PROBLEMS

1. Discuss the role of transportation in the economic and social activities of the country.
2. What are the different modes of transportation ? Explain the specific functions of each of them.
3. Compare the characteristic feature of different modes of transportation.
4. What are the characteristics of road transport in comparison with other systems ?
5. What, in your opinion were the chief causes of neglected conditions of road transportation in India ?
6. Explain the role of transportation in rural development in India ?
7. Outline and discuss the scope of the highway engineering study.

Chapter 2

Highway Development and Planning

2.1 HISTORICAL DEVELOPMENT OF ROAD CONSTRUCTION

2.1.1 Early Development

The oldest mode of travel obviously was on the foot-paths. Animals were also used to transport men and materials. Later simple animal drawn vehicles were developed and this became a common and popular mode of transportation for a very long period after the invention of *wheel*. This brought up the necessity of providing a *hard surface* for these wheeled vehicles to move on. Such a hard surface is believed to have existed in *Mesopotamia* in the period about 3500 B.C. The first road on which there is some authentic record is that of *Assyrian* empire constructed by about 1900 B.C. Only during the period of the *Roman* empire, roads were constructed in large scale and the earliest construction techniques known are of Roman Roads. The Romans constructed an extensive system of roads radiating in many directions from *Rome* through the empire mainly for military operations. Hence Romans are considered to be the pioneers in road construction.

2.1.2 Roman Roads

Many of the early Roman roads were of elaborate construction. Some of these roads are still in existence after over 2000 years. During this period of Roman civilization many roads were built of stone blocks of considerable thickness. The *Appian way* was built in 312 B.C. extending over 580 km which illustrate the road building technique used by Romans.

The main features of the Romans roads are :

(i) They were built straight regardless of gradients.

(ii) They were built after the soft soil was removed and a hard stratum was reached.

(iii) The total thickness of the construction was as high as 0.75 to 1.2 metres at some places, even though the magnitude of wheel loads of animal drawn vehicles was very low.

A typical cross section of Roman road is shown in Fig. 2.1. The construction procedure was as follows :

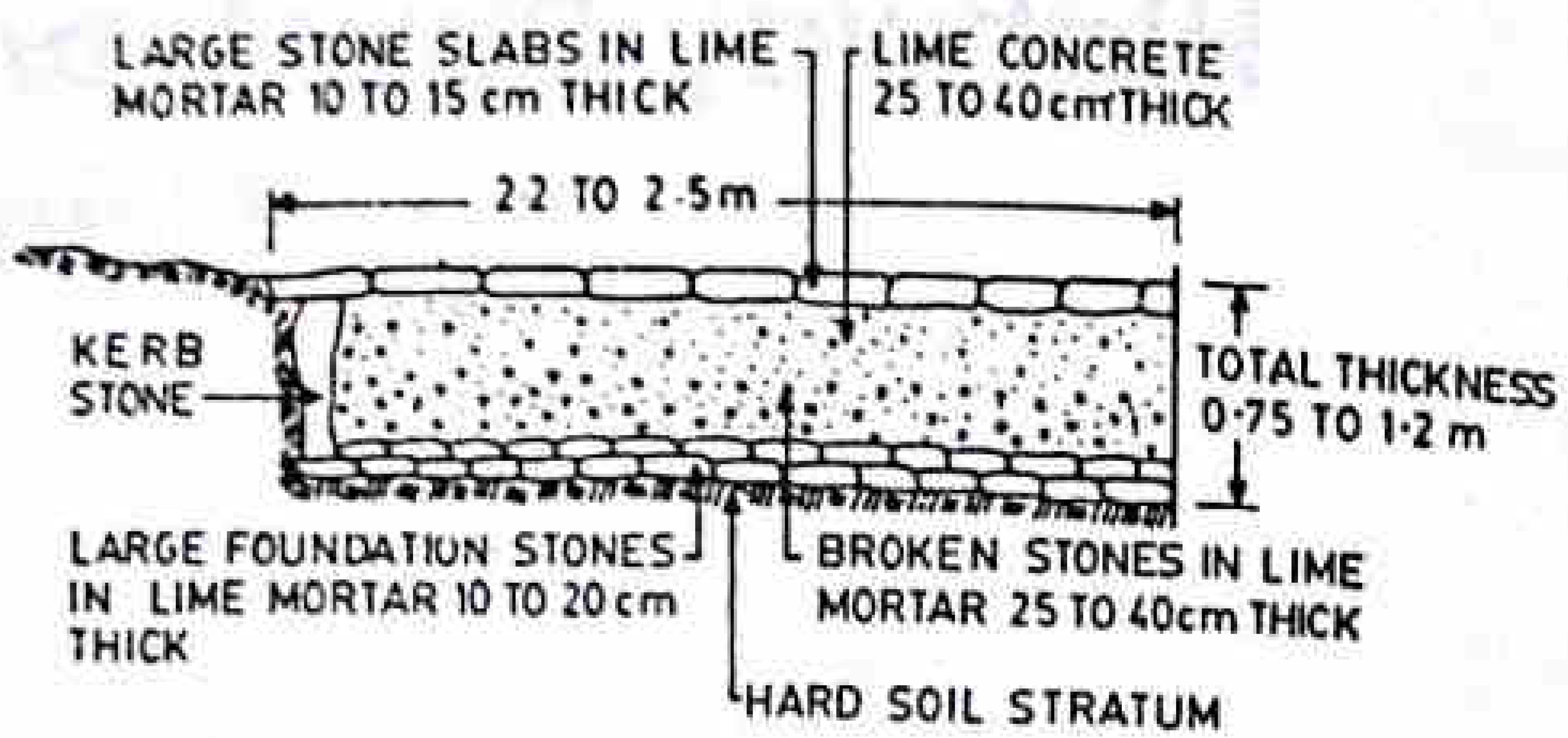


Fig. 2.1 Typical Cross section of Roman Road

(i) A trench of width equal to that of the carriage way was dug along a straight path by removing the loose soil from the top. The trench was cut upto a depth until a hard stratum was reached.

(ii) One or two layers of large foundation stones were laid in lime mortar at the bottom. The thickness of this bottom layer ranged from 10 to 20 cm. Vertical kerb stone were placed along the edges of the pavement.

(iii) A second layer of lime concrete with large size broken stones mixed in lime mortar was laid over the bottom course up to a thickness of 25 to 40 cm.

(iv) Another layer of lime concrete was laid over this with smaller broken stones mixed in lime mortar to a thickness of 25 to 40 cm, or even more if necessary.

(v) The wearing course consisting of dressed large stone blocks set in lime mortar was provided at the top. The thickness of these blocks also varied from 10 to 15 cm.

Obviously the above construction should have been much stronger than what was required for the animal drawn carts in those days. The enormous cost of construction cannot be justified at all, if this technique is compared with the modern trend of pavement design based on more scientific approaches.

2.1.3 Tresaguet Construction

After the fall of the Roman empire, their technique of road construction did not gain popularity in other countries. Until the eighteenth century there is no evidence of any new road construction method, except the older concept of using *thick* construction of road beads as the Roman did.

Pierre Tresaguet (1716-1796) developed an improved method of construction in France by the year 1964 A.D. Tresaguet developed several methods of construction which were considered to be quite meritorious. The main feature of his proposal was that the thickness of construction need be only in the order of 30 cm. Further due consideration was given by him to subgrade moisture condition and drainage of surface water. Tresaguet was the Inspector General of Roads in *France* from 1775 to 1785 and

so his method of construction was implemented in that country in 1775. During the regime of *Napoleon* the major development of road system in France took place.

The typical cross section of Tresaguet's road construction is given in Fig. 2.2 and the construction steps may be enumerated as below :

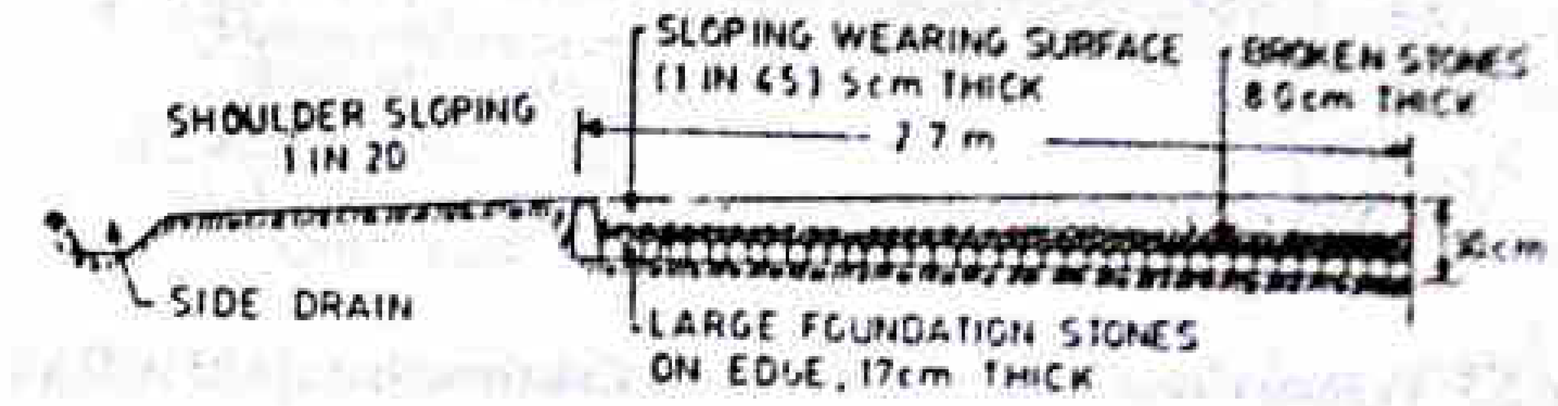


Fig. 2.2 Typical Cross Section of Tresaguet's Construction (1775 A.D.)

(i) The subgrade was prepared and a layer of large foundation stones were laid on edge by hand. At the two edges of the pavement large stones were embedded edgewise to serve as submerged kerb stones.

(ii) The corners of these heavy foundation stones were hammered and then the interstices filled with smaller stones. Broken stones were packed to a thickness of about 8 cm and compacted.

(iii) The top wearing course was made of smaller stones and compacted to a thickness of about 5 cm at the edges and gradually increased towards the centre, giving a cross slope of 1 in 45 to the surface, to provide surface drainage.

(iv) The shoulders were also provided cross slope to drain the surface water to the side drain.

2.1.4 Metcalf Construction

John Metcalf (1717-1810) was engaged on road construction works in *England* during the period when Tresaguet was working in France. He apparently followed the recommendations of *Robert Phillips* whose paper was presented in Royal Society. Metcalf was responsible for the construction of about 290 km of road in the northern region of England. As Metcalf was blind, much of his work was not recorded.

2.1.5 Telford Construction

Thomas Telford (1757-1834) began his work in early 19th century. He was the founder of the Institution of Civil Engineers at London. He also believed in using heavy foundation stones above the soil subgrade in order to keep the road foundation firm. He insisted on providing a definite cross slope for top surface of the pavement by varying the thickness of foundation stones.

A typical cross section of Telford's construction by the year 1803 is shown in Fig. 2.3.

The construction steps are given below :

(i) A level subgrade was prepared to designed width of about 9 meters.

(ii) Large foundation stones of thickness 17 to 22 cm were laid with hand with their largest face down so as to be laid in a stable position. The stones of lesser thickness

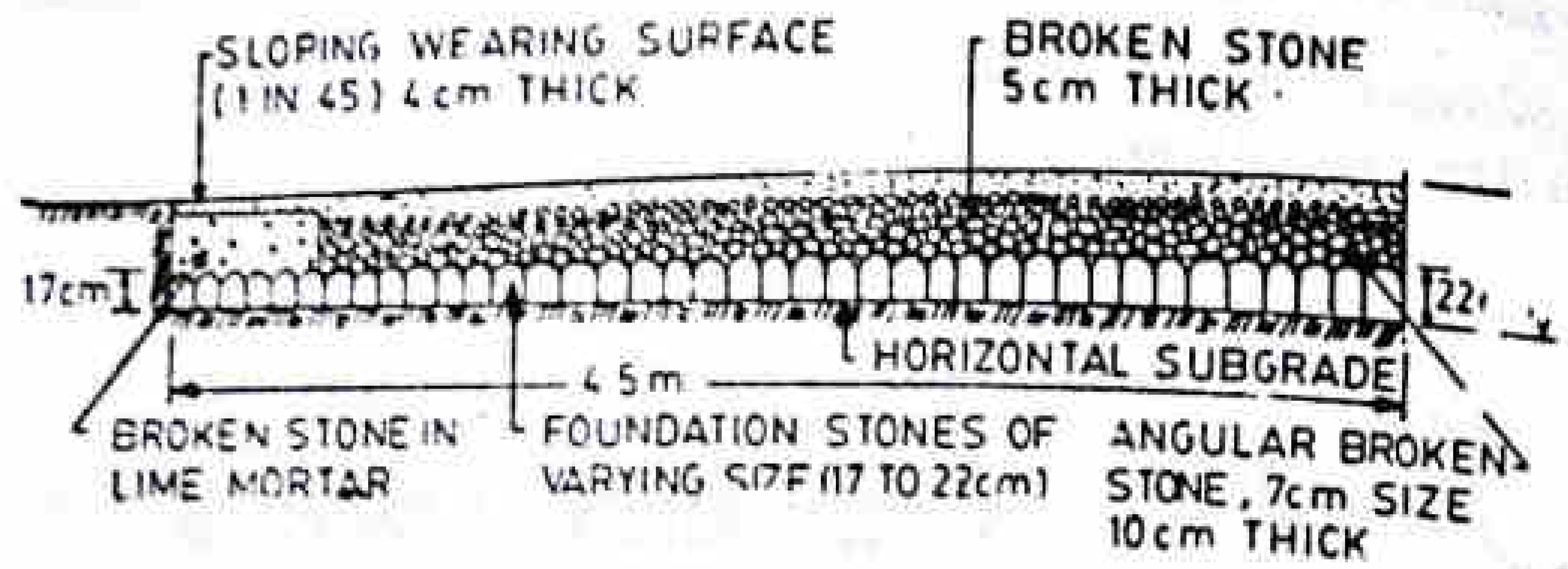


Fig. 2.3 Typical Cross Section of Telford's Construction (1803 A.D.)

(17 cm) were placed towards the edges and stones of increasing thickness were laid towards the centre. At the centre the largest stones of approximate thickness 22 cm were used such that these foundation stones of varying thickness provide the cross slope designed by Telford.

(iii) The interstices between foundation stones were filled with smaller stone and chipping and properly beaten down.

(iv) The central portion of about 5.5 metre width was covered with two layers of angular-broken stones to compacted thickness of 10 and 5 cm. These layers were initially rammed and later allowed to be compacted under the traffic and get consolidated by the rains.

(v) A certain width of the pavement towards the edges was constructed by compacted broken stones, 15 cm thick, sometimes in lime mortar instead of using the kerb stones so as to provide lateral stability.

(vi) A binding layer of wearing course 4 cm thick was constructed on the top using gravel. The finished surface had a cross slope of about 1 in 45.

Telford proposed to provide cross drains at intervals of about 90 meters. They were usually laid below the foundation level as the interstices were large enough to allow the water to percolate from top to the bottom of the construction and thus soften the level subgrade.

2.1.6 Macadam Construction

John Macadam (1756-1836) put forward an entirely new method of road construction as compared to all the previous methods. The first attempt to improve the road condition was made by him in 1815. Macadam was the Surveyor General of Roads in *England* and his new concept of road construction became known by the year 1827.

A typical cross section of Macadam's construction is shown in Fig. 2.4.

The most important modifications made in Macadam's methods with respect to the older methods are :

(i) The importance of subgrade drainage and compaction were recognised and so the subgrade was compacted and was prepared with a cross slope of 1 in 36.

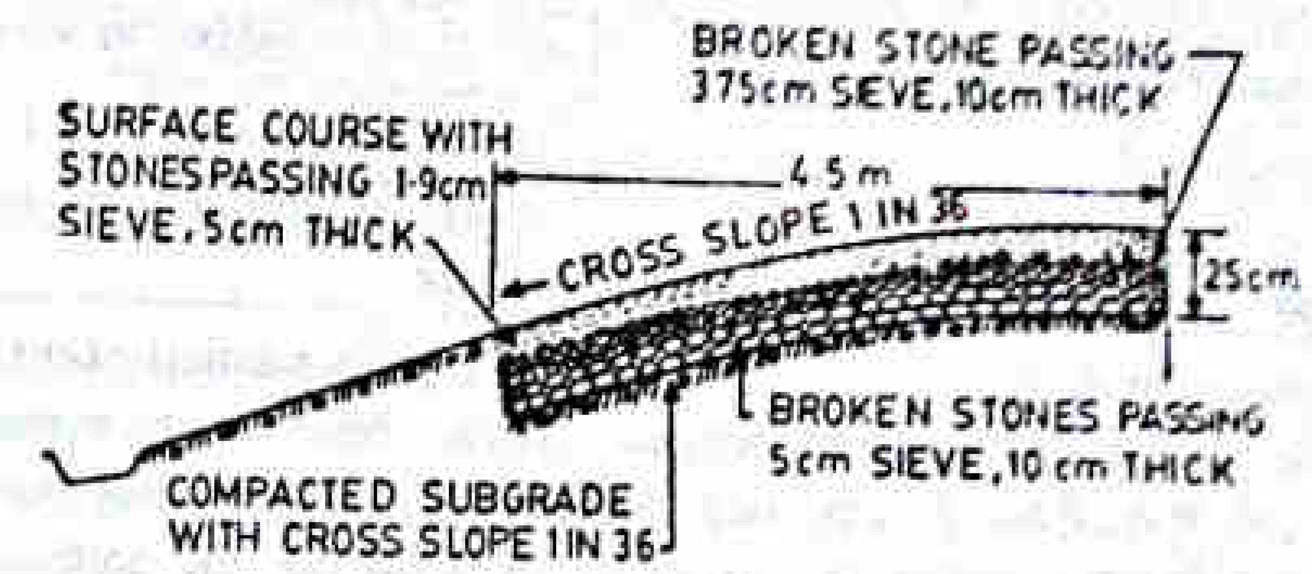


Fig. 2.4 Typical Cross Section of Macadam's Construction (1827 A.D.)

(ii) Macadam was the first person to suggest that heavy foundation stones are not at all necessary to be placed at the bottom layer of construction. He realised that the subgrade being the lowest portion of the pavement should be prepared properly and kept drained so as to carry the load transmitted through the pavement. Compacted layer of smaller size broken stones placed at the bottom, according to Macadam, could replace, with advantage, the heavy foundation stones.

(iii) Though the total thickness of construction, was less than previous methods, this technique could serve the purpose in a better way, due to better load dispersion characteristics of compacted broken stone aggregates of smaller sizes.

(iv) The size of broken stones for the top layer was decided based on the stability under animal drawn vehicles. The pavement surface was also prepared with a cross slope of 1 in 36 for drainage of surface water.

Macadam's method is the first method based on scientific thinking. It was realised that the stresses due to wheel load of traffic gets decreased at the lower layers of the pavement and therefore it is not necessary to provide large and strong boulder stones as foundation or soling course at the lowest layer of the pavement. This method became very popular far and wide. Various subsequent improved methods were based on Macadam's construction and some of the methods still in use are known after his name, such as water bound macadam, penetration macadam and bituminous macadam constructions.

The construction steps are :

(i) Subgrade is compacted and prepared with a cross slope of 1 in 36 upto a desired width (about 9 metres).

(ii) Broken stones of a strong variety, all passing through 5 cm size sieve were compacted to a uniform thickness of 10 cm.

(iii) The second layer of strong broken stones of size 3.75 cm was compacted to thickness of 10 cm.

(iv) The top layer consisted of stones of size less than 2 cm compacted to a thickness of about 5 cm and finished so that the cross slope of pavement surface was also 1 in 36.

The Macadam and Telford methods of construction differ considerably though both the methods were put forward in the early nineteenth century.

The two methods have been compared here :

	Macadam method	*Telford method*
(i)	The subgrade was given a cross slope of 1 in 36 to facilitate subgrade drainage.	The subgrade was kept horizontal and hence subgrade drainage was not proper.
(ii)	The bottom layer of pavement or the sub-base course consisted of broken stones of less than 5 cm size to uniform thickness equal to 10 cm only.	Heavy foundation stones of varying sizes, about 17 cm towards the edges and 22 cm towards the centre were hand packed and prepared to serve as sub-base course.
(iii)	Base and surface courses consisted of broken stones of smaller sizes to compacted thickness of 10 and 5 cm respectively and the top surface was given a cross slope of 1 in 36.	Two layers of broken stones were compacted over the foundation stones before laying the wearing course, 4 cm thick with a cross slope of 1 in 45.
(iv)	The total thickness of pavement construction was kept uniform from edge to centre to a minimum value of only 25 cm.	The total thickness of construction varied from about 35 cm at the edge to about 41 cm at the centre.

2.1.7 Further Developments

Macadam's method of construction gained recognition as a scientific method of construction and hence was adopted by various countries with slight modifications. One of the most popular methods which is even now prevalent in many countries is the *water bound macadam* (WBM) construction, known after Macadam's technique. In this method the broken stones of the base course and surface course, if any, are bound by the stone dust in presence of moisture and hence the name. WBM roads are in use in India both as a finished pavement surface for minor roads and as a good base course for superior pavements carrying heavy traffic. There are also bituminous construction methods which are known after Macadam. The methods adopted in our country include the bitumen bound macadam and penetration macadam. The details of the construction methods have been given in the Chapter, 'Highway Construction'.

The water bound macadam roads were considered to be one of the superior methods of construction until the fast moving vehicles started using these roads. Dust is formed on the road surface during dry weather due to the crushing and abrading action of steel-tyred animal drawn vehicles. This dust is easily raised by the fast moving automobiles. Further during monsoons, mud is formed and is churned again due to the movement of automobiles. Under the combined action of the mixed traffic and under adverse weather conditions the WBM roads could not last long. In order to minimise the dust nuisance, several dust palliatives including heavy oils and bituminous materials were tried with varying degrees of success.

The next development was the penetration and bituminous macadam roads and other types of surface dressing methods using bituminous materials. For better performance superior bituminous mixes like the bituminous carpet and bituminous concrete were also developed in a scientific way.

The use of cement concrete for roads has been popular even prior to the use of bituminous mixes. The cement concrete roads could be designed to kept up the heaviest loads expected on the roads even in adverse soil and climatic conditions and to last for a long service life. They are known to give a good and even riding surface. Due to the high initial cost involved in the construction of cement concrete road, it is not being extensively used in our country at present.

As the main problem in developing countries like India is to have maximum road length at minimum cost, the only solution is to resort to the construction of low cost roads and stage construction of roads. Hence the best utilisation of locally available and the cheapest materials have to be made in road construction. In this respect there is good scope for the use of *soil stabilization* and other low cost pavement materials. There are several techniques of soil stabilization which have been explained in a later chapter of the book. The choice of the method of stabilization depends on several factors such as the soil type, availability of stabilizers, climatic conditions, the component of pavement which is being constructed and the traffic.

2.2 HIGHWAY DEVELOPMENT IN INDIA

2.2.1 Roads in Ancient India

The excavations of Mohenjo-daro and Harappa have revealed the existence of roads in India as early as 25 to 35 centuries B.C. Old records reveal that in early periods the roads were considered indispensable for administrative and military purposes. The ancient scriptures refer to the existence of roads during the Aryan period in the fourth century B.C. *Kautilya* the first prime minister of Emperor *Chandra Gupta Maurya*, laid down the rules in the literary piece titled *'Arthasastra'*. Rules have been mentioned about regulating the depth of roads for various purposes and for different kinds of traffic. Mention has been made regarding the punishment for obstructing roads. In the beginning of fifth century A.D. emperor *Ashoka* had improved the roads and the facilities for the travellers.

2.2.2 Roads in Mughal Period

During the Pathan and Mughal periods, the roads of India were greatly improved. Some of the highways either built or maintained by Mughals received great appreciation from the foreign visitors who visited India during that periods. Roads were built running from North-West to the Eastern areas through the Gangetic plains, linking also the coastal and central parts.

2.2.3 Roads in Nineteenth Century

At the beginning of British rule, the conditions of roads deteriorated. The economic and political shifts caused damage to a great extent in the maintenance of the road transportation. The fall of Mughal empire led therefore to the scant attention to the communication. Prior to the introduction of railways, a number of trunk roads were metalled and bridges were provided. this was mainly done on the remains of old roads which existed, under the supervision of the British Military Engineers. In fact these roads connected important military and business centres.

Military maintenance was not quite adequate and in 1865 *Lord Dalhousie*, when he was Governor-General formed the *Public Works Department* in more or less the same form that exists today. The construction of the *Grand Trunk Road* was undertaken by this new department. Immediately with the development of railways, attention of the Government was shifted from road development except for providing feeder roads and the railway was gaining the privileges.

2.2.4 Jayakar Committee and the Recommendations

After the first World War, motor vehicles using the roads increased and this demanded a better road network which can carry both bullock cart traffic and motor vehicles. The existing roads when not capable to withstand the *mixed traffic* conditions. A resolution was passed by both Chambers of the Indian Legislature 1927 for the appointment of a committee to examine and report on the question of road development in India. In response to the resolution, Indian Road Development committee was appointed by the government with *M.R. Jayakar* as Chairman, in 1927.

The Jayakar Committee submitted its report by the year 1928. The most important recommendations made by the committee are :

(i) The road development in the country should be considered as a national interest as this has become beyond the capacity of provincial governments and local bodies.

(ii) An extra tax should be levied on petrol from the road users to develop a road development fund called *Central Road Fund.*

(iii) A semi-official technical body should be formed to pool technical know how from various parts of the country and to act as an advisory body on various aspects of roads.

(iv) A research organisation should be instituted to carry out research and development work and to be available for consultations.

Most of the recommendations of the Jayakar Committee were accepted by the government, and the major items were implemented subsequently. The Central Road Fund was formed by the year 1929, the semi-official technical body called the Indian Roads Congress was formed in 1934 and the Central Road Research Institute was started in 1950.

Central Road Fund

Based on the authority of a resolution adopted by the Indian Legislature, the Central Road Fund (C.R.F.) was formed on 1st march 1929. The consumers of petrol were charged an extra leavy of 2.64 paisa per litre (then two annas per gallon) of petrol to build up this road development fund 20 percent of the annual revenue is to be retained as a *Central Reserve*, from which grants are to be given by the Central Government for meeting expenses on the administration of the road fund, road experiments and research on road and bridge projects of special importance. The balance 80 percent is to be allotted by the Central Government to the various states based on actual petrol consumption or revenue collected. The accounts of the Central Road Fund are maintained by the Accountant General of Central Revenues and the control on the expenditure is exercised by the Roads Wing of Ministry of Transport. Recently the rate of collection of the levy towards the CRF has been revised in order to augment the revenue under this fund.

Indian Roads Congress

At the instance of central government a semi-official technical body known as *Indian Roads Congress* (IRC) was formed in 1934. This, it may be recalled, is one of the main recommendations made by the Jayakar Committee. The Indian Roads Congress was constituted to provide a forum for regular pooling of experience and ideas on all matters affecting the planning, construction and maintenance of roads in India, to recommend standard specifications and to provide a platform for the expression of professional opinion on matters relating to road engineering including such questions as those of organisation and administration. The IRC has played important role in the formulation of the three 20-year road development plans in India. Now the Indian Roads Congress has become an active body of national importance controlling specifications, standardisation and recommendations on materials, design and construction of roads and bridges. The IRC publishes journals, research publications, standards specifications guidelines and other special publications on various aspect of Highway Engineering. The technical activities of the IRC are mainly carried out by the Highway research Board and several committees and subcommittees consisting of experts in each subject. The IRC works in close collaboration with Roads Wing of the Ministry of Surface Transport, Government of India.

Economic depression during the thirties of this century delayed the road development programmes. During this period the share from the Central Road Fund was almost the only source for highway financing. During the second world war intensive efforts were made to develop the road net work essential required for strategic considerations. These projects were substantially supported by defence services funds.

After the second world war, there was a revolution in respect of automobiles using the roads in our country and a large number of military vehicles started plying on the roads. Thus the road development could not cope up with rapid increase in road vehicles and so the existing roads started deteriorating fast. The need for proper highway planning was urgently felt by this time by the authorities.

Motor Vehicle Act

In 1939 the Motor Vehicles Act was brought into effect by Government of India to regulate the road traffic in the form of traffic laws, ordinances and regulations. The three phases primarily covered are control of the driver, vehicle ownership and vehicle operation on roads and in traffic stream. The Motor Vehicle Act has been appended with several ordinances subsequently. The Motor Vehicles Act has been revised in the year 1988.

2.2.5 Nagpur Road Conference

A conference of the Chief Engineers of all the states and provinces was convened in 1943 by the Government of India at Nagpur, at initiative of the Indian Roads Congress to finalise the first road development plan for the country as a whole. This is a landmark in the history of road development in India, as it was the first attempt to prepare a co-ordinated road development programme in a planned manner. In this first 20 year road development plan, popularly known as the *Nagpur Road Plan*, all roads were classified into five categories and a twenty year development programme for the period 1943-63 was finalised. At the end of this plan the target road length aimed at was 16 km per 100 square km area of the country.

During the first and second five-year plan periods (1951-56 and 1956-61), the road development programme also was systematic and hence the Nagpur plan target of total road length was achieved about two years ahead, in 1961. But even as early as 1957 a meeting of the Chief Engineers of the central and state Governments was convened, to consider the future road development programme. A committee was appointed to prepare the Second Twenty-year Road Development plan starting from the year 1961.

Central Road Research Institute

In the year 1950 the Central Road Research Institute (CRRI) was started at New Delhi for research in various aspect of highway engineering. It may be indicated that one of the recommendations of Jayakar Committee report was to set up a central organisation for research and dissemination of information.

The CRRI is one of the national laboratories of the Council of Scientific and Industrial Research; the institute is mainly engaged in applied research and offers technical advice to state governments and the industries on various problems concerning roads.

National Highway Act

In 1956 the National Highway Act was passed. The main features of the act are :

(i) the responsibility of development and maintenance of the national highway (NH) to be provisionally taken by the central government.

(ii) the central government to be empowered to declare any other highway as NH or to omit any of the existing national highways from the list.

2.2.6 Second Twenty Year Road Development Plan 1961-81

The second twenty year road development plan for the period 1961-81 was initiated by the IRC and was finalised in 1959 at the meeting of the Chief Engineers and the same was forwarded to the Central government. This road development plan is also known as Bombay Road Plan. The plan gave due consideration to the development that are taking place and developments that have to take place in our country in various fields during the plan period. The target road length at the end of this second 20 year plan was almost double that of the Nagpur road plan target i.e. a total road length of 10,57,330 km or about 32 km per hundred sq. km area. An outlay of Rs. 5,200 crores for the period ending 1980-81 was envisaged for this second twenty year plan, based on 1958 price level. The construction of 1,600 km of Express ways was also then included in the plan.

During the third five year plan period 1961-66, the annual plans 1966-69 and the fourth five year plan period 1969-74, the road development in India continued at a steady pace. The total length of all categories of roads achieved by the year 1974 was 11.45 lakhs km, the density of road length being 34.8 km per 100 sq. km area, which is higher than the 1981 target of the Second Twenty Year Road Development Plan1961-81. Thus there was an immediate need to prepare the third long term road development plan for the country by then. However, due to change in planning policies during the fifth plan period 1974-78, annual plans 1978-80 and the sixth five year 1980-85, the preparation of the third long term road development plan got delayed.

The Third Twenty Year Road Development Plan for the period 1981-2001 was prepared by a committee of experts and was approved by the Council of the Indian Roads Congress and also at the meeting of the Chief Engineers of the Country in the year 1984.

Highway Research Board

The Highway Research Board of the Indian Roads Congress was set up in 1973 with a view to give proper direction and guidance to road research activities in India. The board is expected to act as a national body for co-ordination and promotion of highway research. The Highway Research Board (HRB) has recommended suitable financial allocation of research by central and state governments and has chosen high priority research schemes for being taken up first.

The objective of IRC Highway Research Board are :

(i) To ascertain the nature and extent of research required.

(ii) To correlate research information from various organisations in India and abroad with a view to exchange publications and information on roads.

(iii) To co-ordinate and conduct correlation services.

(iv) To collect and disseminate results on research

(v) To channelise consultative services

There are three technical committees of the HRB for (i) identification, monitoring and research application (ii) road research evaluation and dissemination and (iii) bridge research, evaluation and dissemination.

2.2.7 National Transport Policy Committee

The Government of India appointed the National Transport Policy Committee (NTPC) in the year 1978 to prepare a comprehensive national transport policy for the country for the next decade or so, keeping in view the objectives and priorities set out in the five year plans. The NTPC report was made available in the year 1980 and many of the major recommendations of this report have been accepted by the Government of India. Some of the important recommendations of the NTPC report relate to the liberalisation of the transport sector, inclusion of transport in the priority sector, optimal in-er-modal mix between railway and road transport based on resource-cost consideration and energy conservation. A number of suggestions were made on the road development, these include the need to take into account the requirements of roads in rural, hilly and tribal areas in the next perspective road development plans, strengthening of National Highway system, increase in funds for the maintenance of roads and to connect all the villages with all-weather low-cost roads within next twenty years. Separate recommendations were also made for various factors connected with the development and growth of road transport by the year 2001.

2.2.8 Third Twenty Year Road Development Plan 1981-2001

The Third Twenty Year Road Development plan 1981-2001 was prepared by the Road Wing of the Ministry of Shipping and Transport with the active co-operation from a number of organisations and experts in the field of Highway Engineering and Transportation. This document was released during the 45th Annual Session and the Golden Jubilee celebrations of the Indian Road Congress in February 1985 at Lucknow. Therefore this road development, plan for 1981-2001 is also called 'Lucknow Road Plan'. This plan has been prepared keeping in view the growth pattern envisaged in various fields by the turn of the century. Some of the points which were given due consideration while formulating the plan are improvement of transportation facilities in villages, towns and small cities, conservation of energy, preservation of environmental quality and improvement in road safety.

This twenty year road plan aims at increasing the total road length (including urban and project roads) from 15,02,700 km in the year 1981 to 27,02,000 km by the year 2001. This will result in an increase in road density from 46 km per 100 sq. km in the year 1981 to 82 km per 100 sq. km by the year 2001. As the development of National Highways fell short of the targets set by the first two twenty year road development plans, the present road plan of 1981-2001 has set the target length of NH to be completed by the end of seventh, eighth and ninth five year plan periods.

2.2.9 Review of Highway Development in India after Independence

When India achieved independence on 15th August 1947, the total road length in the country was 3,88,226 km with the density of road length working out to about 11.8 km per 100 sq. km area, out of this the length of surfaced roads was only about 36.8 percent. Since then the pace of road development in the country has improved considerably. The total road length in the country increased from 3,97,600 km in the year 1950-51 to 15,02,700 km by the year 1980-81.

There has also been a tremendous pressure on road transportation due the rapid growth in the number of road vehicles and considerable increase in freight and passenger traffic carried by roads during the above thirty year period. The total number of motor vehicles in the country increased from about three lakhs to over 44 lakhs during the period 1951-1981. The freight traffic on roads increased from about 5.5 to over 104 billion (i.e. 1×10^9) tonne-km and the passenger traffic from about 23 to over 315 billion passenger-km during the above thirty years. Obviously the above growth in the road traffic has been due to overall growth in the National income and the population and due to the increase in agricultural and industrial production. The annual revenue from taxation on road transport sector also increased from about Rs. 61 crores to Rs. 2,388 crores during the above thirty year period.

The growth of total road length, density of road length and the length of surfaced roads in the country during the period since independence are given in Table 2.1. The total revenue from road transport due to taxation and the total expenditure on roads including development and maintenance expenditure on roads by the centre and the states are also given in this table. It may be seen that only a fraction of the revenue from road transport is being spent on development and maintenance of roads.

The development of National Highways in India has not been at the desired pace. Though the achievements in terms of total road length by the end of Nagpur Road Plan in 1961 and Bombay Road Plan in 1981 exceeded the targets of the two twenty-year road development plans, the length of NH achieved fell short of both the plan targets. As the NH system caters for a high proportion of traffic in the country, provision has now been made for the improvement of deficiencies in the existing NH system and also for the construction of additional length of NH to cater for the growing traffic needs upto the end of this century.

Table 2.1 Growth of Road Length, Revenue and Expenditure on Roads in the Country

Year	Total road length in lakh km	Density of total road length in km per 100 sq. km area	Length of surfaced roads in lakh km	Revenue from road transport taxation in crores	Expenditure on roads in crores Rs.
1947	3.88	11.8	1.43		-
1950-51	3.98	12.1	1.56	61.0	-
1960-61	7.05	21.4	2.34	166.9	159.8
1965-66	8.80	26.8	3.43	399.1	173.7
1970-71	10.12	30.8	4.36	683.2	257.6
1975-76	12.49	38.0	5.51	1436.6	502.6
1977-78	13.72	41.7	5.96	1587.6	693.5
1980-81	15.03	45.7	6.92	2387.6	1209.3

2.3 NECESSITY OF HIGHWAY PLANNING

In the present era planning is considered as a pre-requisite before attempting any development programme. This is particularly true for any engineering work, as planning is the basic requirement for any new project or an expansion programme. Thus highway planning is also a basic need for highway development. Particularly planning is of great importance when the funds available are limited whereas the total requirement is much higher. This is actually the problem in all developing countries like India as the best utilisation of available funds has to be made in a systematic and planned way.

The objects of highway planning are briefly given below :

(i) To plan a road net work for efficient and safe traffic operation, but at minimum cost. Here the costs of construction, maintenance and renewal of pavement layers and the vehicle operation costs are to be given due consideration.

(ii) To arrive at the road system and the lengths of different categories of roads which could provide maximum utility and could be constructed within the available resources during the plan period under consideration.

(iii) To fix up date wise priorities for development of each road link based on utility as the main criterion for phasing the road development programme.

(iv) To plan for future requirements and improvements of roads in view of anticipated developments.

(v) To work out financing system.

2.4 CLASSIFICATION OF ROADS

2.4.1 Types of Roads

The different types of roads are classified into two categories, depending on whether they can be used during different seasons of the year :

(i) All-weather roads and

(ii) Fair-weather roads. *All weather roads* are those which are negotiable during all weather, except at major river crossings where interruption to traffic is permissible upto a certain extent, the road pavement should be negotiable during all weathers. Roads which are called *fair weather roads*; on these roads, the traffic may be interrupted during monsoon season at causeways where streams may overflow across the road.

Based on the type of the carriage way or the road pavement, the roads are classified as :

(i) *paved roads*, if they are provided with a hard pavement course which should be atleast a water bound macadam (WBM) layer and

(ii) *unpaved roads*, if they are not provided with a hard pavement course of atleast a WBM layer. Thus earth roads and gravel roads may be called unpaved roads.

Based on the type of pavement surfacing provided; the road types are divided as :

(i) *surface roads*, which are provided with a bituminous or cement concrete surfacing and

(ii) *unsurfaced roads* which are not provided with bituminous or cement concrete surfacing. The roads provided with bituminous surfacing are also called *black toped roads*.

2.4.2 Methods of Classification of Roads

The roads are generally classified on the following basis :

(a) Traffic volume

(b) Load transported or tonnage

(c) Location and function

The classification based on traffic volume or tonnage have been arbitrarily fixed by different agencies and there may not be a common agreement regarding the limits for each of classification group. Based on the traffic volume, the roads are classified as heavy, medium and light traffic roads. These terms are relative and so the limits under each class should be clearly defined and expressed as vehicles per day etc. Likewise the classification based on load or tonnage is also relative and the roads may be classified as class I, II etc. or class A, B etc. and the limits may be expressed as tonnes per day.

The classification based on location and function should therefore be a more acceptable classification for a country as they may be defined-clearly. The Nagpur Road Plan classified the roads in India based on location and function into following five categories and described in section 2.4.3.

(i) National Highways (NH)

(ii) State Highways (SH)

(iii) Major District Roads (MDR)

(iv) Other District Roads (ODR) and

(v) Village Roads (VR)

2.4.3 Classification of Roads by Nagpur Road Plan

(i) *National Highways (NH)* are main highways running through the length and breadth of India, connecting major ports, foreign highways, capitals of large states and large industrial and tourist centres including roads required for strategic movements for the defence of India.

It was agreed that a first step *National Trails* should be constructed by the Centre and that latter these should be converted into roads to suit the traffic conditions. It was specified that national highways should be the frame on which the entire road communication should be based and that these highways may not necessarily be of same specification, but they must give an uninterrupted road communication through out India and should connect the entire road network.

All the national highways are assigned the respective numbers. The highway connecting *Delhi-Ambala-Amritsar* is denoted as NH-1, whereas a bifurcation of this highway beyond *Jalandar to Srinagar and Uri* is denoted NH-1-A. The highway connecting *Maduri and Rameswaram* is NH-49 and *Bombay-Agra* road is NH-3. A map showing National Highways is given in Plate *I*.

(ii) *State Highways* (SH) are arterial roads of a state, connecting up with the national highways of adjacent state, district head quarters and important cities within the state and serving as the main arteries for traffic to and from district roads.

These highways are considered as main arteries of commerce by roads within a state or a similar geographical unit. In some places they may even carry heavier traffic than some of the national highways but this will not alter their designation or function. The NH and SH have the same design speed and geometric design specifications.

(iii) *Major District Roads* (MDR) are important roads within a district serving areas of production and markets and connecting those with each other or with the main highways of a district. The MDR has lower speed and geometric design specifications than NH/SH.

(iv) *Other District Roads* (ODR) are roads serving rural areas of production and providing them with outlet to market centres, taluk head quarters, block development head quarters or other main roads. These are of lower design specifications than MDR.

(v) *Village Roads* (VR) are roads connecting villages or groups of villages with each other to the nearest road of a higher category.

It was specified that these village roads should be in essence farm tracks, but it was desired that the prevalent practice of leaving such tracks to develop and maintain by themselves should be replaced by a plan for a designed and regulated system.

A general note was assigned by the Nagpur Road Conference regarding the economics of road construction that all roads of whatever type or class, should be so constructed that maintenance and capital costs over a period of 20 years will be minimum. The responsibility of construction and maintenance of national highways was decided to be with the central government; it was stated that "Centre should select the national highways and trails, accord priorities and pay for all construction and maintenance".

2.4.4 Modified Classification of Road System by Third Road Development Plan, 1981-2001

The roads in the country are now classified into three classes, for the purpose of transport planning, functional identification, earmarking administrative jurisdictions and assigning priorities on a road net work viz.;

(i) Primary system

(ii) Secondary system and

(iii) Tertiary system or rural roads.

Primary system consists of two category

(a) Expressways and

(b) National Highways (NH)

Expressways are a separate class of highways with superior facilities and design standards and are meant as through routes having very high volume of traffic. The expressways are to be provided with divided carriage ways, controlled access, grade separations at cross roads and fencing. These highways should permit only fast moving vehicles. Expressways may be owned by the Central Government or a State Government, depending on whether the route is a National Highway or State Highway.

The Secondary system consists of two categories of roads

(a) State Highways (SH) and

(b) Major District Roads (MDR)

The Tertiary system are rural roads and these consists of two categories of roads :

(a) Other District Road (ODR)

(b) Village Roads (VR)

The definitions of NH, SH, MDR, ODR and VR are the same as given under classification of roads by Nagpur Road Plan in Art. 2.4.3.

2.4.5 Classification of Urban Roads

The road system within urban areas are classified as Urban Roads and will form a separate category of roads to be taken care by the respective urban authorities. The length of urban roads are not included in the targets of the Third Twenty Year Road Development Plan 1981-2001.

The urban roads, other than expressways, are classified as :

(i) Arterial roads

(ii) Sub-arterial roads

(iii) Collector streets and

(v) Local streets

Arterials and sub-arterials are streets primarily for through traffic on a continuous route, but the sub-arterials have a lower level of traffic mobility than the arterials. Collector streets provide access to arterial streets and they collect and distribute traffic from and to local streets which provide access to abutting property.

2.5 ROAD PATTERNS

The various road patterns may be classified as follows :

(a) Rectangular or block pattern

(b) Radial or star and block pattern

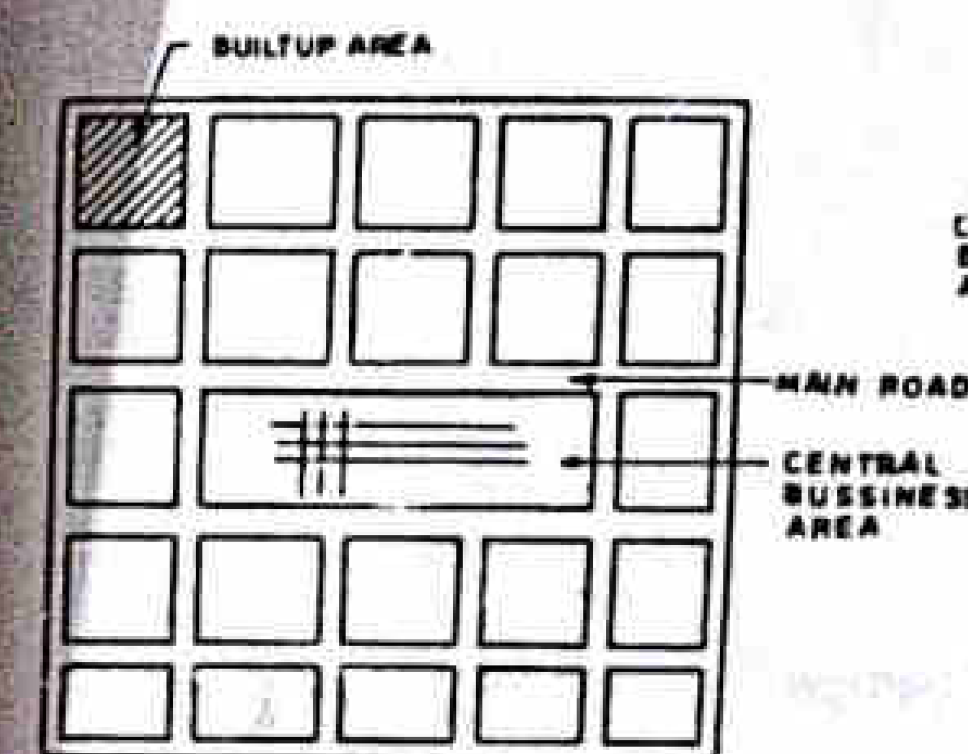
(c) Radial or star and circular pattern

(d) Radial or star and grid pattern

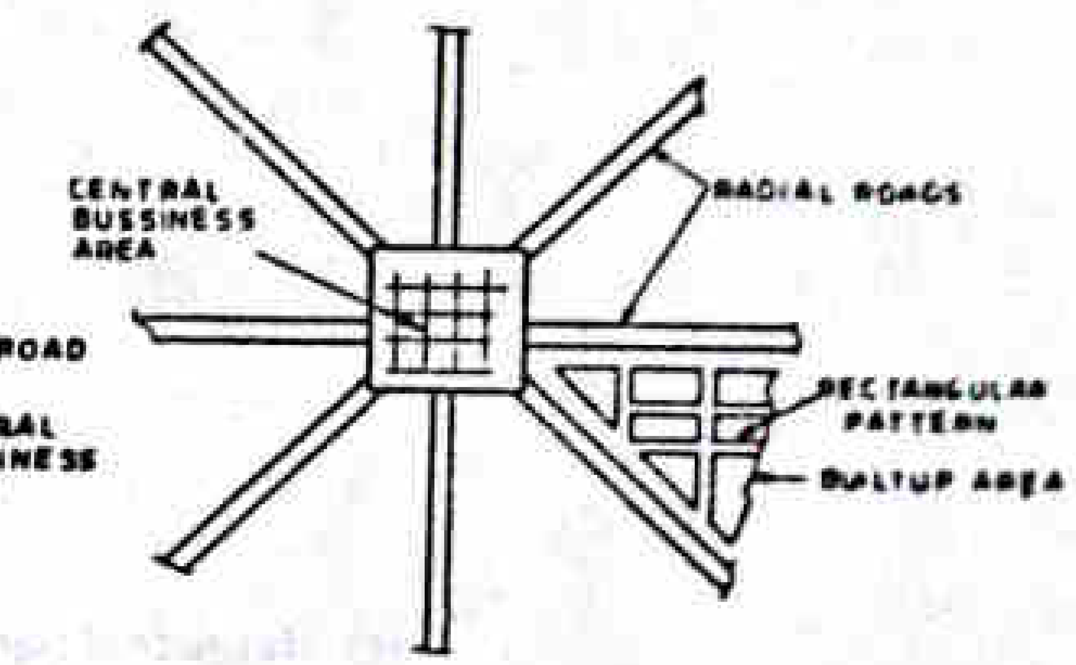
(e) Hexagonal pattern

(f) Minimum travel pattern

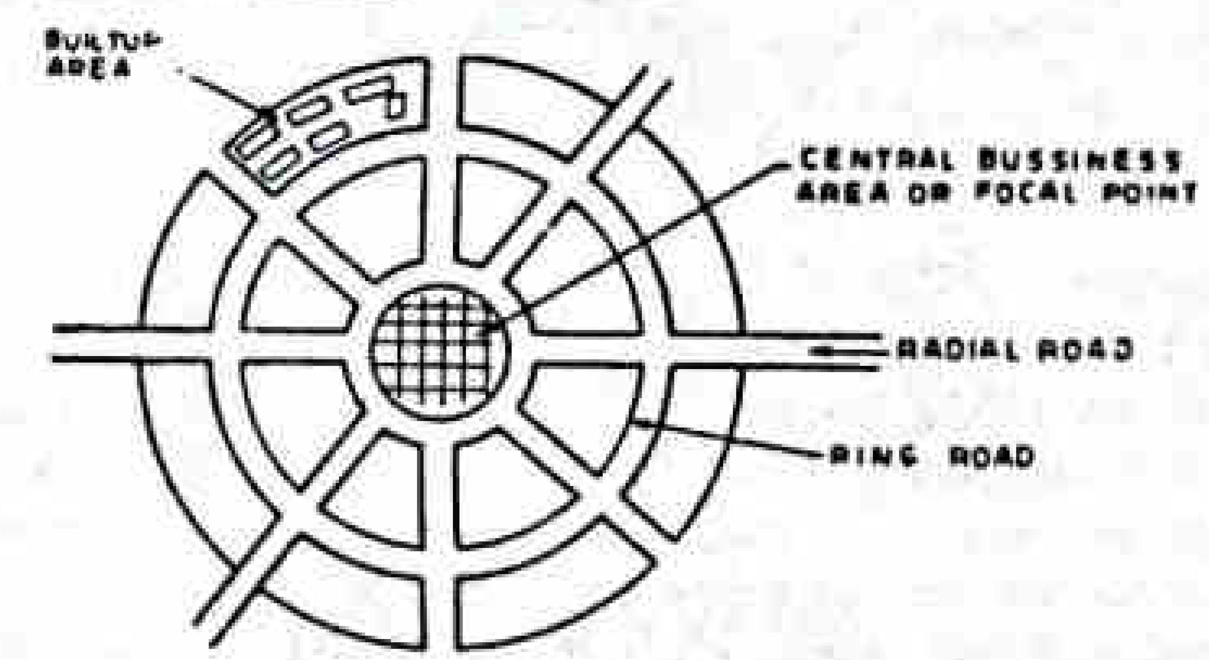
These have been shown in Fig. 2.5 a, b, c, d, e & f.



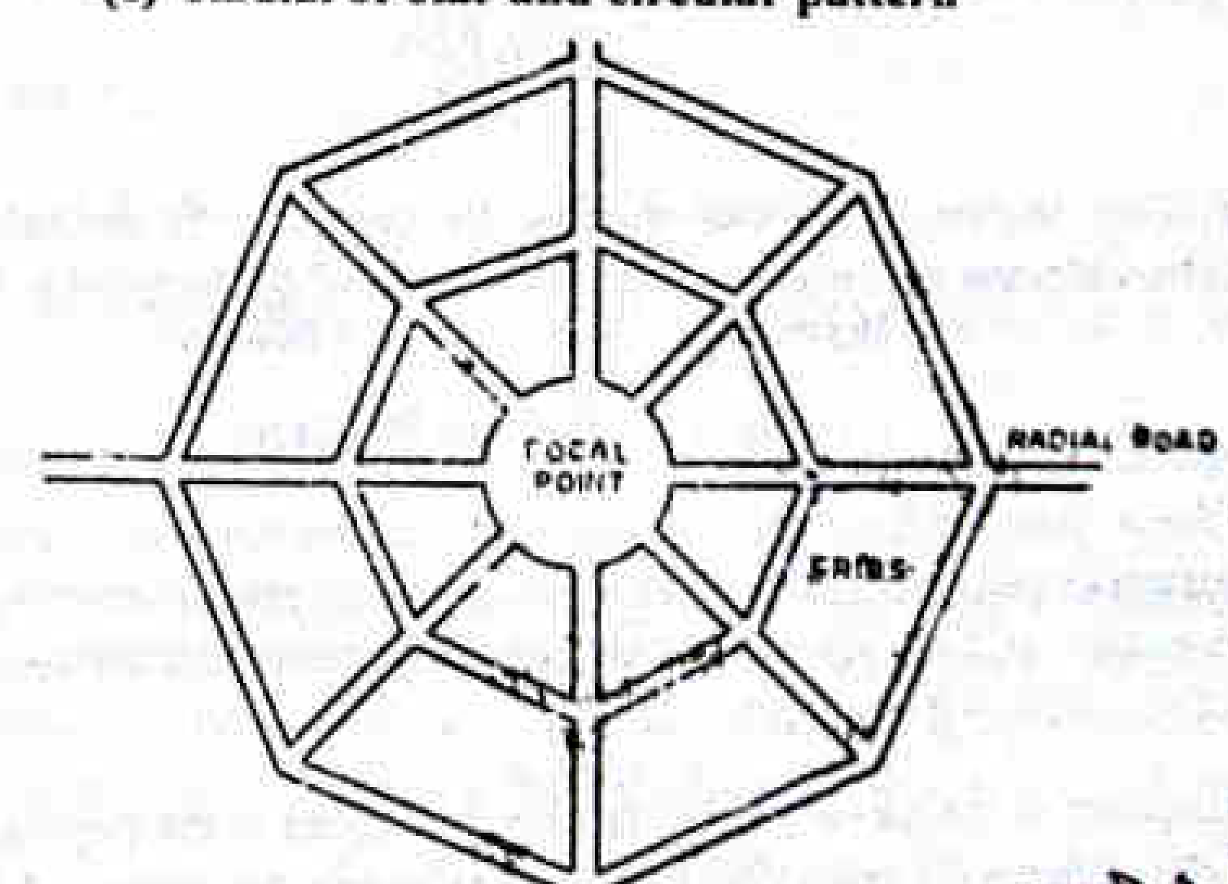
(a) Rectangular or block pattern



(b) Radial or star and block pattern

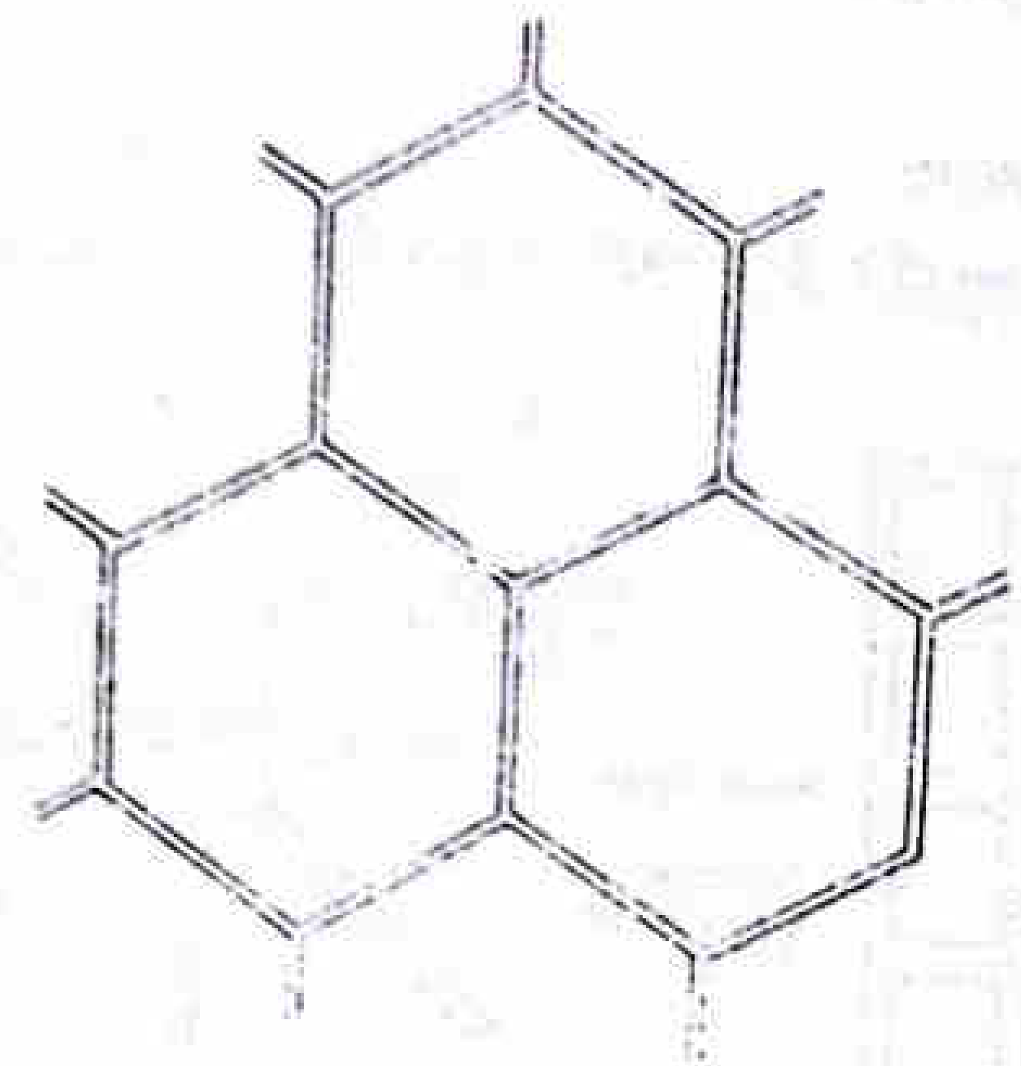


(c) Radial or star and circular pattern

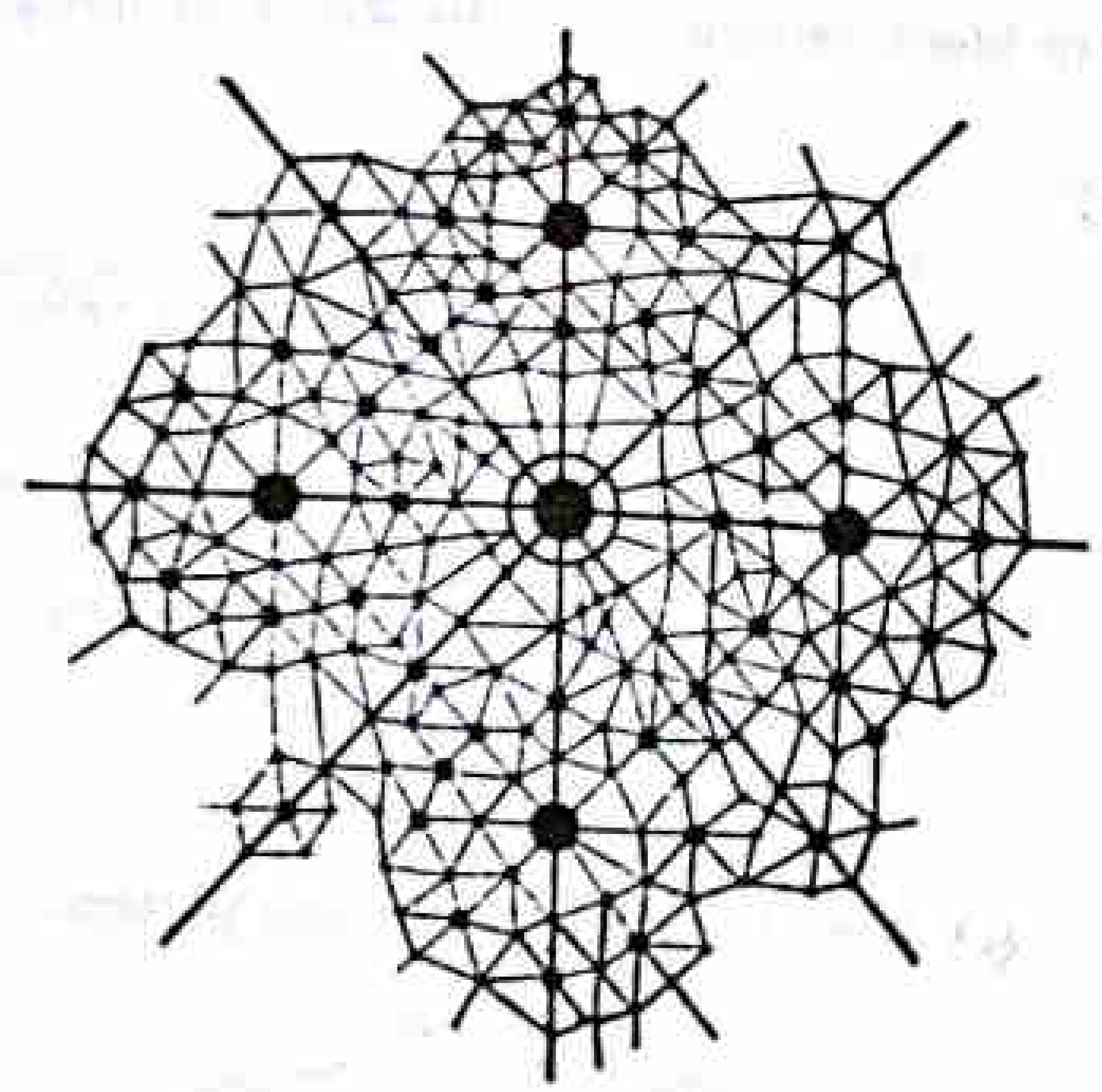


(d) radial or star and grid pattern → Nagpur

Fig. 2.5 Road Patterns *(Contd.)*



(e) Hexagonal pattern



Legend : City centre – encircled dot, sector centers - ●, Suburban centers - •, Neighbourhood centers - •, Representation of a "Minimum Travel" city (Assumed population of 2 million)

Fig. 2.5 (f) Road Patterns

Each of these patterns have their advantages and limitations. There can be a number of other geometric patterns also. The choice of the pattern very much depends on the locality, the layout of different towns, villages, industrial and production centres and on the choice of the planning engineer.

The rectangular or the block pattern has been adopted in the city roads of *Chandigarh*. But from traffic operation point this is not considered convenient. An example of radial and circular pattern is the road net work of *Connaught Place* in New Delhi. The Nagpur road plan formulae were prepared assuming *Star and Grid pattern*.

The concept of star and gird patterns has been explained below and illustrated in Fig. 2.6.

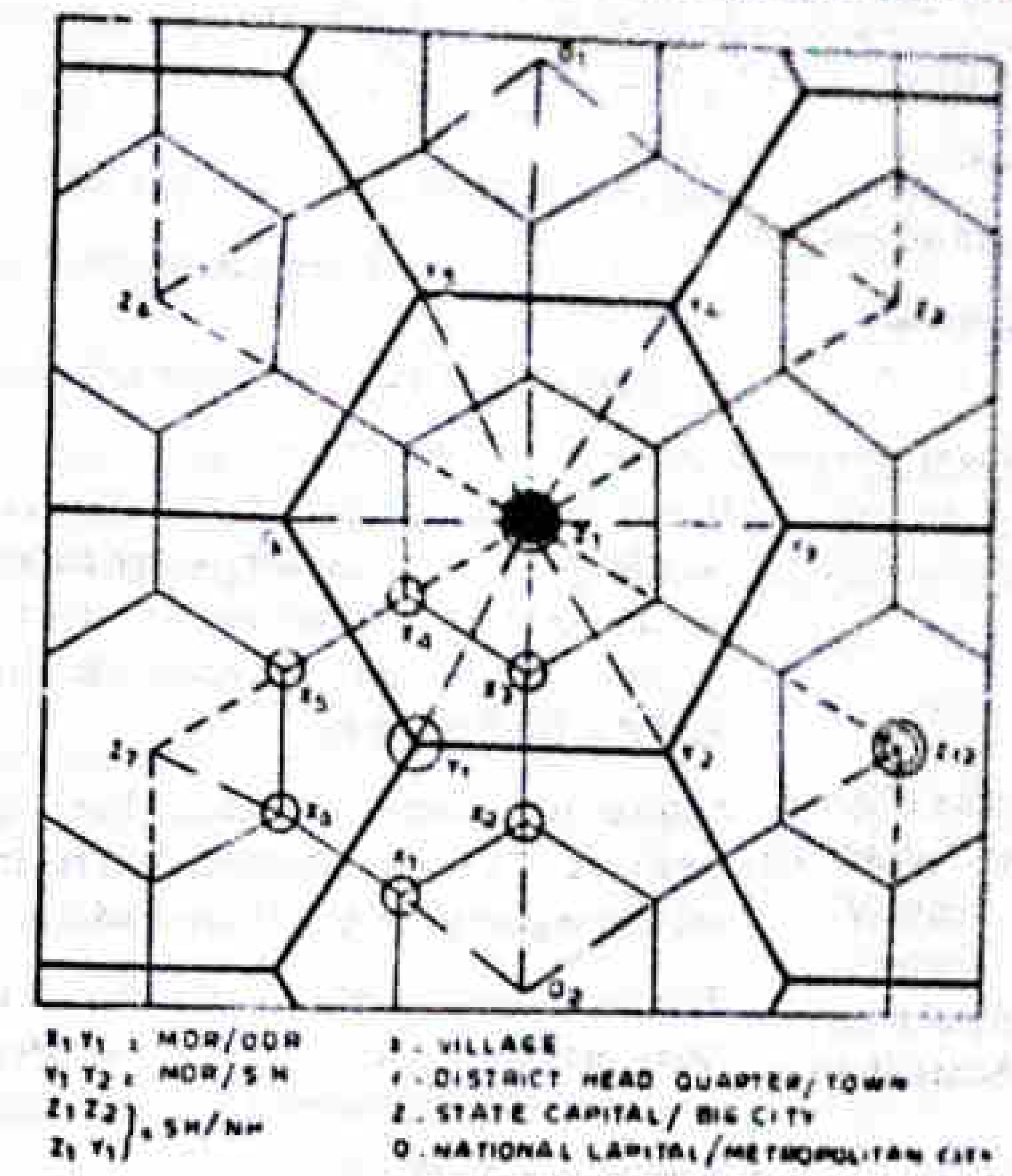


Fig. 2.6 Concept of Star and Gird Pattern

Let us assume that 'X' and 'Y' represent the villages and towns; 'Z' represent the capital towns of cities or state capitals Y_1, Y_2, Y_3 etc. are therefore acting as focal points for connecting X_1, X_2, X_3 etc., the villages. Similarly, Z_1, Z_2, Z_3 etc. are focal points for connecting Y_1, Y_2, Y_3 etc., the capital towns or cities or state capitals. Thus star and grid pattern is formed between points X_1, X_2, X_3 etc. Similarly a bigger star and grid pattern is formed with Y_1, Y_2, Y_3 etc. and Z_1, Z_2, Z_3 etc. as focal points, the whole area can thus be covered on an expanding scale. Such a network therefore, provides inter-communication facilities to each of the villages, towns, district headquarters, state capitals etc.

2.6 PLANNING SURVEYS

Highway planning phase includes

(i) Assessment of road length requirement for an area (it may be a district, state or the whole country)

(ii) Preparation of master plan showing the phasing of plan in annual and or five year plans.

Thus for assessing the road length requirement, field surveys are to be carried out to collect the data required for determining the length of the road system. The field surveys thus required for collecting the factual data may be called as planning surveys or *fact finding surveys*. The planning based on the factual data may be considered scientific and sound.

The factual studies point to an intelligent approach for planning and these studies should be carried out if the highway programme is to be protected from inconsistent and short sighted policies.

The planning surveys consist of the following studies; the details shown in Fig. 2.7.

(a) Economic studies

(b) Financial studies

(c) Traffic or road use studies

(d) Engineering studies

PLANNING SURVEYS

Economic studies		Population, its distribution and classification. Trend of population growth; Listing of agricultural and industrial development, their future trends-classification and listing of these details; other activities viz. Income per capita, banking, post office etc.
Financial Studies	Data Collected Must Confirm To : Adequacy, Accuracy Availability, Accessibility	Source of income, Revenue from taxation on road transport. Living standard, future trends-details like vehicle registration, Court fees and Local taxes etc.
Traffic or road use studies		Traffic volume, traffic flow patterns- O and D studies, Mass transportation facilities, Accidents - their costs, trends; Growth of vehicular traffic, passenger trips and good movements.
Engineering studies		Road location and alignment studies, Classification; Types of roads in use; Maintenance problems - Soil and topography studies; Road life studies.

Fig. 2.7 Details of Planning Surveys

(a) Economic Studies

The various details to be collected are useful in estimating the economics involved in the highway development programme. Hence it is desirable to find the service given by each road system to the population and products of the area. All details of the existing facilities should be available before estimating the requirement such that economic justification can be made for each plan. The details to be collected include the following :

(i) Population and its distribution in each village, town or other locality with the area classified in groups.

(ii) Trend of population growth.

(iii) Agricultural and industrial products and their listing in classified groups, area wise.

(iv) Industrial and agricultural development and future trends.

(v) Existing facilities with regard to communication, recreation and education etc.

(vi) Per capita income.

(b) Financial Studies

The financial studies are essential to study the various financial aspects like sources of income and the manner in which funds for the project may be mobilized. The details to be collected include :

(i) Sources of income and estimated revenue from taxation on road transport

(ii) Living standards

(iii) Resources at local level, toll taxes, vehicle registration and fines.

(iv) Future trends in financial aspects.

(c) Traffic or Road Use Studies

All the details of the existing traffic, their volume and pattern of flow should be known before any improvement could be planned. Traffic surveys should be carried out in the whole area and on selected routes and locations in order to collect the following particulars :

(i) Traffic volume in vehicles per day, annual average daily traffic, peak and design hourly traffic volume.

(ii) Origin and destination studies

(iii) Traffic flow patterns

(iv) Mass transportation facilities

(v) Accidents, their cost analysis and causes

(vi) Future trend and growth in traffic volume and goods traffic; trend in traffic pattern

(vii) Growth of passenger trips and the trend in the choice of modes.

(d) Engineering Studies

All details of the topography, soil and other problems such as drainage, construction and maintenance problems should be investigated before a scientific plan or programme is suggested. The studies include :

(i) Topographic surveys

(ii) Soil surveys

(iii) Location and classification of existing roads

(iv) Estimation of possible developments in all aspects due to the proposed highway development.

(v) Road life studies

(vi) Traffic-studies-Origin and Destination studies

(vii) Special problems in drainage, construction and maintenance of roads.

Thus all the above studies for collecting the factual data for highway planning are known as *fact finding surveys*. The details collected are tabulated and plotted on the maps of the area under planning.

2.7 PREPARATION OF PLANS

Before finalising the alignment and other details of the road development programme, the information collected during the fact finding surveys should be presented in the form of plans. Usually four drawings are prepared showing the various details of the area as listed below.

PLAN I General area plan showing almost all existing details viz. topography, existing road network and drainage structure, rivers, canals, nallahs etc., towns and villages with the population; commercial industrial or agricultural activities are also shown in this map.

PLAN II This plan includes the distribution of population groups in accordance with the categories made in the appropriate plan.

PLAN III This plan shows the locations of places with their respective quantities of productivity.

PLAN IV This plan shows the existing road network with traffic flows and desire lines obtained from Origin and Destination studies of traffic. Proposals received from different sources may also be shown in this plan.

2.8 INTERPRETATION OF PLANNING SURVEYS

The various details collected from the planning surveys and presented in the form of plans should be interpreted in a scientific way before arriving at the final road development programme.

The data collected could be interpreted and used for the following important purposes :

(i) To arrive at the road net-work, out of the several alternate possible systems, which has the maximum utility.

(ii) To fix up priority of the construction projects, so as to phase the road development plan of an area in different periods of time such as five year plans and annual plans.

(iii) To assess the actual road use by studying the traffic flow patterns. This data may therefore show areas of congestion which need immediate relief.

(iv) Based on the traffic type and intensity and the performance of existing types of pavement and cross drainage structures, a new structure may be designed using the data and the past experience.

(v) Comparison of the areas may be obtained on the basis of their economic activities. This information may therefore suggest the areas of immediate need for road network.

(vi) On statistical basis, the data obtained in fact finding surveys may be analysed for the future trends in development of an area i.e., growth in productivity and population which in turn generate higher traffic volume. This information may be useful in the future planning.

2.9 PREPARATION OF MASTER PLAN AND ITS PHASING

Master plan is the final road development plan for the area under study which may be a block, taluk, district, state or the whole country. Based on the above plans, different possible net work of new roads and improvement of some of the existing roads are proposed. In each proposal the population and productivity (industrial and agricultural) of each locality, the traffic flow, topography and all other details, both existing and possible changes in future are kept in view.

If some target of road length has been fixed for the country on the basis of area or population and production or both, the same may be taken as a guide for deciding the total length of the road system in each alternative proposal. In India, the target road lengths were decided by the Nagpur road plan formulae for the period 1943-63 and by the second 20-year road development plan for the period 1961-81, as mentioned in Art. 2.2.5 and 2.2.6 and also as described in Art. 2.10. These plan formulae for finding the road length are based on population and areas divide into different categories, depending on development achieved.

The next step is to compare the various alternate proposals of road systems in hand and to select the one which may be considered as best under the plan period. This is a quite difficult problem as the decision has to be a balanced one. In arriving at the best road system out of the alternate proposals, it is desirable to make use of the concept of *saturation system* based on U. S. system of highway planning.

After deciding the optimum road length for a plan period the final step is the phasing of the road development plan by fixing up the priorities for the construction of different road links.

Saturation system

In this system the optimum road length is calculated for area, based on the concept of obtaining maximum utility per unit length of road. Hence this system is called *saturation system or maximum utility system*. The factors which are taken for obtaining the utility per unit length of road are :

(a) Population served by the road network

(b) Productivity served by the net work

(i) Agricultural products

(ii) Industrial products

The following steps may be followed to find the road net work having maximum utility per unit length by the saturation system.

Step (i) Population units. Since the area under consideration may consist of villages and towns with different populations, it is required to group these into some convenient population ranges and to assign some reasonable values of utility units to each range of populations served. For example, villages having population range between 1001 and 2000 may be grouped together and be assigned one utility unit per village. Similarly the various villages and towns may be grouped in different population ranges and be assigned suitable utility units as given below :

Population less than 500, utility unit = 0.25

501 to 1000, utility unit = 0.50

1001 to 2000, utility unit = 1.00

2001 to 5000, utility unit = 2.00 etc.

From plan II of population prepared earlier, the number of towns and villages with population ranges served by each road system is found and then converted into the utility units served by each road. Thus the total number of units based on population can be obtained for each road system proposed.

Step (ii) Productivity units. The total agricultural and industrial products served by each road system should be worked out. The productivity served may be assigned appropriate values of utility units per unit weight. For example one thousand tonnes of agricultural products may be considered equivalent to one unit. Similarly the industrial products may also be assigned some suitable utility units per unit weight. However, coal, raw materials like ores etc. may be assigned lower utility values than the industrial products. From plan III showing the products in the area, the total productivity units served by each road system may be estimated.

Step (iii) Utility. The total utility units of each road system is found by adding the population units and productivity units. The total units are divided by the total road length of each system to obtain the utility rate per unit length.

Each road system having different layout and length would show different values of utility per unit length. The proposal which gives maximum utility per unit length may be chosen as the final layout with optimum road length, based on maximum utility on the saturation system.

This method is useful not only to choose the best layout from the alternate proposals, but also to phase the road development plan. The only limitation of the system is the possible variation in the relative weightages assigned to population and productivity. It is possible to give a relatively higher weightage either to the population or to a certain type of products. A sound judgment based on professional skill and experience should be helpful in providing balanced weightages for arriving at the optimum road length or the best road system with maximum utility per unit length of road.

Phasing of Road Programme

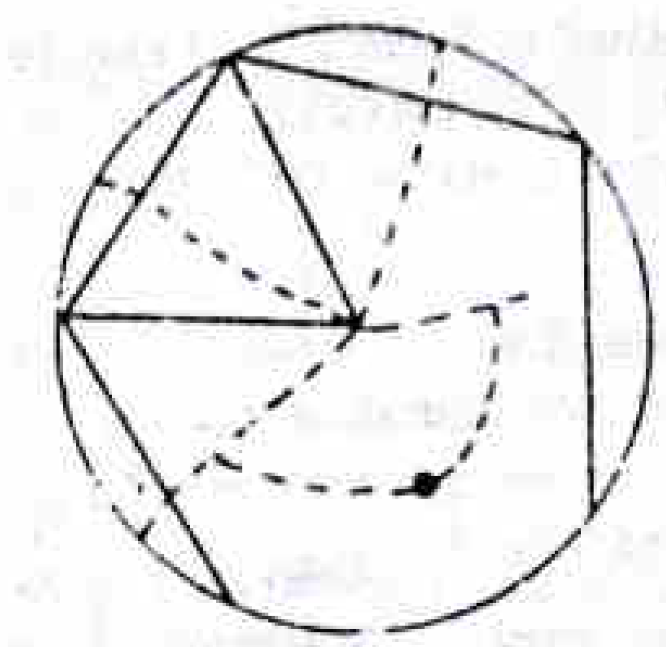
The road net-work to be constructed and improved in the plan period is decided while finalising the master plan of the road development project. The plan period may be of a long term, like that of the 20-year road plan or of shorter period like five year plans. But whatever be the plan period, it is necessary to phase the road development programme from financial considerations. In other words, it is necessary to fix up the priorities for the construction of each link of the road net work development programme to decide which link should be taken up first and which one the next and so on. The phasing may also be done for each annual budget year by fixing up the priorities.

Here again the priority for each road link may be fixed scientifically based on maximum utility. The utility per unit length of road based on population and productivity for each road is worked out. Then each link of the net work is listed in the order of priority based on utility per unit length of the road.

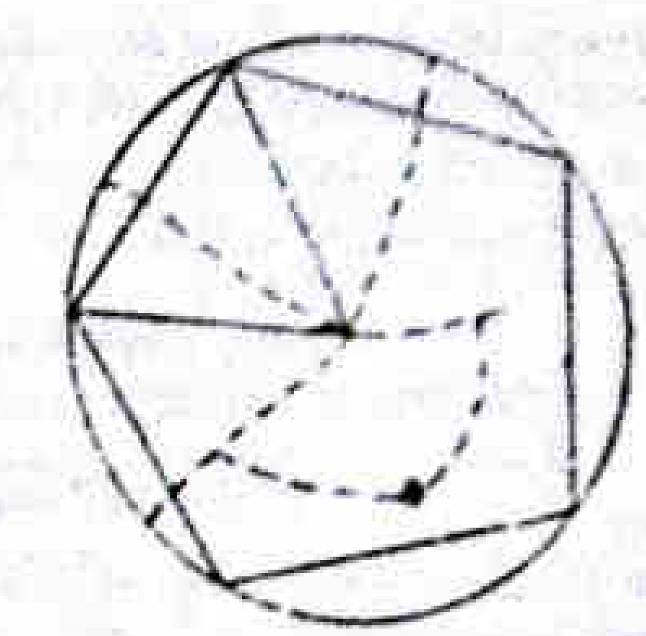
Example 2.1

An imaginary area with existing roads is shown in Fig. 2.8. There are four alternate plan proposals P, Q, R and S with different road length by adding extra road links to the existing roads in the area and the details of the population and products served are given below :

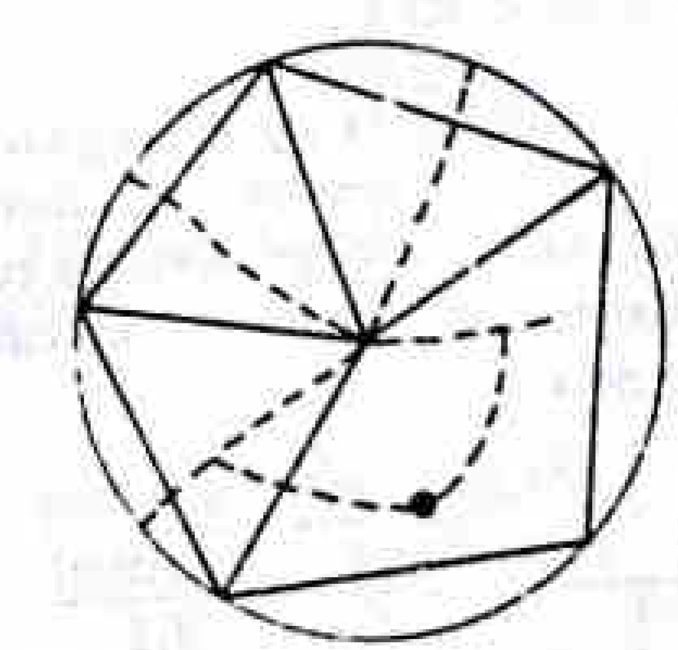
Prop-osal	Total road length km.	Number of towns and villages served with population range				Total agricultural & industrial products thousand tones
		1001-2000	2001-5000	5001-10000	> 10000	
P	300	160	80	30	6	200
Q	400	200	90	60	8	270
R	500	240	110	70	10	315
S	550	248	112	73	12	335



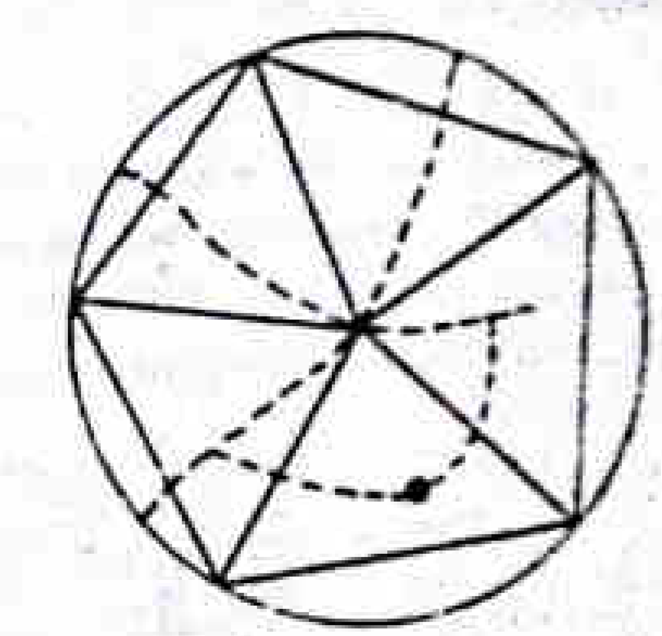
Plan – P
Road Length = 300 km
Population units = 125
Productivity units = 200



Plan – Q
Road Length = 400 km
Population units = 175
Productivity units = 270



Plan – R
Road Length = 500 km
Population units = 210
Productivity units = 315



Plan – S
Road Length = 550 km
Population units = 221
Productivity units =

.... Existing roads in the area
——— Proposed roads in the

Fig. 2.8 Example 2.1

Work out the utility per unit length for each of the systems and indicate which of the plans yield the maximum utility based on saturation system.

Assume utility units as given below :

(a)	Population	unit
	1001-2000	0.25
	2001-5000	0.50
	5001-10000	1.00
	> 10000	2.50
(b)	Productivity	unit
	1000 tonnes	1.0

Solution

The problem is solved and values obtained are tabulated in Table 2.2. It may be seen that the plan proposal Q (with total road length of 400 km) has maximum utility per unit length of road (based on population and productivity), equal to 1.12; therefore the optimum road length in this area is 400 km.

Table 2.2 Solution of Example 2.1

(Method of arriving at optimum road length based on saturation system)

Road plan proposal	Road length Km	No. of towns & villages served with population				Total units		Utility per unit length	Priority based on utility
		1001-2000	2001-5000	5001-10000	> 10000	popu-lation	produ-ctivity		
P	300	160 × 0.25	80 × 0.5	30 × 1	6 × 2.5	125	200	325/300 = 1.083	II
Q	400	200 × 0.25	90 × 0.5	60 × 1	8 × 2.5	175	270	445/400 = 1.112	I
R	500	240 × 0.25	110 × 0.5	70 × 1	10 × 2.5	210	315	525/500 = 1.050	III
S	550	248 × 0.25	112 × 0.5	73 × 1	12 × 2.5	221	335	556/550 = 1.010	IV

Example 2.2

Three new roads A, B and C are to be completed in a district during a five year plan period. Work out the order of priority for phasing the plan programme by maximum utility principle, from the data given below. Adopt utility unit of 1.0 for serving a village with population range 2000 to 5000, or for catering for 1000t of agricultural products/100t of industrial products. Assume any other data.

Road	Length km	No. of village served population			Productivity 1000 tonnes	
		< 2000	2000-5000	> 5000	Agricultural	Industrial
A	15	10	8	3	15	1.2
B	12	16	3	1	11	0.0
C	18	20	10	2	20	0.8

Solution

Table 2.3

(Phasing of road development plan)

Road	Length, km	Total utility units served by the road	Utility per unit length	Priority
A	15	10 × 0.5 + 8 ×1 + 3 × 2 + 15 × 1 + 1.2 ×10 = 46	46/15 = 3.07	I
B	12	16 × 0.5 + 3 × 1 + 1 × 2 + 11 × 1 + 0 = 24	24/12 = 2.0	III
C	18	20 × 0.5 + 10 × 1 + 2 × 2 + 20 × 1 + 0.8 × 10 = 52	52/18 = 2.89	II

Therefore order of priority is A, C and B

Assume the following utility units as per the given guide lines :

Per village served with population < 2000 = 0.5

Per village served with population 2000-5000 = 1.0

Per village served with population > 5000 = 2.0

Agricultural products served per 1000 t = 1.0

Industrial products served per 1000 t = 10.0

2.10 HIGHWAY PLANNING IN INDIA

The first attempt for proper planning of the highway development programme in India on a long term basis was made at the Nagpur Conference in 1943, as indicated in Art. 2.2.6. After the completion of the Nagpur Road Plan targets, the Second Twenty Year Plan was drawn for the period 1961-1981. The Third Twenty Year Road Development Plan for the period 1981-2001 was approved only by the year 1984.

2.10.1 Nagpur Road Plan or First 20-Year Road Plan

The Conference of Chief Engineer held at Nagpur in 1943 finalized the first twenty year road development plan for India called Nagpur Plan for the period 1943-63. The road net-work in the country was classified into five categories viz. (i) National Highways (ii) State Highways (iii) Major District Roads (iv) Other District Roads and (v) Village Roads as, explained in Art. 2.4.3.

Recommendations were made for the geometric standards of roads, bridge specifications and highway organizations. Two plan formulae were finalised at the Nagpur Conference for deciding two categories of road length for the country as a whole as well as for individual areas (like district). This was the first attempt for highway planning in India.

The two plan formulae assumed the *Star and Grid pattern* of road net work. Hence the two formulae are also called *Star and Grid Formulae.*

The total length of the first category or metalled roads for National and State Highways and Major District Roads in km is given by the formula :

$$NH + SH + MDR\ (km) = \left[\frac{A}{8} + \frac{B}{32} + 1.6N + 8T\right] + D - R \qquad (2.1)$$

where A = Agricultural area, km^2

B = Non-agricultural area, km^2

N = Number of towns and villages with population range 2001-5000.

T = Number of towns and villages with population over 5000.

D = Development allowance of 15 percent of road length calculated to be provided for agricultural and Industrial development during the next 20 years.

R = Existing length of railway track, km.

The total length of second category roads for Other District Road and Village Roads in km is given by the formula :

$$ODR + VR\ (km) = [0.32\,V + 0.8Q + 1.6P + 3.2S] + D \qquad (2.2)$$

where V = Number of villages with population 500 or less

Q = Number of villages with population range 501-1000

P = Number of villages with population range 1001-2000

S = Number of villages with population rang 2001-5000

D = Development allowance of 15 % for next 20 years.

From the above two formulae, it may be seen that in addition to the road length based on agricultural and non agricultural areas, specific road length were allocated for towns and villages of different population ranges. For example a town or village with population between 2001 and 5000 is allocated a road length of 1.6 km of first category road and 3.2 km of second category road whereas a village with population less than 500 is allotted only 0.32 km of second category road. A length of 1/8 km of first category road is provided per km^2 of agricultural area. This means that grids of first category roads are spaced at 16 kms, such that an area of 16×16 km^2 is provided with (16 + 16) or 32 km of road length, i.e., 32 km road length is available in an agricultural area of 256 km^2 or 1.0 km per 8 sq. km area and therefore the term A/8 is used in the Eq. 2.2.

Salient Features of Nagpur Road Plan

(i) The responsibility of construction and maintenance of national highways was assigned to the central government.

(ii) It was a 20-year plan intended for the period 1943-63 aiming to provide for about two lakh km of surfaced roads and remaining unsurfaced roads, so that when this target is reached, the total road length of 5, 32, 700 km with a density of about 16 km of road length per 100 sq. km area would be available in the country by the year 1963.

(iii) The formulae were based on star and gird pattern of road network. But the existing irregular pattern of roads and obligatory points not fitting in the geometric pattern were to be given due consideration.

(iv) The first category roads are meant to provide main grids bringing the farthest points in developed and agricultural area within 8 km of metalled road. The size of the gird of this category of road in agricultural area would be 16 km so that the maximum distance from the centre is 8 km and the average distance of the villages from metalled road would be less than 3.2 km. In non-agricultural area the size of the gird is of 64 km sides, the farthest distance from the centre to the metalled roads being 32 km. The length of road of this category is governed by the area, particularly the agricultural area and towns or villages with population greater than 2001.

(v) The second category roads are meant to provide internal road system linking small villages with first category roads. The road length of second category is worked out on the basis of villages of different population ranges, of population less than 5000.

(vi) An allowance for agricultural and industrial development during the next 20 years was estimated as 15 percent and this allowance was to be provided while calculating the road length for both the categories of roads.

(vii) The length of railway tracks in the area was also considered in deciding the length of first category road. The length of railway track is directly subtracted from the estimated road length of metalled roads.

The length of various categories of roads as per the target of Nagpur Road Plan of 1943-63 and the road lengths achieved by year 1961 are given in Table 2.4. Though the achievement of total road length was higher than the plan targets, the lengths of NH and SH achieved were lesser than the plan targets.

Table 2.4 Targets of Nagpur Road Plan and Achievement by the year 1961

Sl. No.	Category of road	Nagpur Plan targets, km	Achievement by 1961, km
1.	National Highway		
	(a) NH	26,715	
	(b) National Trails	6,680	
	Total NH	33,395	22,636
2.	State Highways	86,825	62,052
3.	Major District Roads	80,145	1,13,483
	Total main roads (metalled roads)	2,00,365	1,98,171
4.	Other District Roads	1,33 ,580	1,11,961
5.	Village Roads	1,98,755	3,88,841
6.	Unclassified Roads	-	10,149
	Total	5,32,700	7,09,122

Example 2.3

The following data were collected for planning the road development programme of a backward district.

(i) Total area = 9600 km^2

(ii) Agricultural and developed area = 3200 km^2

(iii) Existing railway track length = 105 km.

(iv) Existing length of metalled road = 322 km.

(v) Existing length of unmetalled road = 450 km.

(vi) Number of towns or villages in different population ranges are as below

Population	> 5000	2001-5000	1001-2000	501-1000	< 500
Number of villages and towns	8	40	130	280	590

Calculate the additional lengths of metalled and unmetalled roads for the road system based on Nagpur Road Plan formulae for this district.

Solution

(i) The total length of metalled roads by Nagpur Plan formula is obtained from equation 2.1 and is equal to :

$$\frac{A}{8} + \frac{B}{32} + 1.6N + 8T + D - R$$

Here,

$$A = 3200\ km^2;\ B = 9600 - 3200 = 6400\ km^2$$

$$N = 40;\ T = 8;\ D = 15\ \text{percent};\ R = 105\ km$$

$$\text{Metalled road length} = \left[\frac{3200}{8} + \frac{6400}{32} + 1.6 \times 40 + 8 \times 8\right] + 15\%\ \text{of total road length} - 105$$

$= [400 + 200 + 64 + 64] + 15\%$ of RL $- 105$

$$= 728 + \frac{15 \times 728}{100} - 105 = 732.2 \text{ km}$$

Additional metalled road needed

$= 732.2 - 322 = 410.2$ km

(ii) Total length of unmetalled roads by Nagpur plan formula may be obtained from equation 2.2 and is equal to :

$$[0.32\,V + 0.8\,Q + 1.6\,P + 3.2\,S] + D$$

Here,

$V = 590, Q = 280, P = 130, S = 40, D = 15\%$

Unmetalled road length

$= [0.32 \times 590 + 0.8 \times 280 + 1.6 \times 130 + 3.2 \times 40] + 15\%$ road length

$= [188.8 + 224 + 208 + 128] + 15\%$ of RL

$$= 748.8 + \frac{748.8 \times 15}{100} = 861 \text{ km}$$

Additional unmetalled roads required

$= 861 - 450 = 411$ km

2.10.2 Second Twenty Year Road Plan (1961-81)

The Nagpur road plan was intended for the period 1943-63, but the target road length was nearly completed earlier in 1961 (as shown in Table 2.4), mainly because of the phased development that took place in the country during the first two 5-year plans. Hence the next long term plan for the twenty year period commencing from 1961 was initiated by the IRC and was finalised by the sub committee and this was approved by the Chief Engineers. *The Second Twenty Year Road Development Plan 1961-81* is also called *Bombay Road Plan.*

The second road plan envisaged overall road length of 10,57,330 km by the year 1981. The cost of the plan has been worked out to Rs. 5,200 crores based on 1958 price level for a period of 20 years from 1961.

Five different formulae were framed to calculate the lengths of National Highways, State Highways, Major District Roads, Other District Roads and Village Roads.

These five formulae are given below :

(i) National Highways (km)

$$= \left[\frac{A}{64} + \frac{B}{80} + \frac{C}{96}\right] + [32K + 8M] + D \qquad (2.3)$$

(ii) National Highways + State Highways (km)

$$= \left[\frac{A}{20} + \frac{B}{24} + \frac{C}{32}\right] + [48K + 24M + 11.2N + 1.6P] + D \qquad (2.4)$$

(iii) National Highways + State Highways + Major District Roads (km)

$$= \left[\frac{A}{8} + \frac{B}{16} + \frac{C}{24}\right] + [48K + 24M + 11.2N + 9.6P + 6.4Q + 2.4R] + D \qquad (2.5)$$

(iv) National Highways + State Highways + Major District Roads + Other District Roads (km)

$$= \left[\frac{3A}{16} + \frac{3B}{32} + \frac{C}{16}\right] + [48K + 24M + 11.2N + 9.6P + 12.8Q + 4R + 0.8S + 0.32T] + D \qquad (2.6)$$

(v) National Highways + State Highways + Major District Roads + Other District Roads + Village Roads i.e., all roads (km)

$$= \left[\frac{A}{4} + \frac{B}{8} + \frac{C}{12}\right] + [48K + 24M + 11.2N + 9.6P + 12.8Q + 5.9R + 1.6S + 0.64T + 0.2V] + D \qquad (2.7)$$

where
- A = Developed and agricultural areas; km^2
- B = Semi-developed area, km^2
- C = Undeveloped area, km^2
- K = Number of towns with population over 1,00,000
- M = Number of towns with population range 1,00,000-50,000
- N = Number of towns with population range 50,000-20,000
- P = Number of towns with population range 20,000-10,000
- Q = Number of towns with population range 10,000-5,000
- R = Number of towns with population range 5,000-2,000
- S = Number of towns with population range 2,000-1,000
- T = Number of towns with population range 1,000-500
- V = Number of towns with range below 500
- D = Development allowance of 5 percent of road length calculated for further development and other unforeseen factors.

Salient features of the Second 20-year Plan (1961-81)

(i) This plan is considered to be drawn more scientifically in view of development needed in under-developed areas. The target of this plan is to provide a total road length of 32 km per 100 sq. km area which is almost double of that achieved up to the year 1961.

(ii) Maximum distance of any place in a developed or agricultural area would be 6.4 km from a metalled road and 2.4 km from any category of roads.

(iii) The maximum distance from any place in a semi-developed area would be 12.8 km from a metalled road and 4.8 km from any road; similarly the maximum distance in an undeveloped area would be 19.2 km from a metalled road and 8.0 km from any road.

(iv) Every town with population above 2000 in plains and above 1000 in semi-hilly areas and above 500 in hilly areas should be connected by a metalled road.

(v) While calculating road length in hilly regions, an allowance up to 100 percent may be made in arriving at the road length. Hills with altitude above 2300 metres may be ignored in calculating road length in view of thin population.

(vi) Expressways have also been considered in this plan and 1600 km of length has been included in the proposed target of National Highways.

(vii) Length of railway track is considered independent of the road system and hence it is not subtracted to get the road length.

(viii) The development factor of only 5 percent is provided for future development and unforeseen factors.

Comparison of Nagpur Plan & Second 20-year Road Plan or Bombay Road Plan

(i) Nagpur road plan gives two formulae, one is to find the length of first category roads or metalled roads consisting of National Highways, State Highways and major District Roads; the second formula is to find the length of second category roads or unmetalled roads consisting of other District Roads and Village Roads. Hence it is not possible to get the road length for each class of the road separately. In the second 20-year plan (1961-81), five different formulae have been given from which the length of each class of road i.e., NH, SH, MDR, ODR and VR, could be obtained individually.

(ii) The Nagpur road plan divides the area into two parts, viz. agricultural and non-agricultural area. In Bombay road plan, the area is divided into three parts.

(1) developed and agricultural area

(2) semi-developed area and

(3) undeveloped and uncultivated area

(iii) The second 20-year plan has a target road length of 32 km per 100 sq. km area which is double the Nagpur plan target.

(iv) Nagpur road plan formula does not take into account the towns with very large population. First category road length is decided based on towns with population range 2001-5000 and those with population above 5000, thus grouping all larger towns with population higher than 5000 together. But at present there are large number of towns having population varying from few thousands to several lakhs. It appears that such high growth of population in towns was not anticipated while the Nagpur road plan was drawn in 1943. In second 20-year plan, towns have been divided into nine different population ranges from less than 500 for the smallest town or villages to above 1,00,000 for larger towns.

(v) Nagpur road plan allowed deduction of the length of railways track in the area while calculating the length of first category roads. But it has been realised later that the highway system should be able to develop independently and so in the Bombay Road Plan, the length of railway track is not deducted.

(vi) Allowance for development of agriculture and industry during the next 20 years was made in Nagpur plan by allowing 15 percent increase in the calculated road length of both categories. The allowance for development due to unforeseen factors according to the second plan is only 5 percent.

(vii) The 1961-81 plan has provided 1600 km of expressways out of the proposed National Highways.

The lengths of various categories of roads as per the targets of Bombay Road Plan of 1961-81 and the road lengths achieved by the year 1981 are given in Table 2.5. The lengths of NH, SH and MDR achieved by the year 1981 fell short of the Plan targets. Further there were considerable deficiencies in geometric design standards, pavement surfacing and bridging requirements specified in the Plan. The lengths of ODR and VR achieved were however much higher. Therefore the total road length achieved by the year 1981 was higher than the targeted total length, resulting in a overall road density of 45.7 km of road length per 100 sq. km area in the country (including unclassified roads) as against the targeted density of about 32 km per 100 sq. km area in the Plan.

Table 2.5 Targets of Bombay Road Plan and Achievements by the Year 1981

Category of Road	Bombay Plan targets, km	Road length by 1981, km
National Highways	51,500	31,737
State Highways	1,12,650	95,491
Major District Roads	2,41,400	1,53,000
Other District Roads	2,89,680	-
Village Roads	3,62,100	-
Total ODR and VR	6,51,780	9,12,684
Total or NH, SH, MDR, ODR and VR	10,57,330	11,92,912
Unclassified roads such as urban roads and project roads	-	3,09,785
Grand total of all categories	10,57,330	15,02,697

Example 2.4

Calculate the lengths of National and State highways required in a district with a total area of 7200 km^2, developed, semi-developed and undeveloped areas being 30, 45 and 25% of the district. The number of towns with population over 1.0, 0.5-1.0, 0.2-0.5 and 0.1 - 0.2 lakhs are 3, 7, 12 and 20 respectively in the district. Use the formulas :

$$NH = [A/64 + B/80 + C/96 + 32K + 8M] + D$$

$$NH + SH = [A/20 + B/24 + C/32 + 48K + 24M + 11.2N + 1.6P] + D$$

Solution

$A = 7200 \times 0.30 = 2160 \text{ km}^2;$

$B = 7200 \times 0.45 = 3240 \text{ km}^2;$

$C = 7200 \times 0.25 = 1800 \text{ km}^2;$

$K = 3; M = 7; N = 12;$

$P = 20; D = 5\% \text{ of road length}$

$$NH = \left[\frac{2160}{64} + \frac{3240}{80} + \frac{1800}{96} + 32 \times 3 + 8 \times 7\right] + 5\% \text{ of RL}$$

$$= 245 \times 10.5 = 257.25 \text{ km}$$

$$NH + SH = \left[\frac{2160}{20} + \frac{3240}{24} + \frac{1800}{32} + 48 \times 3 + 24 \times 7 + 11.2 \times 12 + 1.6 \times 20\right] + 5\% \text{ of RL}$$

$$= 777.65 \times 1.05 = 816.53 \text{ km}$$

$$SH = 816.53 - 257.25 = 559.28 \text{ km}$$

Example 2.5

Calculate the total lengths of NH, SH, MDR, ODR and VR needed in a district as per second 20-year road development plan or Bombay Road Plan. The data collected from the district are given below :

(i) Total area = 18,400 km^2

(ii) Developed and agricultural area = 8000 km^2

(iii) Undeveloped area = 4800 km^2

(iv) Population centres are as given below :

Population range	Number of towns
< 500	200
500 - 1000	350
1000 - 2000	750
2000 - 5000	360
5000 - 10,000	150
10,000 - 20,000	80
20,000 - 50,000	25
50,000 - 1,00,000	10
> 1,00,000	5

Solution

(i) $$NH\ (km) = \frac{A}{64} + \frac{B}{80} + \frac{C}{96} + [32K + 8M] + D$$

Here, $A = 8{,}000\ km^2$; $C = 4{,}800\ km^2$

$B = 18{,}400 - [8{,}000 + 4{,}800] = 5{,}600\ km^2$

$K = 4$; $M = 10$; $D = 5\%$

$$NH\ (km) = \left[\frac{8000}{64} + \frac{5600}{80} + \frac{4800}{96} + 32 \times 5 + 8 \times 10\right] + 5\% \text{ of RL}$$

$$= [125 + 70 + 50 + 160 + 80]\frac{105}{100} = 485 \times \frac{105}{100} = 509.25$$

(ii) $$NH + SH\ (km) = \left[\frac{A}{20} + \frac{B}{24} + \frac{C}{32} + 48K + 24M + 11.2N + 1.6P\right] + D$$

Here, $N = 25$; $P = 80$

$$NH + SH = \left[\frac{8000}{20} + \frac{5600}{24} + \frac{4800}{32} + 48 \times 5 + 24 \times 10 + 11.2 \times 25 + 1.6 \times 80\right] + 5\% \text{ of RL}$$

$$= [400 + 233 + 150 + 240 + 240 + 280 + 128]\frac{105}{100}$$

$$= 1671 \times \frac{105}{100} = 1754.5 \text{ km}$$

$$SH = 1754.5 - 509.25 = 1245.25 \text{ km}$$

(iii) NH + SH + MDR (km) =

$$\left[\frac{A}{8} + \frac{B}{16} + \frac{C}{24} + 48K + 24M + 11.2N + 9.6P + 6.4Q + 2.4R\right] + D$$

Here, $Q = 150$; $R = 360$

$$NH + SH + MDR = \left[\frac{8000}{8} + \frac{5600}{16} + \frac{4800}{24} + 48 \times 5 + 24 \times 10 + 11.2 \times 25 + 9.6 \times 80 + 6.4 \times 150 + 2.4 \times 360\right] + 5\% \text{ of RL}$$

$$= [1000 + 350 + 200 + 240 + 240 + 280 + 768 + 960 + 864]\frac{105}{100}$$

$$= 4902 \times \frac{105}{100} = 5147 \text{ km}$$

$$MDR = 5147 - 1754.5 = 3392.5 \text{ km}$$

(iv) $$NH + SH + MDR + ODR\ (km) = \frac{3A}{16} + \frac{3B}{32} + \frac{C}{16} + 48K + 24M + 11.2N + 9.6P + 12.8Q + 4R + 0.8S + 0.32T + D$$

Here $S = 750$; $T = 350$

$$NH + SH + MDR + ODR = \left[\frac{3 \times 8000}{16} + \frac{3 \times 5600}{32} + \frac{4800}{16} + 48 \times 5 + 24 \times 10 + 11.2 \times 25 + 9.6 \times 80 + 12.8 \times 150 + 4 \times 360 + 0.8 \times 750 + 0.32 \times 350\right] + 5\% \text{ of RL}$$

$$= [1500 + 525 + 300 + 240 + 240 + 280 + 768 + 1920 + 1440 + 600 + 112]\frac{105}{100}$$

$$= 7925 \times \frac{105}{100} = 8321.2 \text{ km}$$

$$ODR = 8321.2 - 5147.0 = 3174.2 \text{ km}$$

(v) NH + SH + MDR + ODR + VR (km) =

$$\left[\frac{A}{4} + \frac{B}{8} + \frac{C}{12} + 48K + 24M + 11.2N + 9.6P + 12.8Q + 5.9R + 1.6S + 0.64T + 0.2V\right] + D$$

$$= \left[\frac{8000}{4}+\frac{5600}{8}+\frac{4800}{12}+48\times 5+24\times 10+11.2\times 25+9.6\times 80+ 12.8\times 150+5.9\times 360+1.6\times 750+0.64\times 350+0.2\times 200\right]+5\%\text{ of RL}$$

$$= [2000+700+400+240+240+280+768+1920+2124+1200+224+40]\frac{105}{100}$$

$$= 10136\times\frac{105}{100} = 10642.8\text{ km}$$

Here V = 200

VR = 10,642.8 − 8321.2 = 2321.6 km

The various road length required are as follows :

NH = 509.25 km;

SH = 1245.25 km;

MDR = 3392.50 km;

ODR = 3174.2 km;

VR = 2321.6 km

2.10.3 Third Twenty Year Road Development Plan 1981-2001

Policies and Objectives :

As mentioned in Art. 2.2.8, the Third Twenty Year Road Development Plan, 1981-2001 (also known as *Lucknow Road Plan*) was finalised and the plan document was published by the year 1984. The major policies and objectives of this road plan are listed below :

(i) The future road development should be based on the revised classification of road system consisting of primary, secondary, and tertiary road systems as mentioned in Art. 2.4.4.

(ii) The road net work should be developed so as to preserve the rural oriented economy and to develop small towns with all the essential facilities. All the villages with population over 500 (based on 1981 census) should be connected by all weather roads by the end of this century.

(iii) The overall road density in the country should be increased to 82 km per 100 sq. km area by the year 2001. The corresponding values of planned road densities are 40 for hill areas of altitude upto 2100 metres above MSL and 15 km per sq. km area for altitude above 2100 metre.

(iv) The National Highway net work should be expanded to form square grids of 100 km sides so that no part of the country is more than 50 km away from a NH.

(v) The lengths of SH and MDR required in a state or region should be decided based on both areas and number of towns with population above 5,000 in the state or region.

(vi) Expressways should be constructed along major traffic corridors to provide fast travel.

(vii) All the towns and villages with population over 1500 should be connected by Major District Roads and the villages with population 1000 to 1500 by Other District Roads. There should be a road within a distance of 3.0 km in plains and 5.0 km in hilly terrain connecting all villages or groups of villages with population less than 500.

(viii) Roads should also be built in less industrialized areas to attract the growth of industries.

(ix) Long term master plans for road development should be prepared at various levels, i.e., taluk, district, state and national levels. The road net work should be scientifically decided to provide maximum utility.

(x) The existing roads should be improved by rectifying the defects in the road geometrics, widening of the pavements, improving the riding quality of the pavement surface and strengthening of the pavement structure to save vehicle operation cost and thus to conserve energy.

(xi) There should be improvements in environmental quality and road safety.

Determination of Road Lengths by Third Road Plan Formulae

I. Primary Road System

(i) Expressways of total length 2000 km to be developed for fast travel based on traffic requirements.

(ii) National Highways are to be based on the concept of 100 km square grids, by providing 100 + 100 = 200 km of road length per 100 × 100 = 10000 sq. km area i.e., one km per 50 sq. km area. Therefore the total length of NH in the country or in a state could be obtained by dividing the total area of the country by 50

Length of NH in the country, km = 32,87,782/50 = 65,756 km,

say 66,000 km

*II. Secondary System :*Length of SH

The roads consisting of NH and SH should pass through every town or urban area; there are 3364 such towns in the country as defined by 1981 census. Therefore the area of each of the square grids would be equal to total area divided by the number of towns = 32,87,782/3364 = 977.3 sq. km, with sides $\sqrt{977.3}$ = 31.26 km. Therefore the length of (NH + SH) will be 2 × 31.26 = 62.5 km for each such square gird. Thus the total of (NH + SH) for 3364 towns in the country = 62.5 × 3364 = 2,10,250 km. The total length of NH for the country as determined earlier is 66,000 km. Thus the total length of SH in the country = 2,10,250 − 66,000 = 1,44,250 km, or say 1,45,000 km.

The total length of SH required for any State may be determined from the following two relations :

(a) By total area, SH, km = Area of the State, sq. km/25

(b) By total no. of towns and area in the State, SH, km = 62.5 × no. of towns in the State − area of the State, sq. km/50.

(iii) Length of MDR

Total length of MDR in the country has been worked out as 3,00,000 km.

The total length of MDR required in a State is determined from one of the following formulas :

(a) By total area, MDR, km = Area of the State, sq. km/12.5.

(b) By no. of towns in the State, MDR, km = 90 × no. of towns in the State.

III. Tertiary System or Rural Roads : Length of ODR and VR.

The total length of ODR and VR in the country by the year 2001 as per the third road development plan shall be 21,89,000 km so that the overall length of all categories of roads i.e., NH, SH, MDR, ODR and VR will be 27 lakh km by the end of the plan period. The total length of all the above five categories of roads (excluding urban roads) as per this plan target have been worked out for each State separately; the targeted total road lengths of some of the States in India are given in Table 2.6. The length of Rural Roads consisting of ODR and VR in each State may be determined by subtracting the length of (NH + SH + MDR) calculated for each state as mentioned in the previous paragraphs from the total road length given in Table 2.6. The distribution of the lengths of ODR and VR is to be decide by each state depending on the requirement.

Table 2.6 Estimated total road lengths in some states by the year 2001, as per third road development plan targets

State	Total road length (NH, SH, MDR, ODR & VR) by the year 2001, km
1. Andhra Pradesh	1,74,856
2. Assam	85,282
3. Bihar	2,12,032
4. Gujarat	1,14,886
5. Haryana	34,738
6. Himachal Pradesh	61,262
7. Jammu & Kashmir	53,840
8. Karnataka	1,44,654
9. Kerala	1,28,963
10. Madhya Pradesh	3,41,268
11. Maharashtra	2,20,877
12. Orissa	1,65,507
13. Punjab	50,132
14. Rajasthan	2,09,392
15. Tamil Nadu	1,38,115
16. Uttar Pradesh	3,55,160
17. West Bengal	1,15,792

Example 2.6

The area of a certain district in India is 13,400 sq. km and there are 12 towns as per 1981 census. Determine the lengths of different categories of roads to be provided in this district by the year 2001.

Solution

(i) Length of NH, km = 13400/50 = 168 km

(ii) Length of SH :

(a) By area, SH, km = 13400/25 = 536 km

(b) By area and no. of towns, SH, km = 62.5 × 12 – 13400/50 = 482 km

Adopt length of SH (higher of the two criteria) = 536 km

(iii) Length of MDR, in the District :

(a) By area, MDR, km = 13400/12.5 = 1072 km

(b) By no. of towns, MDR, km = 90 × 12 = 1080 km

Provide length of MDR (higher of the two criteria) = 1080 km

(iv) Total length of all categories of roads may be assumed to provide an overall density of road length equal to 82 km per 100 sq. km area by the year 2001.

NH + SH + MDR + ODR + VR = 13400 × 82/100 = 10988 km

Length of NH + SH + MDR = 268 + 536 + 1080 = 1884 km

Therefore length of Rural roads consisting of ODR + VR = 10988 – 1884 = 9104 km

(i) Primary system of NH = 268 km

(ii) Secondary system consisting of SH = 536 and MDR = 1080, total length = 1616 km

(iii) Tertiary system of Rural Roads consisting of ODR and VR = of length = 9104 km

(iv) Total road length = 10,988 km

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PROBLEMS

1. Briefly discuss the historical development of road construction.
2. What are the salient features of early Roman Roads ? How do these differ from the present day road construction ?
3. Compare the construction methods of Telford and Macadam; bring out the points of differences.
4. Briefly explain the Macadam's method of road construction. Why is this method considered better and more scientific compared to the previous methods ?
5. Discuss briefly with reasons how further improvements to the water bound macadam road became necessary.
6. Briefly outline the highway development in India.
7. Explain the necessity and objects of highway planning.
8. What are the various methods of classifying roads ? Briefly outline the classification based on location and function as suggested in the Nagpur Road Plan.
9. What are the significant recommendations of Jayakar Committee Report ? Mention how this helped in road development in India ?
10. Explain briefly the modified classification of road system in India as per the Third Twenty Year Road Development Plan, 1981-2001.
11. Briefly outline the main features of various road patterns commonly in use. Explain with sketches the star and grid pattern.
12. What are the various surveys to be carried out before planning a highway system for a given area ? Explain briefly.
13. What are the various plans to be prepared after the planning surveys are carried out ?
14. What are the uses of fact finding surveys ? How are these used and interpreted ?
15. Explain how the master plan is prepared and the road development programme is phased.
16. Explain why the saturation system is considered a rational method to decide the final road network and for phasing the road development programme. Illustrate the saturation system with an example.
17. There are five alternate proposals of road plans for a backward district. The details are given below. Justify with reasons which proposal is the best assuming, Utility units of 0.5, 1.0, 2, 4 and 8 for the five population ranges and 1.0 and 5 per 1000 t of agricultural and industrial products served.

Pro-posal	Total road length, km	Number of towns and villages served with population range					Productivity in thousand tonnes	
		<2000	2001-5000	5001-10000	10001-20000	>20000	Agricultural	Industrial
P	500	100	150	40	20	3	150	20
Q	600	200	250	68	28	3	220	25
R	700	270	350	82	36	4	300	35
S	800	280	410	91	41	4	400	42
T	900	290	430	96	44	4	430	45

[Ans. : Proposal S with 1.923 units/km is the best; R = 1.857, T = 1.806, Q = 1.612, P = 1.268]

18. Four new road links A, B, C and D are to be constructed during a five-year plan period. Suggest the order of priority for phasing the road construction programme based on maximum utility approach. Assume utility units of 0.5, 1.0, 2 and 4 for the four population ranges and 2, 2 and 5 units per 1000 t of agricultural, raw material and industrial products from the following data :

Road link	Length km	No. of villages served with population range				Productivity served, t		
		< 500	501-1000	1001-2000	> 2000	Agric-ultural	Raw Material	Industrial product
A	75	30	15	10	3	8000	3000	1000
B	35	20	8	6	3	5000	1000	1600
C	40	15	6	5	5	6000	2000	3200
D	50	40	4	3	2	3000	7000	500

[Ans.: I Priority = C (1,888 units/km), II = B (1.771), III = A (1.453), IV = D (1.21)]

19. What is the importance of Nagpur road plan in highway planning of our country ? Explain the plan formulae and the salient features of the plan.
20. Discuss the second twenty year road plan of 1961-81 and its salient features.
21. Compare the Nagpur road plan and the second twenty year road plan; discuss the merits of each.
22. From the following data for a district, calculate the road length required based on Nagpur road plan.

    Total area = 6300 km^2

    Agricultural area = 2800 km^2

    No. of villages with population ranges < 500, 501-1000, 1001-2000, 2001-5000, and above 5001 are 450, 320, 110, 50 and 10 respectively. Length of railway track = 75 km.

Population range of towns and villages	Number of towns and village
2001 - 5000	120
5001 - 10,000	35
10,001 - 20,000	20
20,001 - 50,000	10
50,001 - 100,001	6
> 100,001	2

[Ans.: I category roads = 637.3 and II category roads = 846.4 km]

23. Work out the lengths of NH, SH and MDR required in a district by second 20-year road development plan (1961-81) using the following plan formulas and data of Problem 22 :

$$NH = A/64 + B/80 + C/96 + 32K + 8M + D$$

$$NH + SH = A/20 + B/24 + C/32 + 48K + 24M + 11.2N + 1.6P + D$$

$$NH + SH + MDR = 3A/16 + 3B/32 + C/16 + 48K + 24M + 11.2N + 9.6P + 12.8Q + 4R + 0.8S + 0.32T + D$$

Area of the district = 10,800 km^2

Developed and agricultural area = 4100 km^2

Undeveloped area = 2300 km^2

[Ans. : NH = 267.8, SH = 618.6, MDR = 1149.9 km]

24. What are the policies and goals of the Third Road Development Plan for 1981-2001 ?

25. Explain how the road lengths of different categories for a state are determined for the year 2001 using the Third Road Development Plan concept.

26. Determine the length of different categories of roads in a state in India by the year 2001, using the Third Road Development formula and the following data :

Total area of the state = 80,000 sq. km

Total no. of towns as per 981 census = 86

Overall road density aimed at = 82 km per 100 sq. km area

[Ans.: Primary/NH = 1600, Secondary : SH = 3200, MDR = 7740, Tertiary : ODR & VR = 52,485, Total = 65,600 km]

27. Write short notes on :

(a) Central road fund

(b) Nagpur road plan

(c) Fact finding surveys

(d) Master plan

(e) Saturation system

(f) Star and grid pattern

(g) Indian Roads Congress

(h) Jayakar Committee

Chapter 3

Highway Alignment and Surveys

3.1 HIGHWAY ALIGNMENT

The position or the layout of the centre line of the highway on the ground is called the alignment. The horizontal alignment includes the straight path, the horizontal deviations and curves. Changes in gradient and vertical curves are covered under vertical alignment of roads.

A new road should be aligned very carefully as improper alignment would result in one or more of the following disadvantages :

(a) increase in construction cost

(b) increase in maintenance cost

(c) increase in vehicle operation cost

(d) increase in accident rate.

Once the road is aligned and constructed, it is not easy to change the alignment due to increase in cost of adjoining land and construction of costly structures by the road side. Hence the importance of careful considerations while finalizing the alignment of a new road need not be over emphasised.

3.1.1 Requirements

The basic requirements of an ideal alignment between two terminal stations are that it should be :

(a) short

(b) easy

(c) safe, and

(d) economical

Short : It is desirable to have a short (or shortest) alignment between two terminal stations. A straight alignment would be the shortest, though there may be several practical considerations which would cause deviations from the shortest path.

Easy : The alignment should be such that it is easy to construct and maintain the road with minimum problems. Also the alignment should be easy for the operation of vehicles with easy gradients and curves.

Safe : The alignment should be safe enough for construction and maintenance from the view point of stability of natural hill slopes, embankment and cut slopes and foundation of embankments. Also it should be safe for the traffic operation with safe geometric features.

Economical : The road alignment could be considered economical only if the total cost including initial cost, maintenance cost and vehicle operation cost is lowest. All these factors should be given due consideration before working out the economics of each alignment.

The alignment should be such that it would offer maximum utility by serving maximum population and products. The utility of a road should be judged from its utility value per unit length of road. (For details refer Art. 2.9).

3.1.2 Factors Controlling Alignment

For an alignment to be shortest, it should be straight between the two terminal stations. This is not always possible due to various practical difficulties such as intermediate obstructions and topography. A shortest route may have very steep gradients and hence not easy for vehicle operation. Similarly, there may be construction and maintenance problems along a route which may otherwise be short and easy. Roads are often deviated from the shortest route in order to cater for intermediate places of importance or obligatory points.

A road which is economical in the initial construction cost, need not necessarily be the most economical in maintenance or in vehicle operation cost. It may also happen that the shortest and easiest route for vehicle operation may work out to be the costliest of the different alternatives from construction view point. Thus it may be seen that an alignment can seldom fulfill all the requirements simultaneously; hence a judicial choice is made considering all the factors.

The various factors which control the highway alignment in general may be listed as :

(a) Obligatory points

(b) Traffic

(c) Geometric design

(d) Economics

(e) Other considerations

In hill roads additional care has to be given for :

Stability

Drainage

Geometric standards of hill roads, and

Resisting length

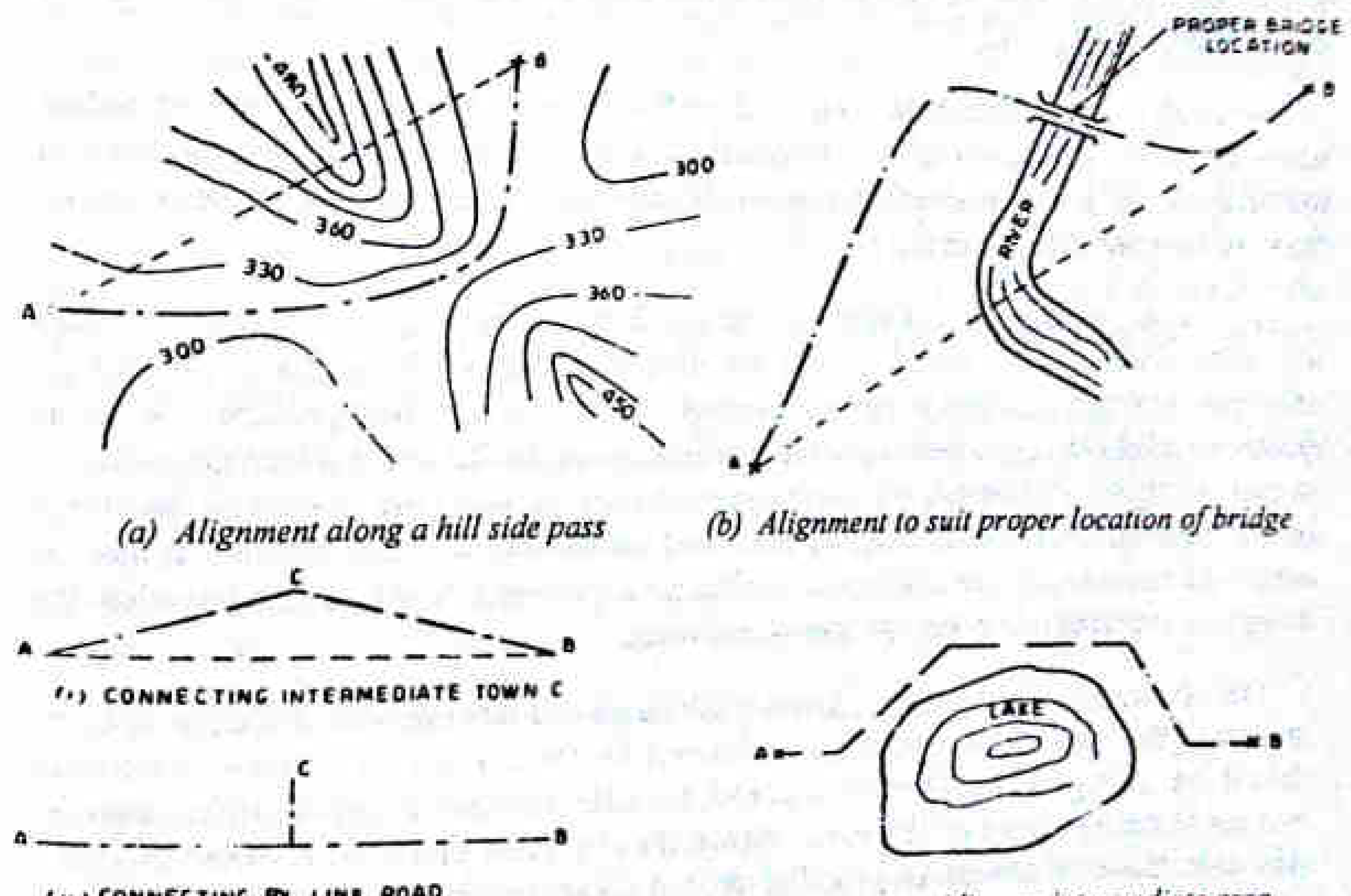
(a) *Obligatory Points* : There are control points governing the alignment of the highways. These control points may be divided broadly into two categories.

(i) Points through which the alignment is to pass.

(ii) Points through which the alignment should not pass.

(i) Obligatory points through which the road alignment has to pass may cause the alignment to often deviate from the shortest or easiest path. The various examples of this category may be bridge site, intermediate town, a mountain pass or a quarry.

When it is necessary to cross hill range, mountains or high ridges the various alternatives are to cut a tunnel across or to go round the hills or to deviate until a suitable hill pass is available. The suitability of these alternatives depend on many other factors, like the topography and site conditions and cost considerations. Figure 3.1 a shows how the straight alignment AB is deviated along the hill side pass, thus avoiding a tunnel or heavy cutting.



(a) Alignment along a hill side pass *(b) Alignment to suit proper location of bridge*

(c) Alignment to connect intermediate town *(d) Alignment avoiding an intermediate area*

Fig. 3.1 Obligatory Points Controlling Alignment of Roads

The road bridge across a river can be located only at place where the river has straight and permanent path and where the bridge abutment and pier can be properly founded. The road approaches to this bridge should not be curved near the bridge and as far as possible the skew crossing should be avoided. Thus in order to locate a bridge across a river the alignment may have to be changed. Figure 3.1b shows that the straight alignment between stations A and B which passes across the river bend, is to be deviated along the path shown in order to cross the river at a proper bridge location at the straight portion of the river on the up-stream side of the band.

While aligning a road between two stations, it may often be desirable to connect some of the important intermediate towns, villages or other places. The straight alignment AB may be shifted along line ABC, as shown in Fig. 3.1c in order to connect the intermediate station C. It is also possible to connect the station C with a link road as shown in the same figure, thus avoiding the deviation of the straight alignment.

(ii) Obligatory points through which the road should not pass also may make it necessary to deviate from the proposed shortest alignment. The obligatory points which should be avoided while aligning a road include religious places, very costly structures, unsuitable land etc. Religious places like temple, mosques, church, grave or tomb have been protected by the law from being acquired for any purpose. Acquiring costly structures would mean heavy compensation resulting in increased cost. Marshy, peaty and water logged areas are generally unsuitable for road construction and should be avoided as far as possible. However if there, is no alternative and the alignment has to be taken across such an area, the construction and maintenance costs are likely to be very high due to special construction techniques and drainage measures to be adopted.

A lake, a pond or a valley which falls on the path of a straight alignment will also necessitate the alignment to deviate from the straight path and go round along the grade line as shown in Fig. 3.1d.

(b) *Traffic* : The alignment should suit traffic requirements. Origin and Destination study should be carried out in the area and the *desire lines* be drawn showing the trend of traffic flow. The new road to be aligned should keep in view the desired lines, traffic flow patterns and future trends.

(c) *Geometric Design* : Geometric design factors such as gradient, radius of curve and sight distance also would govern the final alignment of the highway. If straight alignment is aimed at, often it may be necessary to provide very steep gradients. As far as possible while aligning a new road, the gradient should be flat and less than the *ruling* or design gradient. Thus it may be necessary to change the alignment in view of the design speed, maximum allowable superelevation and coefficient of lateral friction. It may be necessary to make adjustment in the horizontal alignment of roads keeping in view the minimum radius of curve and the transition curves.

The absolute minimum *sight distance*, which should invariably be available in every section of the road, is the safe stopping distance for the fast moving vehicles. Also there should be enough distance visible ahead for safe overtaking operations of vehicles moving at design speed on the road. Hence the alignment should be finalised in such a way that the obstructions to visibility do not cause restrictions to the sight distance requirements.

The details of these geometric design factors are given in Chapter 4.

(d) *Economy* : The alignment finalised based on the above factors should also be economical. In working out the economics, the initial cost the cost, of maintenance and vehicle operation should be taken into account. The initial cost of construction can be decreased if high embankments and deep cuttings are avoided and the alignment is chosen in a manner to balance the cutting and filling.

(e) *Other Considerations* : Various other factors which may govern the alignment are drainage considerations, hydrological factors, political considerations and monotony. The vertical alignment is often guided by drainage considerations. The subsurface water level, seepage flow and high flood level are the factors to be kept in view.

A foreign territory coming across a straight alignment will necessitate deviation of alignment around the foreign land. At times the alignment is decided only on strategic considerations.

In a flat terrain it is possible to have a very long stretch of road, absolutely straight without horizontal curves. But straight road of very long stretch may be monotonous for driving. Hence after a few kilometers of straight road, it may be desirable to have a slight bend to break the monotony and keep the driver alert.

Special considerations while aligning roads on hilly areas

Stability : While aligning hill roads, special care should be taken to align the road along the side of the hill which is stable. A common problem in hill roads is that of land slides. The cutting and filling of earth to construct roads on hill-side causes steepening of existing slopes and affect its stability.

Drainage : Numerous hill-side drains should be provided for adequate drainage facility across the road. But the cross drainage structure being costly, attempts should be made to align the road in such a way where the number of cross drainage structures are minimum.

Geometric standard of hill roads : Different sets of geometric standards are followed in hill roads with reference to gradient, curves and speed and they consequently influence the sight distance, radius of curve and other related features. The route should enable the ruling gradient to be attained in most of the length, minimising steep gradients, hair pin bands and needless rise and fall.

Resisting length : The resisting length of a road may be calculated from the total work to be done to move the loads along the route taking the horizontal length, the actual difference in levels between the two stations and the sum of ineffective rise and fall in excess of *floating gradient*. In brief, the resisting length of the alignment should kept as low as possible. Thus the ineffective rise and executive fall should be kept minimum.

The detailed considerations on hill road alignment are discussed in chapter 12.

3.2 ENGINEERING SURVEYS FOR HIGHWAY LOCATIONS

Before a highway alignment is finalised in highway project, the engineering surveys are to be carried out. The surveys may be completed in four stages. The first three stages consider all possible alternate alignments keeping in view the various requirements of highway alignment as discussed in Art. 3.1.2. The fourth stage is meant for the detailed survey of the selected alignment.

The stages of the engineering surveys are

(a) Map study

(b) Reconnaissance

(c) Preliminary surveys

(d) Final location and detailed surveys.

3.2.1 Map Study

If the topographic map of the area is available, it is possible to suggest the likely routes of the road. In India topographic maps are available from the *Survey of India*, with 15 or 30 meter contour intervals. The main features like rivers, hills valleys etc. are also shown on these maps. By careful study of such maps, it is possible to have an idea of several possible alternate routes so that further details of these may be studied later at the site. The probable alignment can be located on the map from the following details available on the map.

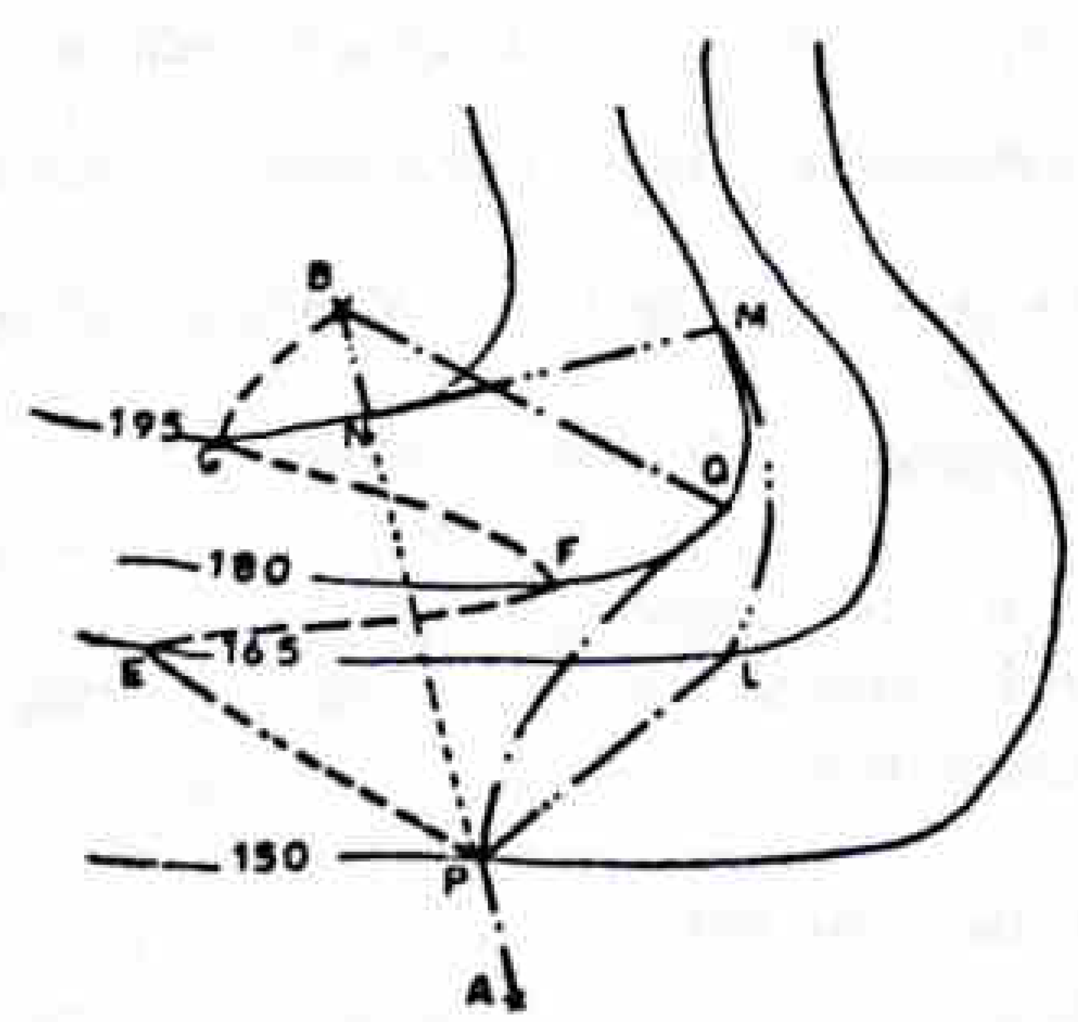
(a) Alignment avoiding valleys, ponds or lakes

(b) When the road has to cross a row of hills, possibility of crossing through a mountain pass

(c) Approximate location of bridge site for crossing rivers, avoiding bend of the river, if any.

(d) When a road is to be connected between two stations, one of the top and the other on the foot of the hill, then alternate routes can be suggested keeping in view the permissible gradient; say the ruling gradient. Refer Fig. 3.2. Suppose the scale of the contour map is known, then from the counter intervals it is possible to decide the length of road required between two consecutive contours, keeping the gradient within allowable limits. In this case, the contour interval is 15 metre and if the ruling gradient is fixed as 1 in 20, the road length between two consecutive contours has to be 15 × 20 = 300 meter. With the known scale of the map, the various possible alternate routes may be drawn by drawing arcs of the above (300 metre) length between the consecutive contour lines.

Let A and B be two stations to be connected by a road, see Fig. 3.2. AB is the shortest route (straight line) APQB is a steep route in which the gradient positively exceeds 1 in



AB - Shortest route
APQB - Steeper gradient
APLMNB - Flatter gradient
APEFGB - Flatter gradient (Alternate route)

Fig. 3.2 Alignment with allowable Gradients

20 as the distance between the contour interval is only about 200 metre (assuming the scale to be 1 cm = 150 metre). APLMNB is a route with an approximate slope of 1 in 20 whereas APEFGB is an alternate alignment with the same gradient.

Thus from the map study alternate routes can be suggested. It may also be possible from map study to drop a certain route in view of any unavoidable obstructions or undesirable ground, enroute. Map study thus gives a rough guidance of the routes to be further surveyed in the field.

3.2.2 Reconnaissance

The second stage of surveys for highway location is the reconnaissance to examine the general character of the area for deciding the most feasible routes for detailed studies. A field survey party may inspect a fairly broad stretch of land along the proposed alternative routes of the map in the field. Only very simple instrument like abney level, tangent clinometer, barometer etc. are used by the reconnaissance party to collect additional details rapidly (not accurately). All relevant details not available in the map are collected and noted down. Some of the details to be collected during reconnaissance are given below :

(i) Valleys, ponds, lakes, marshy land, ridge, hills, permanent structures and other obstructions along the route which are not available in the map.

(ii) Approximate values of gradient, length of gradients and radius of curves of alternate alignments.

(iii) Number and type of cross drainage structures, maximum flood level and natural ground water level along the probable routes.

(iv) Soil type along the routes from field identification tests and observation of geological features.

(v) Sources of construction materials, water and location of stone quarries.

(vi) When the road passes through hilly or mountainous terrain, additional data regarding the geological formation, type of rocks, dip of strata, seepage flow etc. may be observed so as to decide the stable and unstable sides of the hill for highway alignment.

A rapid reconnaissance of the area, especially when it is vast and the terrain is difficult, may be done by an aerial survey.

From the details collected during the reconnaissance, the alignment proposed after study may be altered or even changed completely. As a result of the reconnaissance a few alternate alignments may be chosen for further study based on practical considerations observed at the site.

3.2.3 Preliminary Survey

The main objectives of the preliminary survey are :

(i) To survey the various alternate alignments proposed after the reconnaissance and to collect all the necessary physical information and details of topography, drainage and soil.

(ii) To compare the different proposals in view of the requirements of a good alignment.

(iii) To estimate quantity of earth work materials and other construction aspects and to workout the cost of alternate proposals.

(iv) To finalise the best alignment from all considerations.

The preliminary survey is carried out to collect all the physical information which are necessary in connection with the proposed highway alignment. The preliminary survey may be carried out by any one of the following methods :

(a) Conventional approach, in which a survey party carries out surveys using the required field equipment, taking measurements, collecting topographical and other data and carrying out soil survey.

(b) Modern rapid approach, by serial survey taking the required aerial photographs and by photogrammetric methods and photo-interpretation techniques for obtaining the necessary topographic and other maps including details of soil and geology.

The procedure of the conventional methods of preliminary survey is given in following steps :

(i) *Primary traverse* : The first step in the preliminary survey is to establish the primary traverse, following the line recommended in the reconnaissance. For alternate alignments either secondary traverses or independent primary traverses may be necessary. As these traverses are *open traverses* no adjustment of errors is possible later, so the angles should be very accurately measured by the theodolite. The length of the centre line should be measured by using very good and accurate chaining methods or by tacheometry or by modern instruments.

(ii) *Topographical features* : After establishing the centre lines of preliminary survey, the topographical features are recorded. All geographical and other man made features along the transverse and for a certain width on either side are surveyed and plotted. The width to be surveyed is generally decided by the survey party, but the absolute minimum width is the land width of the proposed alignment.

(iii) *Levelling work* : Levelling work is also carried out side by side to give the centre line profiles and typical cross sections. The levelling work in the preliminary survey is kept to a minimum just sufficient to obtain the approximate earth work in the alternate alignments.

To draw contours of the strip of land to be surveyed, cross section levels should be taken at suitable intervals, generally 100 to 200 metre in plain terrain, upto 50 metre in rolling terrain and upto 30 metre in hilly terrain.

(iv) *Drainage studies and Hydrological data* : Drainage investigations and hydrological data are collected so as to estimate the type, number and approximate size of cross drainage structures. Also the vertical alignment of the highway, particularly the grade line is decided based on the hydrological and drainage data, such as HFL, ponded water level, depth of water table, amount of surface runoff, etc.

(v) *Soil survey* : Soil survey is an essential part of the preliminary survey as the suitability of the proposed location is to be finally decided based on the soil survey data. The soil survey conducted at this stage also helps in working out details of earth work, slopes, suitability of materials, subsoil and surface drainage requirements and pavement type and the approximate thickness requirements. All these details are required to make a comparative study of alternate proposals.

At this stage a detailed soil survey is not necessary. Post hole auger or any other suitable types of hand augers depending on the soil type, may be used to collect the soil sample up to a depth of 1 to 3 metre below the likely finished road level or the existing ground level, whichever is lower. When the road is expected to be constructed over an embankment, the depth of exploration should extend upto twice the height of embankment from the ground level. During the soil exploration if the ground water table is struck, the depth from the ground surface is also noted.

When the work has to be done rapidly, *geophysical method* of soil exploration are best suited as accuracy is not very important during the preliminary survey. The *electrical resistivity* method is commonly used in road projects. The method is based on the principle that the earth and rock materials may be identified by the different values of the resistance to flow of a direct current.

The soil samples collected during the field work are subjected to identification and classification test in the laboratory. *Soil profile* is obtained by drawing the longitudinal section along the proposed road alignment upto the depth of exploration. The types of soils encountered along the route upto the depth under consideration are marked on the soil profile either symbolically or by suitable colour coding.

(vi) *Material survey* : The survey for naturally occurring materials like stone aggregates, soft aggregates, etc. and identification of suitable quarries should be made. Also availability of manufactured materials like cement, lime, brick, etc. and their locations may be ascertained.

(vii) *Traffic survey* : Traffic surveys conducted in the region form the basis for deciding the number of traffic lanes and roadway width, pavement design and economic analysis of highway project. Traffic volume counts of the classified vehicles are to be carried out on all the existing roads in the region, preferably for 24 hours per day for seven days. Origin and destination surveys are very useful for deciding the alignment of the roads. This study may be carried out on a suitable sample of vehicle users or drivers. In addition the required traffic data may also be collected so that the traffic forecast could be made for 10 to 20 year periods.

(viii) *Determination of final centre line* : After completing the preliminary surveys and conducting the comparative studies of alternative alignments the final centre line of the road is to be decided in the office before the final location survey. For this, the preliminary survey maps consisting of contour plans, longitudinal profile and cross sections of the alternate alignments should be prepared and carefully studied to decide the best alignment satisfying engineering, aesthetic and economical requirements. After selecting the final alignment, the grade lines are drawn and the geometric elements of the horizontal and vertical alignments of the road are designed.

Aerial photographic surveys are very much suited for preliminary surveys, especially when the distance and area to be covered are vast. The survey may be divided into the following steps :

(a) Taking aerial photographs of the strips of land to be surveyed with the required longitudinal and lateral overlaps. Vertical photographs are necessary for the preparation of mossaics.

(b) The photographs are examined under stereoscopes and control points are selected for establishing the traverses of the alternate proposals. The control points are located on the maps.

(c) Using stereo-pair observations, the spot levels and subsequently contour lines may be obtained. Also from the stereo pairs the topographical details may be noted down on the maps.

(d) Photo-interpretation methods are used to assess the geological features, soil conditions, drainage requirements etc.

3.2.4 Final Location and Detailed Survey

The alignment finalised at the design office after the preliminary survey is to be first located on the field by establishing the centre line. Next detailed survey should be carried out for collecting the information necessary for the preparation of plans and construction details for the highway project.

Location

The centre line of the road finalised in the drawings is to be translated on the ground during the location survey. This is done using a transit theodolite and by staking of the centre line. The location of the centre line should follow, as closely as practicable, the alignment finalised after the preliminary surveys. Major and minor control points are established on the ground and centre pegs are driven, checking the geometric design requirements. However modifications in the final location may be made in the field, if found essential. The centre line stakes are driven at suitable intervals, say at 50 metre intervals in plain and rolling terrains and at 20 metre in hilly terrain.

Detailed survey

Temporary bench marks are fixed at intervals of about 250 metre and at all drainage and under pass structures. Levels along the final centre line should be taken at all staked points. Levelling work is of great importance as the vertical alignment, earth work calculations and drainage details are to be worked out from the level notes. The cross section levels are taken upto the desired width, at intervals of 50 to 100 metre in plain terrain, 50 to 75 metre in rolling terrain, 50 metre in built-up areas and 20 metre in hilly terrain. The cross sections may be taken at closer intervals at horizontal curves and where there is abrupt change in cross slopes. All river crossing, valleys etc. should be surveyed in detail upto considerably distances on either side.

All topographical details are noted down and also plotted using conventional signs. Adequate hydrological details are also collected and recorded.

A detailed soil survey is carried out to enable drawing of the soil profile. The depth upto which soil sampling is to be done may be 1.5 to 3.0 metre below the ground line or finished grade line of the road whichever is lower. However in case of high embankments, the depth should be upto twice the height of the finished embankment. The spacing of auger borings very much depends upon the soil type and its variations. CBR value of soils along the alignment may be determined for designing the pavement.

The data during the detailed survey should be elaborate and complete for preparing detailed plans, design and estimates of the project.

3.3 DRAWINGS AND REPORT

3.3.1 Drawings

The following drawings are usually prepared in a highway project :

(i) Key map

(ii) Index map

(iii) Preliminary survey plans

(iv) Detailed plan and longitudinal section

(v) Detailed cross-section

(vi) Land acquisition plans

(vii) Drawings of cross drainage and other retaining structures

(viii) Drawings of road intersections

(ix) Land plans showing quarries etc.

Key map should show the proposed and existing roads, and important places to be connected. The size of the plan generally should not exceed 22 × 20 cm. The scale of the map is chosen suitably depending upon the length of road.

Index map should show the general topography of the area. The details are symbolically represented. The index map should also be of suitable scale, the size being 32 × 20 cm.

Preliminary survey plans showing details of the various alternate alignments and all informations collected should be normally drawn to scale of 10 cm = 1 km to 25 cm = 1 km.

Detailed plans show the ground plan with alignment and the boundaries, contours at intervals of 1 to 2 metre in plain country a scale of 1/2400 and in close country, a scale of 1/1200 may be adopted for detailed plans. The size of the drawing may be A-2 size or 60 × 42 cm approximately.

Longitudinal sections should be drawn to the same horizontal scale of the ground as in detailed plan. Vertical scale may be enlarged 10 times of the longitudinal scale. The longitudinal section should show the details such as datum line, existing ground surface, vertical profile of the proposed road and position of drainage crossings.

Detailed cross sections are generally drawn to natural scale of 1 cm = 2.0 to 2.5 m. In Cross section should be drawn every 100 m or where there are abrupt changes in level. The cross section hill roads the cross sections should be drawn at closer intervals. The cross section drawings should extend at least up to the proposed right of way. The cross section number, the reduced distances and the area of filling and/or cutting should be shown on cross section drawings.

Land acquisition plans and schedules are usually prepared from the survey drawings for land acquisition details. These plans show all general details such as buildings, wells, nature of gradients and other details required for assessing the values. The scale adopted may be 1 cm = 40 m or less.

Detailed design for cross drainage and masonry structures are usually drawn to scale of 1 cm = 1 m. For details of any complicated portion of the structure enlarged scales up to 8 cm = 1 m or upto half full size may be employed. However the size of drawing should not exceed the standard size. Cross sections of streams should be to a scale of not less than 1 cm = 10 m.

Drawings of road intersections should be prepared showing all details of pavement, shoulders, islands etc. to scale.

Land plans for quarries. Where quarries for construction materials are to be acquired for new projects, separate land plans should be prepared. The size of these maps and scales may be similar to those suggested under land acquisition.

3.3.2 Estimates

The project estimates should consist of general abstract of cost and detailed estimates for each major head. If the project work is proposed to be executed in stages, the estimate should be prepared for each stage separately.

3.3.3 Project Report

The project report forms an important part of the project document. It should contain information such as

(i) general details of the project and its importance

(ii) feature of the road including selection of the route, alignment, traffic, etc.

(iii) road design and specifications

(iv) drainage facilities and cross drainage structures

(v) materials, labour and equipment

(vi) rates

(vii) construction programming and

(viii) other miscellaneous items like diversion roads, traffic control, road side amenities, rest houses, etc.

3.4 HIGHWAY PROJECT

3.4.1 General

In a new highway project, the engineer has to plan, design and construct either a network of new roads or a road link. There are also projects requiring re-design and re-alignment of existing roads of upgrading the geometric design standards.

Once a highway is constructed, development takes place along the adjoining land and subsequent changes in alignment or improvements in geometric standards become very difficult. A badly aligned highway is not only a source of potential traffic hazard, but also causes a considerable increase in transportation cost and strain on the drivers and the passengers. Therefore, proper investigation and planning are most important in a road project, keeping in view the present day needs as well as the future developments of the region.

3.4.2 New Highway Project

The new highway project work may be divided into the following stages :

(i) Selection of route, finalisation of highway alignment and geometric design details

(ii) Collection of materials and testing of subgrade soil and other construction materials mix design of pavement materials and design details of pavement layers.

(iii) Construction stages including quality control.

Route selection

The selection of route is made keeping in view the requirements of alignment and the geological, topographical and other features of the locality as explained in Art.3.2. However special care shou.d be taken as regards the geometric design standards of the road for possible upgrading of speed standards in future, without being necessary to re-align the road. After the alignment if finalised, the plans and working drawings are prepared. The geometric design requirements of highways have been given in Chapter 4 and the details and requirements of hill roads are given in Chapter 12.

Materials and design

The soil samples collected from the selected route during the soil surveys are tested in the laboratory in order to design the pavement thickness required and the design of embankment and cut slopes. The basic construction materials such as selected soil, aggregates etc. are collected from the nearest borrow pits and quarries and stacked along the roads alignment after subjecting these materials to the specified laboratory tests. In order to design the mixes for the pavement component layers and to specify quality control test values during road construction, mix design tests are carried out in the laboratory.

The possibility of using low-cost construction material like soil-aggregate mixes, soft aggregates, stabilized soil and pozzolanic concrete mixes, in the sub-base or base course layers of pavement should be fully explored. When high quality pavement materials like bituminous mixes or cement concrete are to be used in the surface course, the mix design specification and construction control tests should be strictly followed. The pavement thickness is designed based on anticipated traffic, stability and drainage conditions of the subgrade and the type and thickness of pavement layers chosen for the construction. In India, the *CBR method* has been recommended by the Indian Roads Congress for designing the thickness of flexible pavements. Recommended procedure for the design of cement concrete payment has also been specified by the Indian Roads Congress. (Please see Chapter 7 for details).

Construction

The construction of the road may be divided into two stages, viz. : (i) earth work (ii) pavement construction. The earth work consists of excavation and construction of the embankments. During the excavation for highway cuts, the earth slopes, their protection and construction of drainage network are taken care of. Highway embankments may be best constructed by rolled-fill method by compacting the soil in layers under controlled moisture and density using suitable rollers. In the case of high embankments, the stability of the embankment foundation and slopes and the possible settlement of the embankment with time have to be investigated.

The pavement construction is subsequently taken up starting with the preparation of subgrade and the construction of sub-base, base and surface courses of the pavement.

Steps in a new project work

The various steps in a new highway project may be summarised as given below :

(i) *Map Study* : with the help of available topographic maps of the area.

(ii) *Reconnaissance Survey* : a general idea of a topography and other features, field identification of soils and survey of construction materials, by an on-the-spot inspection of the site.

(iii) *Preliminary Survey* : Topographic details and soil survey along alternate alignments, consideration of geometric design and other requirements of alignment, preparation of plans and comparison of alternate routes; economic analysis and selection of final alignment. Typical plan, longitudinal section and cross section drawing for the new alignment are shown in Fig. 3.3 a & b.

(iv) *Location of Final Alignment* : Transfer of the alignment from the drawings to the ground by driving pegs along the centre line of finally chosen alignment; setting out geometric design elements by location of tangent points, apex points, circular and transition curves, elevation of centre line and superelevation details.

(v) *Detailed Survey* : Survey of the highway construction work for the preparation of longitudinal and cross sections, computations of earth work quantities and other construction material; and checking details of geometric design elements.

(vi) *Materials Survey* : Survey of construction materials, their collection and testing.

(vii) *Design* : Design details of embankment and cut slopes, foundation of embankments and bridges, and pavement layers.

(viii) *Earth Work* : Excavations for highway cutting and drainage system, construction of embankments.

(ix) *Pavement Construction* : Preparation of subgrade, construction of sub-base and surface courses.

(x) *Construction Controls* : Quality control tests during different stages of constructions and check for finished road surface such as unevenness, camber, superelevation and extra widening of pavements at curves.

3.4.3 Re-alignment Project

Most of the present highways in India have been upgraded in stages, from the existing local roads of the pre-automobile era. As these roads were then meant for slow traffic, they are found deficient in the geometric design elements for the present day automobile traffic. There are several stretches of National Highways in the country having single lane of carriage way, narrow bridges and culverts and many locations with sharp horizontal curves and avoidable zig-zags, steep gradients and inadequate sight distances. These defects are to be rectified as early as possible atleast in roads of greater importance like National and State Highways. It will be worth while to adopt more liberal values of geometric design parameters than the ruling minimum values specified, where the conditions are favourable and the costs involved are not excessive. In such cases, it

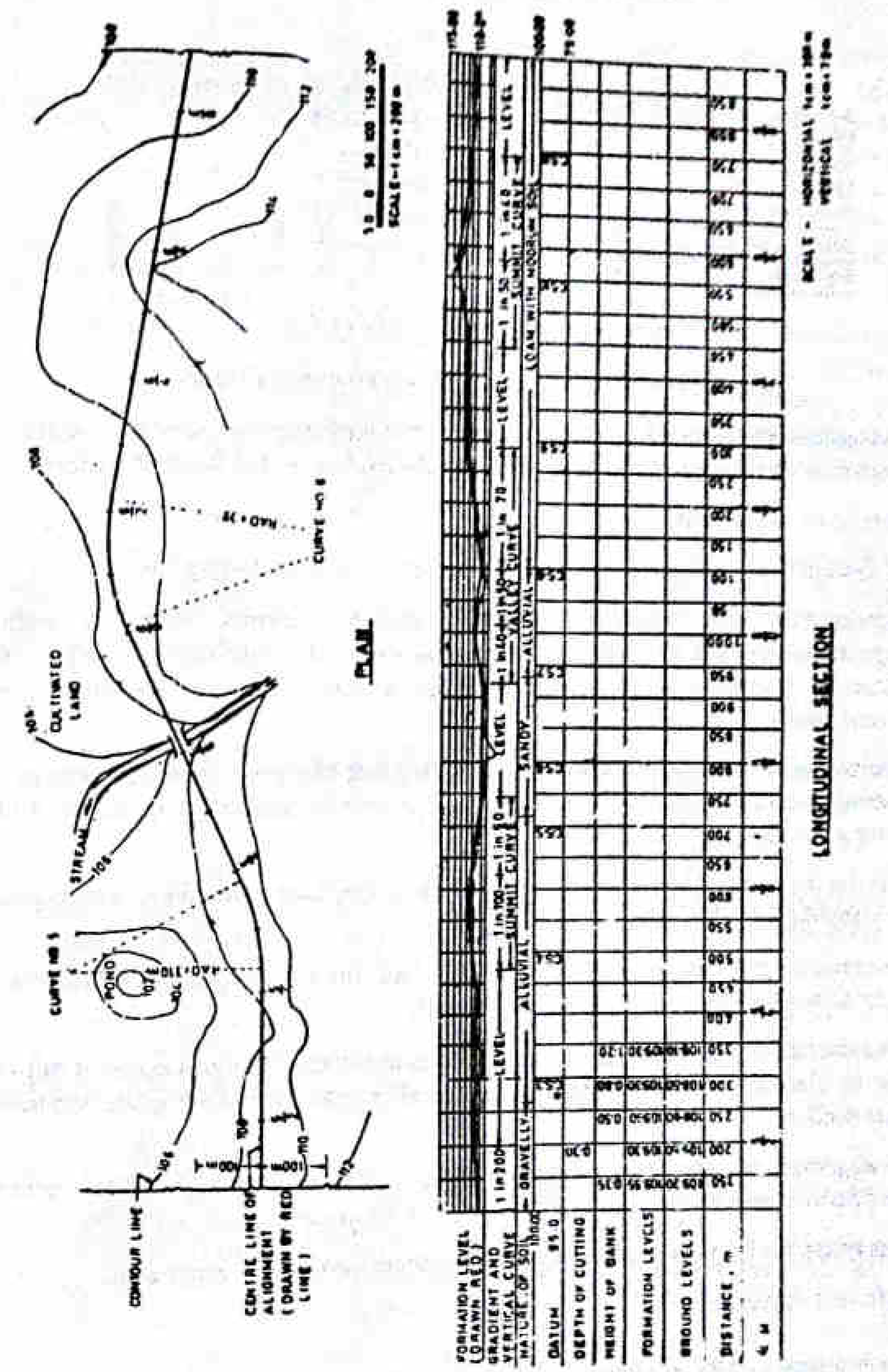


Fig.3.3 (a) Typical Drawing for a Highway Project

would be possible to upgrade the highways if necessary in future by increasing the width standards only, but without the necessity of re-aligning the road. However, in constrained situations and in difficult terrain, it may not always be economical to improve the existing highway geometric to the recommended design standards.

It has been decided as a policy that National Highways should as far as possible be able to fully cater to the traffic moving at design speed, fulfilling the comfort and safety requirements, both for the present and future traffic needs. To achieve this objective, it is necessary to plan improvements in the geometrics of roads wherever deficient, to the

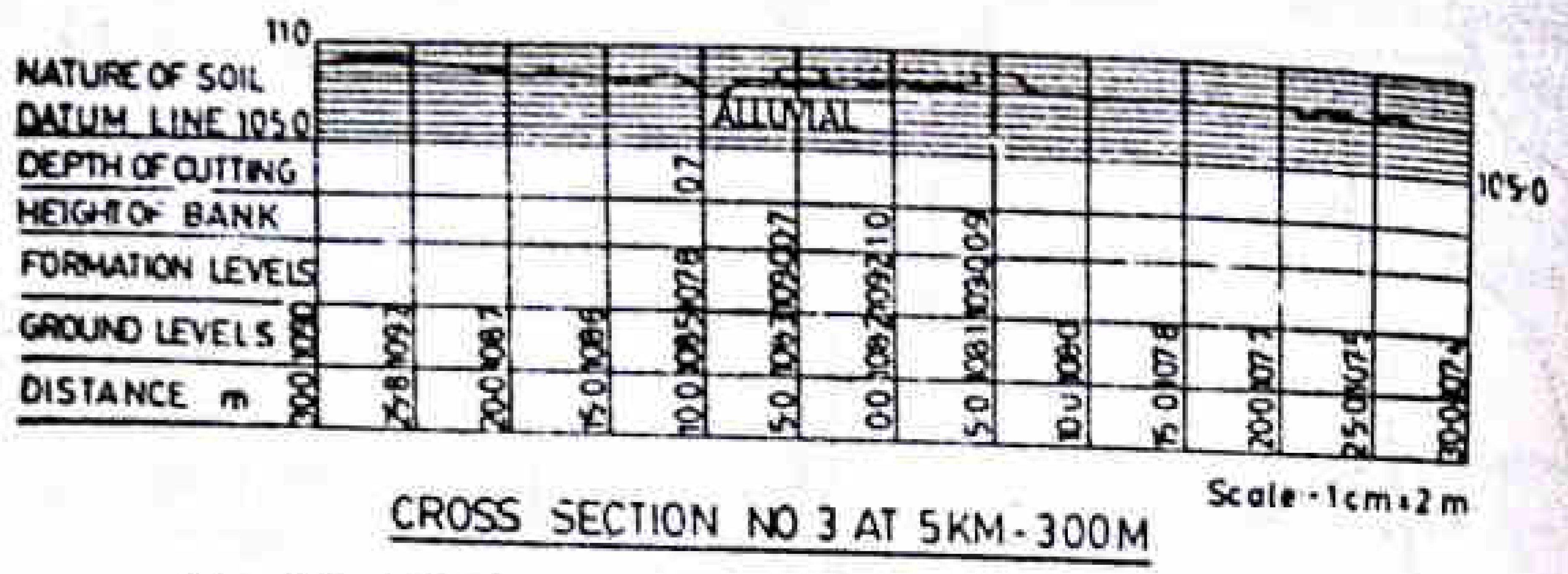


Fig. 3.3 (b) Typical Drawing for a Highway Project

extent economically practicable along with the other improvements such as re-surfacing the pavements, construction of overlay of raising the road above the flood water level.

Necessity of re-alignment

The re-alignment of existing roads may be necessary in the following cases :

(i) Improvement of horizontal alignment design elements, such as radius, superelevation, transition curve, clearance on inner side of the curve of shifting the curve to provide adequate sight distance, elimination of reverse curves and undesirable zig-zags, etc.

(ii) Improvement of vertical alignment design elements like steep gradients, changes in summit curves to increase sight distance, correction of undesirable undulations like humps and dips, etc.

(iii) Raising the level of a portion of a road which is subjected to flooding, submergence or water-logging during monsoons.

(iv) Re-construction of weak and narrow bridges and culverts and changes in water-way at locations slightly away from the existing site.

(v) Construction of over-bridges or under-bridges at suitable locations across a railway line in place of level crossing or across another road to provide grade separated inter-section.

(vi) Re-alignment required due to a portion of the road being submerged under water at the reservoir area on account of construction of a new dam.

(vii) Construction of a bypass to avoid the road running through a town or city.

(viii) Defence requirements.

General Principles of Re-alignment

(i) While improving the horizontal alignment of roads, improvement in sharp curves and zig-zags should be done after considering the whole alignment and not on piece meal basis. The improvement of transition curves would not generally be very costly and therefore the defects should be rectified where-ever necessary. The sight distance available generally gets increased when the horizontal alignment is improved; otherwise the set back distance may be increased at horizontal curves by removing or shifting the obstruction from the inner side of the curve, upto the desired extent.

(ii) While improving the vertical alignment, attempts should be made to provide overtaking sight distance at summit curves. However, if this is not possible, atleast the stopping sight distance should be available for the design speed at all locations of the road. The corrections of minor undulations such as humps and dips may not involve high cost and so it is desirable to provide suitable vertical transition curves for shock-free movement of vehicles travelling at the design speed. Valley curves may be checked for comfort condition and for visibility under the head lights of the vehicles during night driving.

(iii) The road stretches which remain submerged under water even for a short duration of the gear or those which are in water logged areas should be raised before strengthening or widening pavement section. The formation level should be raised such that the subgrade is at least 0.6 m above the *HFL*. Suitable measures should be adopted against water-logging and care should be taken to provide suitable drainage facilities, including the cross drainage works.

(iv) While reconstructing bridges of length greater than 60 m on sites other than the existing ones, separate surveys should be carried out for the selection of suitable sites. The selection of site for major bridges would be governed by the river training works, sub-soil conditions for foundation and hydraulic considerations. However, in small bridges the road alignment would essentially govern the bridge site selection.

(v) The deciding factor which is being considered for providing over-bridges or under bridges for a National Highway across a railway level crossing is the product of number of gate closures and the intensity of traffic on the highway in tonnes per day in the design year. When this product exceeds 50,000 or when the level crossing is within the shunting limits of a railway station, the grade separation is justified. The location is decided keeping in view the highway alignment, the topographic and other site conditions.

(vi) The necessity to provide alternate routes to bypass through-traffic is assessed from the origin and destination studies. If the bypassable traffic is more than the traffic terminating at the town or built-up area, then the bypass may be justified.

Steps in the Re-alignment Project

(i) Reconnaissance of the stretch of road to be re-aligned, study of the deficiencies and the possible changes in alignment.

(ii) Survey of existing road recording the topographic features and all other existing features including drainage conditions along a strip of land on either side of the road. The width of the land to be surveyed depends on the amount of shifting anticipated when the road is re-aligned. The field work may be carried out using plane table and level or by tacheometry.

(iii) Observations of spot levels along the centre line of the road and cross section levels at suitable intervals to note the gradient, cross slope, superelevation etc. The cross section levels should be taken at closer intervals at horizontal and vertical curves and at cross drainage works.

(iv) Soil survey along the stretches of land through which the re-aligned road may possibly pass; preparation of typical soil profiles after testing the soil samples in the laboratory.

(v) Comparison of economics and considerations of feasibility of alternate proposals of re-alignment and special study of stretches which are difficult for the re-alignment.

(vi) Finalisation of the design features of re-aligned road stretches.

(vii) Preparation of drawings (Typical drawings showing plan, longitudinal section and cross section for a re-alignment project are shown in Fig. 3.4).

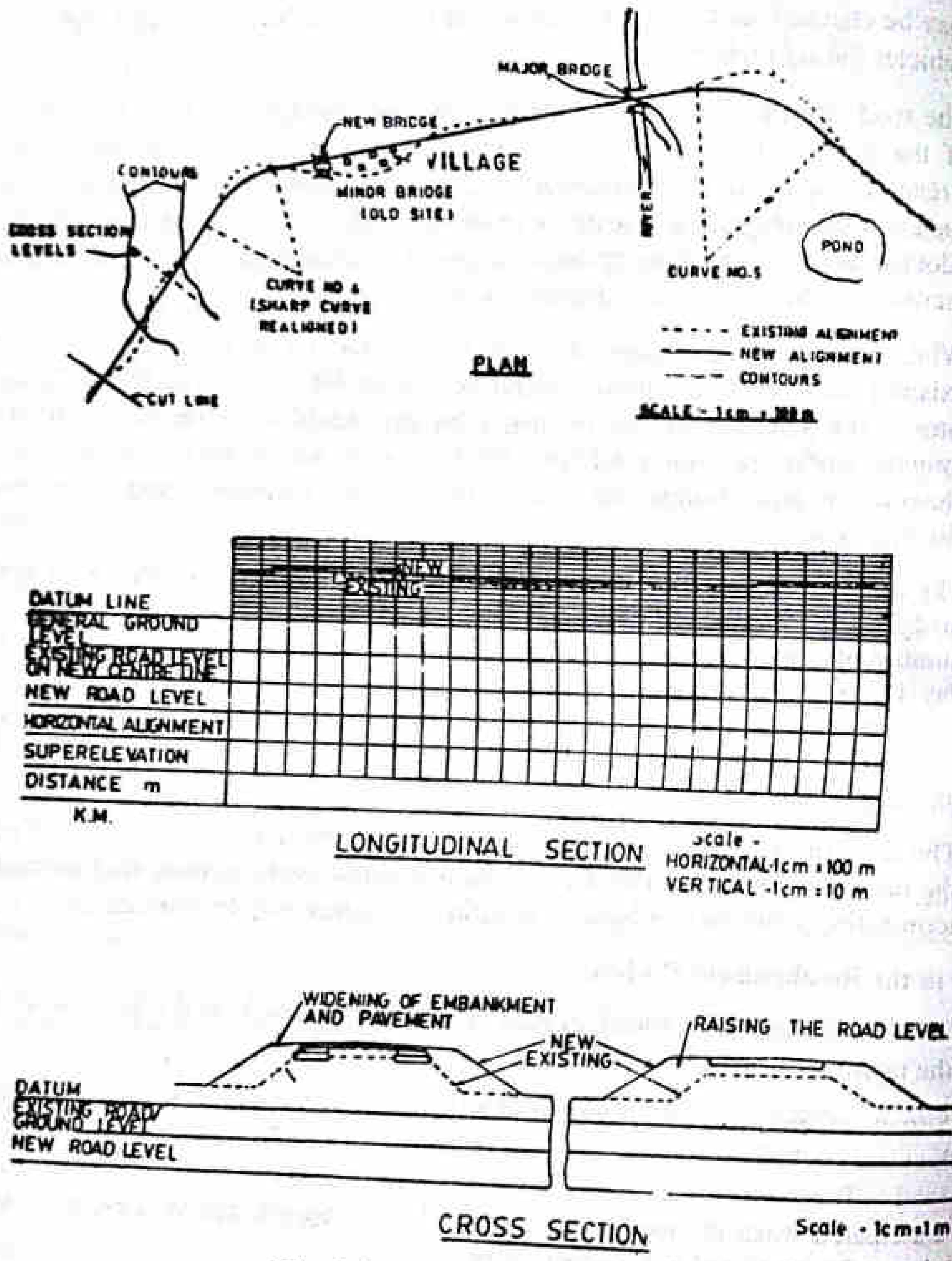


Fig. 3.4 Re-alignment Project

(viii) Marking out the centre line of re-aligned road while trying to utilise the existing road to the maximum extent possible.

(ix) Earth-work and preparation of subgrade of the re-alignment road stretches, setting out and construction of new bridges and culverts.

(x) Checking the geometric design elements of the newly aligned stretches of the road.

(xi) Design and construction of the new highway pavements.

Preparation of Drawings for Re-alignment Project

The drawings for the re-alignment project should show all the existing features of the road as well as all the proposed improvements. The following drawings would be needed :

(i) Plan showing existing road, proposed alignment, contours and all other features of importance.

(ii) Longitudinal section showing natural ground elevation, surface of the existing road and the grade line for the re-construction.

(iii) Cross section showing the existing roadway and new roadway drawn at 250 m intervals on straights, at the beginning and end of transition curves and at the middle of circular curves. Cross sections are drawn at 50 m interval where the new carriageway falls entirely outside the existing one.

A typical set of such drawings is shown in Fig. 3.4. The drawings along with a comprehensive report to justify the re-alignment project should be prepared.

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PROBLEMS

1. What are the various requirements of an ideal highway alignment. Discuss briefly.
2. Explain with sketches the various factors controlling the alignment of roads.
3. Explain obligatory points. With sketches, discuss how these control the alignment.
4. Discuss the special care to be taken while aligning hill roads.
5. Briefly explain the engineering surveys needed for locating a new highway.
6. What are the uses of map study in engineering surveys for highway location ?
7. What are the objects of reconnaissance in engineering surveys ? Discuss the scope of aerial survey for the purpose.
8. What are the various objectives of preliminary survey for highway alignment ? Enumerate the details to be collected and the various steps in the conventional method.