and 6 per cent cement in the top course, with stone grafting and surface carpet. In West Bengal, soil-cement stabilised blocks with 5 to 7 per cent cement mixed with laterite soil were used as good building blocks.

2.3.6. Stabilization with lime and mollases

In the C.R.R.I., some field experiments are being conducted so as to verify the findings already reported by the Institute as well as those of the Karnal B. & R. Research Institute [4]. It has been previously reported that a small experimental length constructed by the B. & R. Laboratory, Karnal [4], with stabilized soil using 2.5 per cent lime and 5 per cent molasses has given satisfactory behaviour for the last 2 years whereas the untreated and the cement-treated stretches had already begun to show signs of distress. Field experiments by the C.R.R.I., have shown that molasses in concentration of about 2.5 per cent alone can be advantageously used for improving the abrasion resisting quality of soil stabilized with soft aggregate. The resistance can be further improved by mixing 2.5 per cent lime before treatment with molasses.

It has, however, been noticed that lime alone will not improve abrasion resisting qualities of alluvial soils in dry season.

It was reported from Madras Highway Research Station [3] that addition of lime alone did not improve the strength characteristics of one type of gravel they tested. This gravel has a L. L. of 20 and P. I. of 10 with 17 per cent passing 200 sieve.

2.3.7. Study of subgrade moisture

The study on the subgrade moisture conducted by the Central Road Research Institute has shown that there is no moisture equilibrium stage in India as found out by the workers in the U. K. The degree of saturation of the subgrade in India during the worst part of the year varies almost from 20 per cent to 100 per cent showing thereby that it is not necessary to carry out the design of the pavement at saturated condition for all parts of India. It further shows that in areas where the degree of saturation is low further research work is desirable to predict how the degree of saturation will be affected as and when there is a tendency for the water table to rise.

2.3.8. Low grade aggregates

Greater enthusiasm for use of locally available low grade aggregates in road construction is evident in different parts of the country. Low grade aggregates like brick, moorum, kankar, soft gravel, laterite, etc., are being used more extensively on large scale field trials as well as in regular construction projects.

Suitability of blast furnace slag for use in base and surface courses is under investigation in the Roads and Buildings Research Station, West Bengal [2]. Work is also being taken up by the same station to improve the quality of bricks.

2.3.9. Construction of embankments on marshy grounds

Work on the construction of embankments on the Eastern Express Highway, Bombay, is being continued. The embankment construction in some of the stretches is on the verge of completion.

Points for discussion

(i) Use of soil-cement as material of construction for roads and runways.

(ii) Use of waste products such as slag and cinder in soil stabilization and embankment construction.

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TRAFFIC AND TRAFFIC SAFETY

1. GEOMETRICS, ECONOMICS, STATISTICS AND SAFETY

Generel

It is gratifying to note the rapid progress made by this branch of the highway engineering in India in the year under report. The Central Road Research Institute undertook many new problems this year while work on others has been extended. Collaboration was sought from traffic Police, Town Planning Organization and various State governments. A comprehensive report on goods traffic survey in Delhi has also been published by the Ministry of Transport and Communications (Roads Wing) this year.

1.1. Geometrics

1.1.1. Design of traffic islands in road junctions

Highways Research Station, Madras[1] took up the study of a number of road junctions for the redesigning of traffic islands in Madras City as well as on all the National Highways in the State. Comprehensive plans of these intersections based on the pattern of traffic flow have been prepared and are being executed. Special attention has been paid to those undersized islands where there are frequent hold-ups and confusion during peak hours. Channelization synchronised with traffic signals has often been recommended in such cases, if found satisfactory, to ensure safety and efficiency.

1.1.2. Origin and destination survey of Delhi

This study which was conducted jointly by the Central Road Research Institute and the Town Planning Organization, Ministry of Health, has since been completed.

1.1.3. Design of kilometer stones

At the instance of Indian Roads Congress, various designs of kilometer stones based on Scientific considerations of colour, size, spacing of letters, glance legibility value, target value and priority value, were tested in the field by Central Road Research Institute and most suitable designs have been recommended to I.R.C. for various types of highways for consideration and adoption.

1.2. Economics

1.2.1. Economics of operational cost of different types of vehicles.

This study was undertaken by the Central Road Research Institute to determine the relationship between value of service rendered by the vehicle and highway cost. These factors in turn influence highway location and enter into the determination of rates of taxation on different types of vehicles. This survey is limited to Delhi State only but the results obtained can be applied anywhere in India with little modifications.

1.3. Statistics and Safety

1.3.1. Short counts

Nowadays traffic volumes in India are being manually counted unlike the Western Countries where automatic traffic counters are used. The inability of these automatic traffic counters for recording mixed, fast and slow vehicles, is well known. An attempt has, therefore, been made by the Central Road Research Institute to arrive at as short a manual count as possible (even upto one hour) by analysing the data collected in Sampling Technique Problem (I.R.C. Bulletin No. 5 – 1958). In this connection "Parent factors" obtained as hourly traffic expressed as a percentage of the total daily traffic for each hour have been calculated. It has been found that these 'Parent factors' are fairly good predictors for the daily traffic under similar conditions of population, number of vehicles and economic activity (as for one particular city).

1.3.2. Comprehensive study of Delhi road traffic

A comprehensive study of the various aspects of Delhi road traffic e.g., counts, traffic laws, traffic police, drivers, pedestrians, cycle traffic, vehicle types, accidents, speed control, etc., has been undertaken by C.R.R.I. The work on traffic counts, traffic laws, and traffic police is complete and the detailed study of other aspects is making headway.

1.3.3. Goods traffic survey in Delhi—1957

On the recommendation of the Statistical Commission of U.N. Economic and Social Council, a sample "Goods Traffic Survey" was conducted by the Roads Wing of the Ministry of Transport and Communications in Delhi in 1957[2]. At the time of survey, there were 2,025 motor goods vehicle and about 12,000 animal drawn carts. The main survey covered

information in respect of 358 motor vehicles and about 200 animal drawn carts. Exhaustive information was collected about the nature of vehicle, laden and unladen weights, age of the vehicle, nature of activity in which engaged, type of fuel used, idle capacity, etc., and a scientific analysis was carried out to assess the present conditions and obtain useful results for future planning. The whole report has now been published by the Ministry.

1.3.4. Parking study in Connaught Place

This study has been undertaken by the Central Road Research Institute to improve the rapidly deteriorationg parking condition in the main shopping and business centre of the Capital. One of the main recommendations made is the metering of the vehicle parking.

1.3.5. Effect of 'road signs and road markings' on driver's behaviour

With the rapidly increasing volume of traffic on the roads, the role of road signs and road marking is assuming greater importance. With a view to achieve more efficient road signs and markings, two separate before and after studies have been undertaken in this connection. One of these studies pertains to the effectiveness of present road signs such as 'STOP' and 'DEAD SLOW' at the intersection and 'Speed Limit Signs' on the various roads, and the other study is being made to determine the effect of road markings at the curves, intersections, straight roads etc.

1.3.6. Before and after studies

Before and after study on pedestrian safety is also making headway now with various types of road markers for comparison with plastic markers (as reported in I.R.C. Bulletin, December 1958). This is being done in an attempt to arrive at more durable and economical road markers.

1.3.7. Scientific investigation of road accidents

In continuation of the investigation reported last year, the C.R.R.I., is now studying the road accidents which occurred in 1958 with a view to analyse them on scientific basis to find out their causes and suggest preventive measures.

The details of 2,838 road accidents which occurred in Delhi and New Delhi in 1958 (collected from Delhi Police) have been

punched on punch cards. About 14 tables showing the number of fatal, non-fatal and property damage accidents, number of persons killed, injured, details of vehicles and drivers, etc., are being prepared. These tables will help in connecting various types of accidents with type of collision, type of vehicle, road conditions, weather conditions, driver's age and sex, traffic violation and other related factors.

Points for discussion

1. Metering of vehicle parking at this stage of road transport development in India.
2. Adoption of 'minimum speed limits' on certain highways where fast-moving vehicles predominate overwhelmingly.

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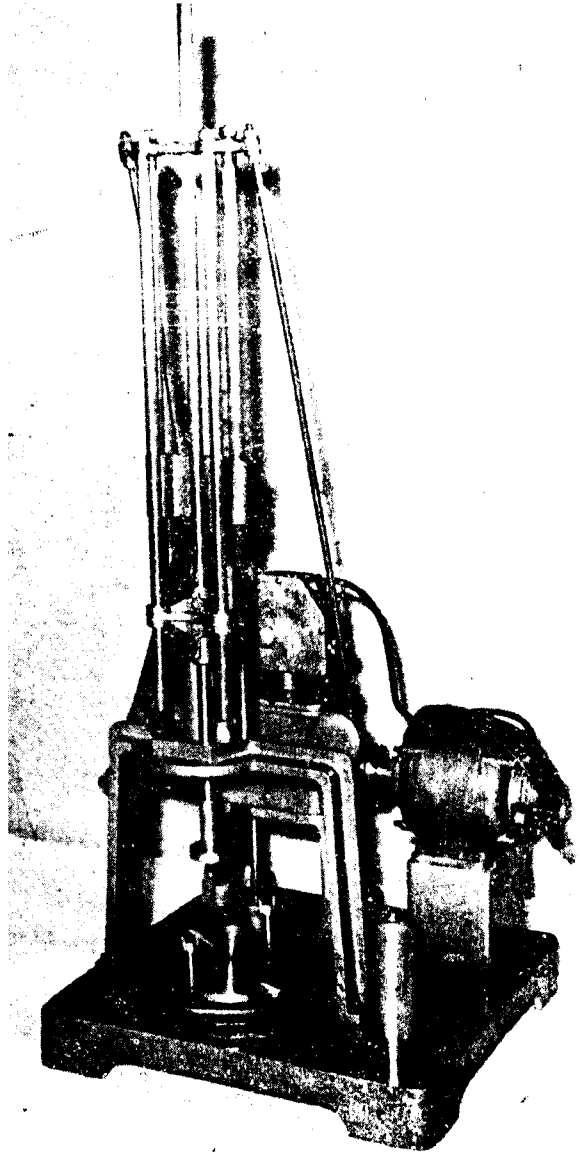

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