TRANSPORTATION ENGINEERING-I
(BCE-28)

Highway Development And Planning

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TransportationEngineering-1(BCE-28)

UNIT-I

- I. Introduction: Role of transportation, Mode of transportation, History of road development, Nagpur road plan, Bombay road plan & 3rd 20 Year Road Plan, Road Types and Pattern.

   ii. Geometric design: cross sectional elements, camber, shoulder, sight distance, horizontal curves, super elevation, extra widening, transition curves and gradient, vehicle curves, summit and valley curves

UNIT-II

   Traffic Engineering: Traffic characteristic, volume studies, speed study, capacity, density, traffic control devices, signs, signals, design of signals, Island, Intersection at grade and grade separated intersections, design of rotary intersection.

UNIT-III

   Design of Highway Pavement: Types of pavements, Design factors, Design of flexible pavements by CBR method (IRC : 37-2001 and 2012), Design of rigid pavement, Westergaard theory, load and temperature stresses, joints, IRC method of rigid pavement design. (IRC 58-2002 and IRC 58-2011).

UNIT-IV

   Road Construction Methods: WBM, WMM, Surface Dressing, Bituminous carpeting, Bituminous
    Bound Macadam and Asphaltic Concrete, Cement Concrete road construction..

Transportation engineering

- **Transportation engineering** is the application of technology and scientific principles to the planning, functional design, operation and management of facilities for any mode of transportation in order to provide for the safe, efficient, rapid, comfortable, convenient, economical, and environmentally compatible movement of people and goods from one place to other.

MODES OF TRANSPORTATION

- **Highways**

  Car, Bus, Truck, non- motorized ..etc

- **Railways**

  Passenger and Goods

- **Airways**

  Aircraft and Helicopters

- **Waterways**

  Ships, boats…

- **Continuous Flow systems**

  Pipelines,belts,elevetor,ropeway…etc.

- Merits and Demerits: Based on accessibility, mobility, cost, tonnage..

Airways

- Fastest among all other modes
- More comfortable
- Time saving
- Uneconomical

Waterways

- slowest among all other modes
- It needs minimum energy to haul unit load through unit distance.
- This can be possible between ports on the sea routes or along the river
- economical

Railways

- The transportation along the railways track could be advantageous by railways between the stations both for the passengers and goods, particularly for long distance.

- It depends upon the road transport i.e. road could serve as a feeder system.

- Energy require to haul a unit load through unit distance by the railway is only ¼ to 1/5 of that required by road.

- Safety

Highways

- It gives the maximum service to one and all
- It gives maximum flexibility for travel with reference to route, direction, time and speed of travel
- It provide door to door service
- Other modes are depend on it
- It requires small investment for the government
- Motor vehicles are cheaper than other carriers like rail locomotive and wagons
- It saves the time for short distance
- High degree of accident due to flexibility of movement

Scope of highway engineering

- Development, planning and location

- Highway design, geometric and structure

- Traffic performance and its control

- Materials, construction and maintenance

- Economic, finance and administration

ROLE /IMPACT OF TRANSPORTATION

- Economic Development

- Social Development

- Spatial Development

- Cultural Development

- Political Development

Characteristics of road transport

- Roads are used by various types of road vehicles, like passenger cars, buses, trucks, pedal cycle and animal drawn vehicle.

- It requires a relatively small investment for the government.

- It offers a complete freedom to road users to transfer the vehicle from one lane to another and from one road to another according to need and convenience.

- Speed and movement is directly related with the severity of accident.

- Road transport is the only means of transport that offers itself to the whole community alike.

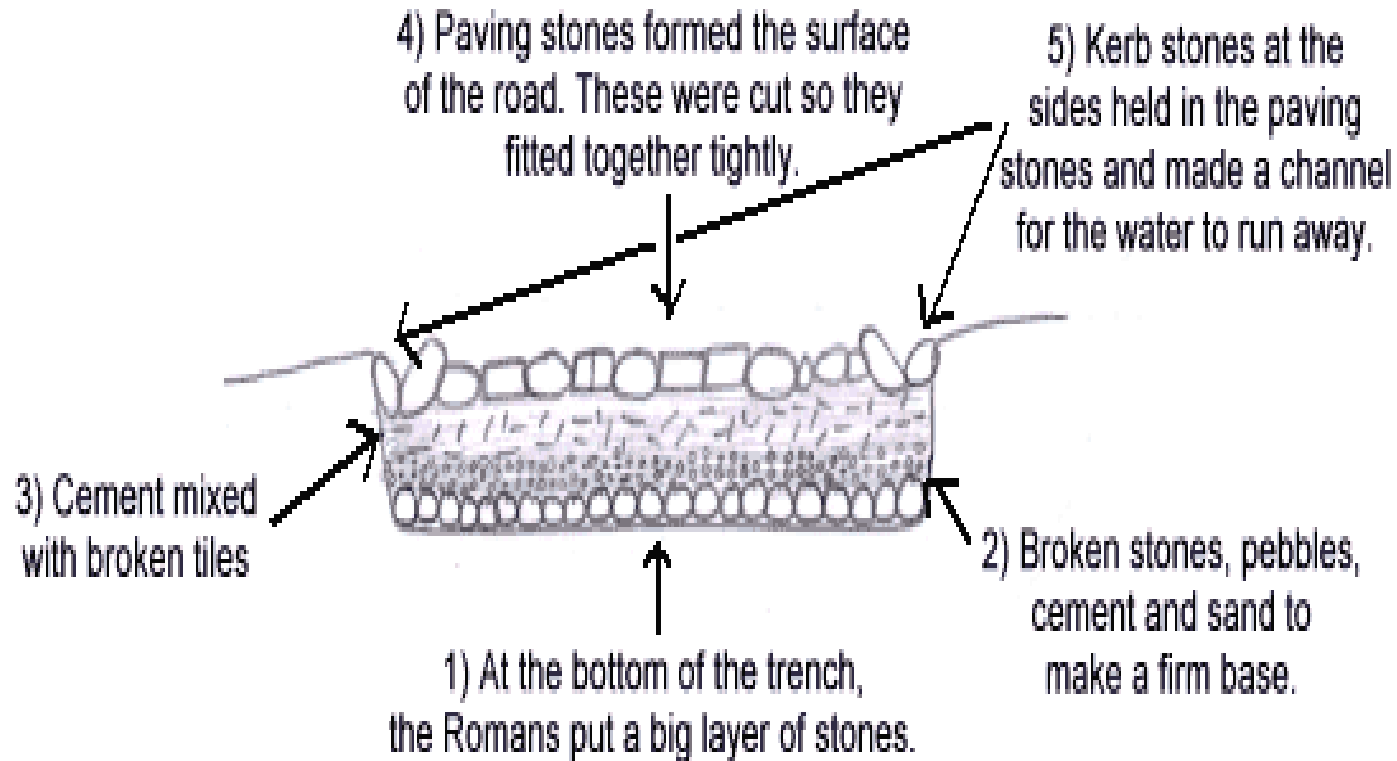# HISTORICAL DEVELOPMENT OF ROAD CONSTRUCTION

- Oldest mode

  - Foot paths- animal ways, cart path……..

- As civilization evolved the need for transportation increased

ROMAN ROAD-(500 B.C.)

➢ They were built straight regardless of gradient

➢ They were built after the soft soil was removed and a hard stratum was reached.
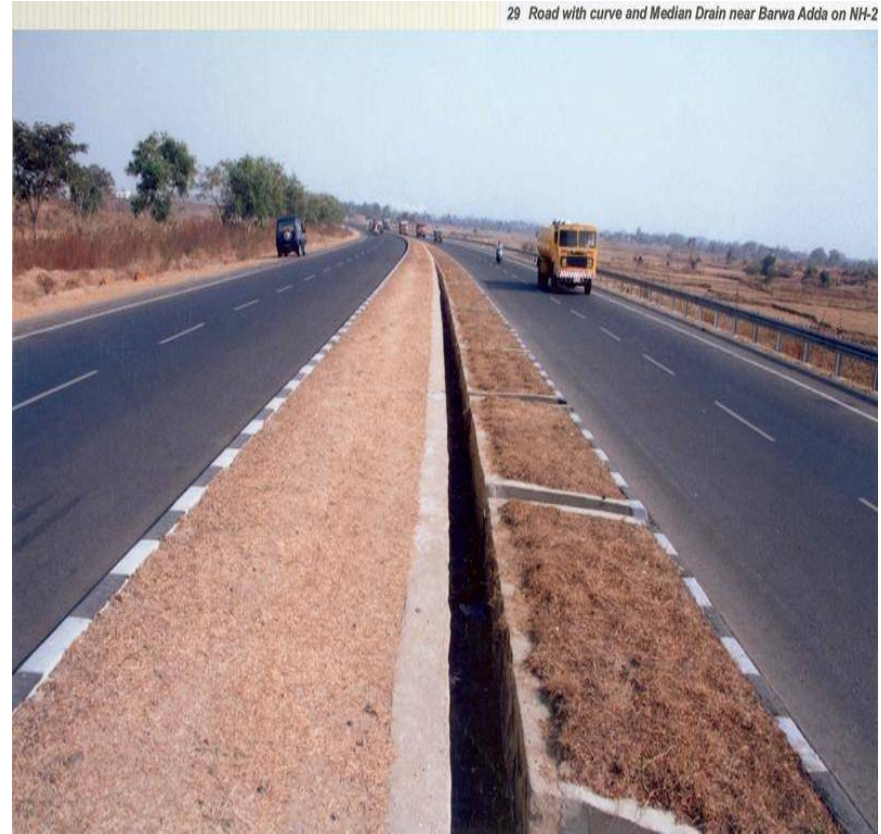
➢ Thickness varies from 0.75 m to 1.2m
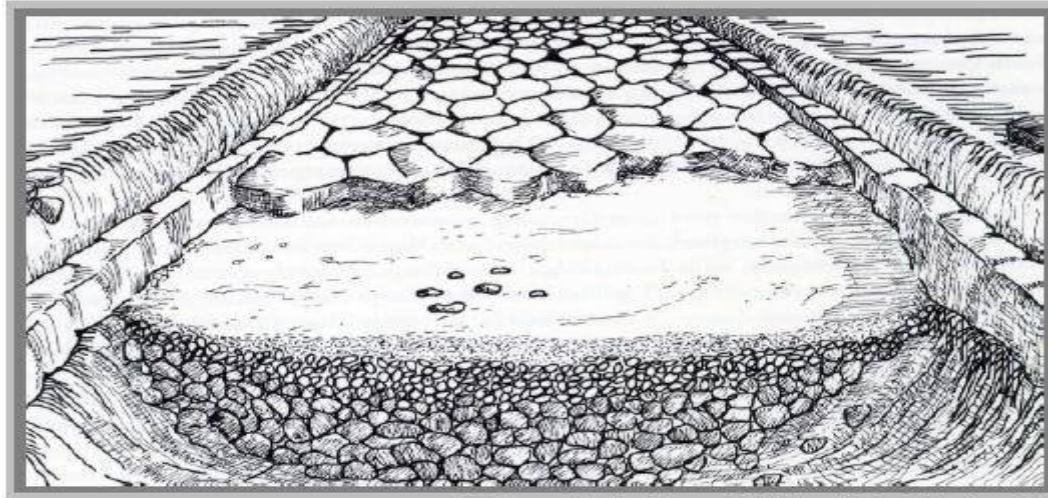
Roman Road Construction
Basic cross section

4) Paving stones formed the surface of the road. These were cut so they fitted together tightly.

5) Kerb stones at the sides held in the paving stones and made a channel for the water to run away.

3) Cement mixed with broken tiles

2) Broken stones, pebbles, cement and sand to make a firm base.

1) At the bottom of the trench, the Romans put a big layer of stones.

Roman Roads

Modern Highway

29 Road with curve and Median Drain near Barwa Adda on NH-2

Ref: Roman Roads of Europe, NHH Sitwell, Cassell-London, 1981

Other oldest road transport are

- Tresaguet construction

- Metcalf construction

- Telford construction

- Mecadam construction

Indian Roads

- India has a large road network of over 3.314 million kilometers of roadways (2.1 million miles), making it 3rd largest road network in the world.

- At 0.66 km of highway per square kilometer of land the density of India's highway network is higher than that of the United States (0.65) and far higher than that of China's (0.16) or Brazil's (0.20).

Highway Development in India

- **Jayakar Committee (1927)**
- **Central Road Fund (1929)**
- **Indian Roads Congress (IRC), 1934**
- **Central Road Research Institute (CRRI), 1950**
- **Motor vehicle act (1936)**
- **National Highway Authority of India (NHAI),1995**
- **First twenty year road plan (1943-61)**
- **Second twenty year road plan (1961-81)**
- **Highway Research board (1973)**
- **National Transport Policy committee (1978)**
- **Third twenty year road plan (1981-2001)**

Jayakar Committee,1927

- After the first World War, motor vehicle using the roads increases, this demanded a better road network.

- In 1927,Indian road development committee was appointed by the government with M.R. Jaykar as chairman.

- Road development in the country should be made as a national interest since local govt. do not have financial and technical capacity for road development.

- An extra tax should be levied on petrol from road users to create the road development fund.

- To establish a semi-official ,technical institution to pool technical knowledge, sharing of ideas and to act as an advisory body.

- To create a national level institution to carry research , development works and consultation.

Central road fund

- It was formed on 1st march 1929
- The consumers of petrol were charged an extra leavy of 2.64 paisa per litre of petrol to built up this road development fund.
- From this 20% of annual reveneu is to be retain as a central reveneu for research and experimental work expenses..etc
- Balance 80% is allowed by central govt. to various states based on actual petrol consumption or revenue collected.

Central Road Fund , 1929

CRF Act , 2000

Distribution of 100% cess on petrol as follows:

➢57.5% for NH

➢30% for SH

MORTH

➢12.5% for safety works on rail-Road crossing.

50% cess on diesel for Rural Road development

Indian Roads Congress, 1934

- Central semi official body known as IRC was formed in 1934.

- To provide national forum for regular pooling of experience and ideas on matters related to construction and maintenance of highways.

- It is a active body controlling the specification, standardization and recommendations on materials, design of roads and bridges.

- It publishes journals, research publications and standard specifications guide lines.

- To provide a platform for expression of professional opinion on matters relating to roads and road transport.

Motor vehicle act

- It was formed in 1939
- To regulate the road traffic in the form of traffic laws, ordinances and regulations.
- Three phases primarily covered are control of driver, vehicle ownership and vehicle operation
- It was revised on 1988

Central road research institute(1950)

- ➢ engaged in carrying out research and development projects.
- ➢ design, construction and maintenance of roads and runways, traffic and transportation planning of mega and medium cities, management of roads in different terrains,
- ➢ Improvement of marginal materials.
- ➢ Utilization of industrial waste in road construction.
- ➢ Landslide control.
- ➢ Ground improvements, environmental pollution.
- ➢ Road traffic safety.

Ministry of Road Transport & Highways

- Planning, development and maintenance of National Highways in the country.

- Extends technical and financial support to State Governments for the development of state roads and the roads of inter-state connectivity and economic importance.

- Evolves standard specifications for roads and bridges in the country.

- It stores the data related to technical knowledge on roads and bridges.

Highway Research Board

- To ascertain the nature and extent of research required
- To correlate research information from various organisation in India and abroad.
- To collect and correlation services.
- To collect result on research
- To channelise consultative services

Classification of Highways

Depending on weather
- All weather roads
- Fair weather roads

Depending the type of Carriage way
- Paved roads(WBM)
- Unpaved roads(earth road or gravel road)

Depending upon the pavement surface
- Surfaced roads(bituminous or cement concrete road)
- Un surfaced roads

Classification of Highways

Based on the Traffic Volume
➢ Heavy
➢ Medium
➢ Light

Based on Load or Tonnage

Class 1 or Class 2 etc   or Class A , B etc   Tonnes per day

## Based on location and function (Nagpur road plan)
➢ **National highway (NH)**
➢ **State highway (SH)**
➢ **Major district road (MDR)**
➢ **Other district road (ODR)**
➢ **Village road (VR)**

Based on modified system of Highways classification

- **Primary**
  - Expressways
  - National Highways

- **Secondary**
  - SH
  - MDR

- **Tertiary**
  - ODR
  - VR

Expressways

- Heavy traffic at high speed (120km/hr)
- Land Width (90m)
- Full access control
- Connects major points of traffic generation
- No slow moving traffic allowed
- No loading, unloading,
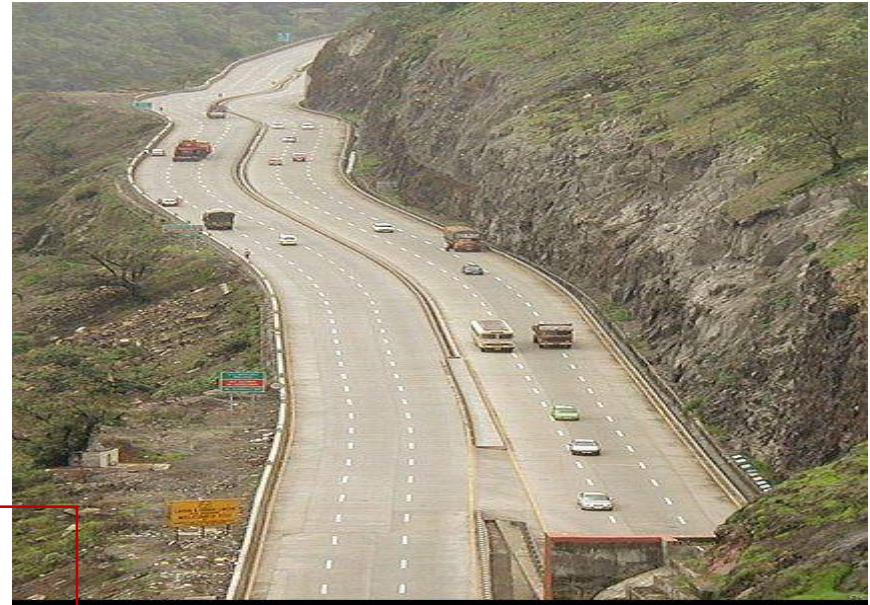
The Mumbai-Pune Expressway as seen from Khandala

National Highways

- NH are the main highways running through the length and breadth of India, connecting major parts,foreign highways,capital of large states and large industrial and tourist centres including roads required for strategic movements for the defence of India.

- The national highways have a total length of 70,548 kms. Indian highways cover 2% of the total road network of India and carry 40% of the total traffic.

- 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 longest highway in India is NH7 which stretches from Varansi in Uttar Pradesh to Kanyakumari in the southern most point of Indian mainland.

National Highways cont...

- The shortest highway is NH47A which stretches from Ernakulam to Kochi and covers total length of 4 Kms.

- **Golden Quadrilateral – (5,846 Kr**
Kolkata-Chennai-Mumbai

  ➢ NH-2 Delhi- Kol (1453 km)

  ➢ NH 4,7&46 Che-Mum (1290km

  ➢ NH5&6 Kol- Che (1684 m)

  ➢ NH 8 Del- Mum (1419 km)

State Highways

- They are the arterial roads of a state, connecting up with the national highways of adjacent states, district head quarters and important cities within the state.

- Total length of all SH in the country is 1,37,119 Kms.

- Speed 80 kmph

Major District Roads

- Important roads with in a district serving areas of production and markets , connecting those with each other or with the major highways.

- India has a total of 4,70,000 kms of MDR.
- Speed 60-80kmph

Other district roads

- serving rural areas of production and providing them with outlet to market centers or other important roads like MDR or SH.

- Speed 50-60kmph

Village roads

- They are roads connecting villages or group of villages with each other or to the nearest road of a higher category like ODR or MDR.

- India has 26,50,000 kms of ODR+VR out of the total 33,15,231 kms of all type of roads.

- Speed-40-50kmph

Urban Road Classification

- Arterial Roads
- Sub Arterial
- Collector
- Local Street

ARTERIAL

- No frontage access, no standing vehicle, very little cross traffic.

- Design Speed : 80km/hr

- Land width   : 50 – 60m

- Divided roads with full or partial parking

- Pedestrian allowed to walk only at intersection

SUB ARTERIAL ROAD

- Bus stops but no standing vehicle.
- Less mobility than arterial.
- Spacing for CBD   : 0.5km
- Design speed   : 60 km/hr
- Land width   : 30 – 40 m

Collector Street

- Collects and distributes traffic from local streets
- Provides access to arterial roads
- Located in residential, business and industrial areas.
- Full access allowed.
- Parking permitted.
- Design speed : 50km/hr
- Land Width   : 20-30m

Local Street

- Design Speed : 30km/hr.
- Land Width   : 10 – 20m.
- Primary access to residence, business or other abutting property
- Less volume of traffic at slow speed
- Unrestricted parking, pedestrian movements. (with frontage access, parked vehicle, bus stops and no waiting restrictions)

First 20-years road plan(1943-63)

- The conference of chief engineer held at Nagpur in 1943 finalized the first 20-years road development plan for India called Nagpur road plan

- Road network was classified into five categories.

- The responsibility of construction maintenance of NH was assign to central govt.

- The target road length was 5,32,700 km at the end of 1961.

- Density of about 16km of road length per 100 sq. km area would be available in the country by the year 1963.

First 20-years road plan cont...

- The formulae were based on star and grid pattern of road network.
- An allowance of 15% is provided for agricultural industrial development during the next 20-years
- The length of railway track in the area was also consider in deciding the length of first category road. The length or railway track is directly subtracted from the estimated road length of metalled roads.

Road Length as per Nagpur Pan

Road density = 16 km/100 sq.km are

- **Category I : (NH,SH, MDR)**

$$length \text{ of road} = \left[\frac{A}{8} + \frac{B}{32} + 1.6N + 8T \right] + D - R$$

A = Developed & agricultural area, Km^2 B = Non – Agricultural area, Km^2

N = No. of towns & Villages with population range 2001 – 5000 T = No. Of towns with population over 5000

D = Development allowance of 15 % of road length calculated for next 20 years

R = Existing length of railway track, km

Category II : (ODR,VR)

$$\text{length of road} = \left[0.32\,V + 0.8\,Q + 1.6\,P + 3.2\,S\right] + D$$

V = Total no. of villages with population 500/less

Q = Total no. of villages with population 500-1000

P = Total no. of villages with population 1001-2000

S = Total no. of villages with population 2001-5000

D = Development allowance of 15 % of road length calculated for next   20 years

Second 20-years road plan(1961-81)

- It was initiated by the IRC and was finalised in 1959 at the meeting of chief engineers.

- It is known as the Bombay road plan.

- The target road length was almost double that of Nagpur road plan i.e. 10,57,330 km.

- Density about 32 km per 100 sq. km. and an outlay of 5200 crores

- Every town with population above 2000 in plans and above 1000 in semi hill area and above 500 in hilly area should be connected by metalled road

Second 20-years road plan   cont…

- the maximum distance from any place in a semi develop area would be 12.8 km from metalled road and 4.8 from any road

- Expressways have also been considered in this plan and 1600km of length has been included in the proposed target NH

- Length of railway track is considered independent of road system

- 5% are to be provided for future development and unforeseen factor

Road Length as per Bombay Plan

$$\mathrm{length\ of\ NH} = \left\lceil \frac{A}{64} + \frac{B}{80} + \frac{C}{96} \right\rceil + \left[32K + 8M \right] + D$$

$$\mathit{length}\ \mathrm{of\ (NH+SH)} = \left\lceil \frac{A}{20} + \frac{B}{24} + \frac{C}{32} \right\rceil + \left[48K + 24M + 11.2N + 1.6P \right]$$

$$\mathrm{Length\ of\ (NH+SH+MDR)} = \left\lceil \frac{A}{8} + \frac{B}{16} + \frac{C}{24} \right\rceil + \left[48K + 24M + 11.2N + 9.6P + 6.4Q + 2.4R \right] + D$$

$$\mathrm{length\ of\ (NH+SH+MDR+ODR)} = \left\lceil \frac{3A}{16} + \frac{3B}{32} + \frac{C}{16} \right\rceil + \left[48K + 24M + 11.2N + 9.6P + 12.8Q + 4R + 0.8S + 0.32T \right] + D$$

$$\mathrm{Total\ length\ of\ road,\ km} = \left\lceil \frac{A}{4} + \frac{B}{8} + \frac{C}{12} \right\rceil + \left[48K + 24M + 11.2N + 9.6P + 12.8Q + 5.9R + 1.6S + 0.64T + 0.2V \right] + D$$

- A = developed or agricultural area, sq.km
- B = semi- developed area, sq.km
- C = undeveloped area, sq.km
- K = no. of towns with population over 100000
- M = no. of towns with population 50000-100000
- N = no. of towns with population 20000-50000
- P = no. of towns with population 10000-20000
- Q = no. of towns with population 5000-10000
- R = no. of towns with population 2000-5000
- S = no. of towns with population 1000-2000
- T = no. of villages with population 500-1000
- V = no. of villages with population less than 500
- D = development allowance of 5 % of road length

Third twenty years road plan (1981-2001)

- The future road development should be based on the revised classification of roads system i.e. primary, secondary and tertiary

- Develop the rural economy and small towns with all essential features.

- Population over 500 should be connected by all weather roads.

- Density increases to 82 km per 100 sq. km

- The NH network should be expanded to form a square grids of 100 km sides so that no part of the country is more than 50 km away from the NH

Third twenty years road plan cont…

- Expressway should be constructed along major traffic corridors

- All towns and villages with population over 1500 should be connected by MDR and villages with population 1000-1500 by ODR.

- Road should be built in less industrialized areas to attract the growth of industries

- The existing roads should be improved by rectifying the defects in the road geometry, widening, riding quality and strengthening the existing pavement to save vehicle operation cost and thus to conserve energy

Method of calculating length of various categories of roads as per Lucknow road plan

- Length of National Highways (NH)

  Length(in km)=Area/50 (in sq km)

- State Highways(SH)

  Length(in km)=Area/25(in sq km) OR

  Length in km=62.5*no.of turns-Length of NH

  =62.5*no.of turns-Area/50

- Major district road (MDR)

  Length(in km)= Area/12.5(in sq. km) OR

  Length(in km)=90*no.of turns

- Total road length

- Length(in km)=4.74*No. of villages and towns.

- Other District Roads and Village Roads(or Rural roads) The length of ODR and VR is obtained by subtracting the length of NH,SH,MDR from total length.

- The area of Maharashtra is 3,08,000 sq km. The number of towns as per 1981 census is 276.The number of villages is 41,833.Calculate the length of various categories of roads.

1. NH

Length of NH=Area/50=3,08,000/50=6160km

2. State Highway

Length of state highway =Area/25=3,08,000/25=12320 km

(b) Length of SH=62.5*No. of turns-Length of NH

$$=62.5*276-6160$$

$$=11090km$$

3.Major district roads

(a)Length of MDR=Area/12.5=3,08,000/12.5=24640km OR
(b)Length of MDR=90*No. of turns=90*276=24840km

4.Length of ODR and VR

No. of villages and towns=276+41,833=42,109

Now: Total length of all categories of roads

=4.74*No. of towns and villages

=4.74*42,109=1,99,597km

Length of ODR and VR=Total length-(length of NH,SH,MDR)

$$=1,99,597-43120=1,56,477km$$

Road Patterns

- Rectangular or Block patterns
- Radial or Star block pattern
- Radial or Star Circular pattern
- Radial or Star grid pattern
- Hexagonal Pattern
- Minimum travel Pattern

Rectangular or Block Pattern

- The whole area is divided into rectangular blocks of plots, with streets intersecting at right angles.

- The main road which passes through the center of the area should be sufficiently wide and other branch roads may be comparatively narrow
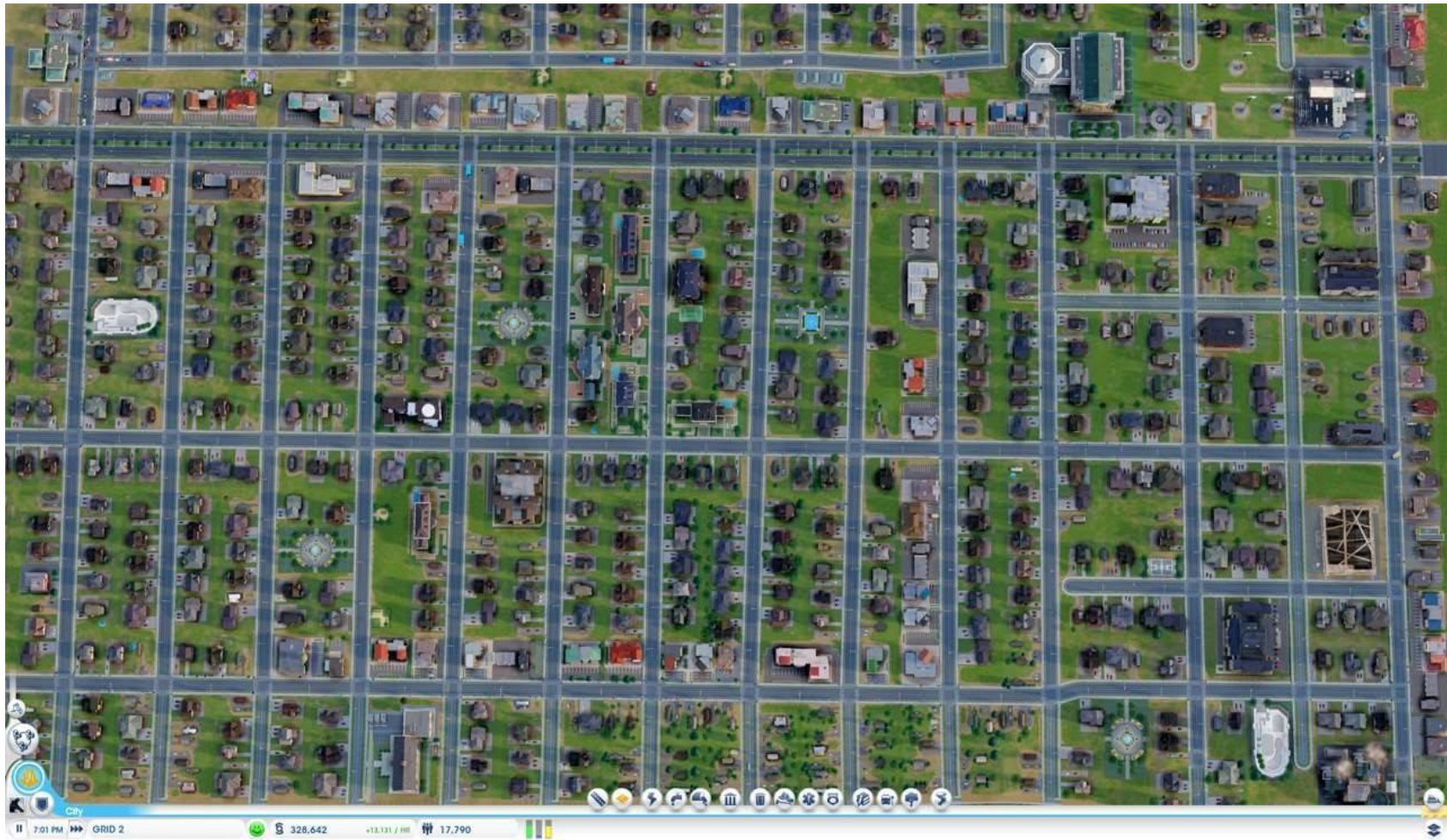
Rectangular or Block Pattern

BUILT UP AREA
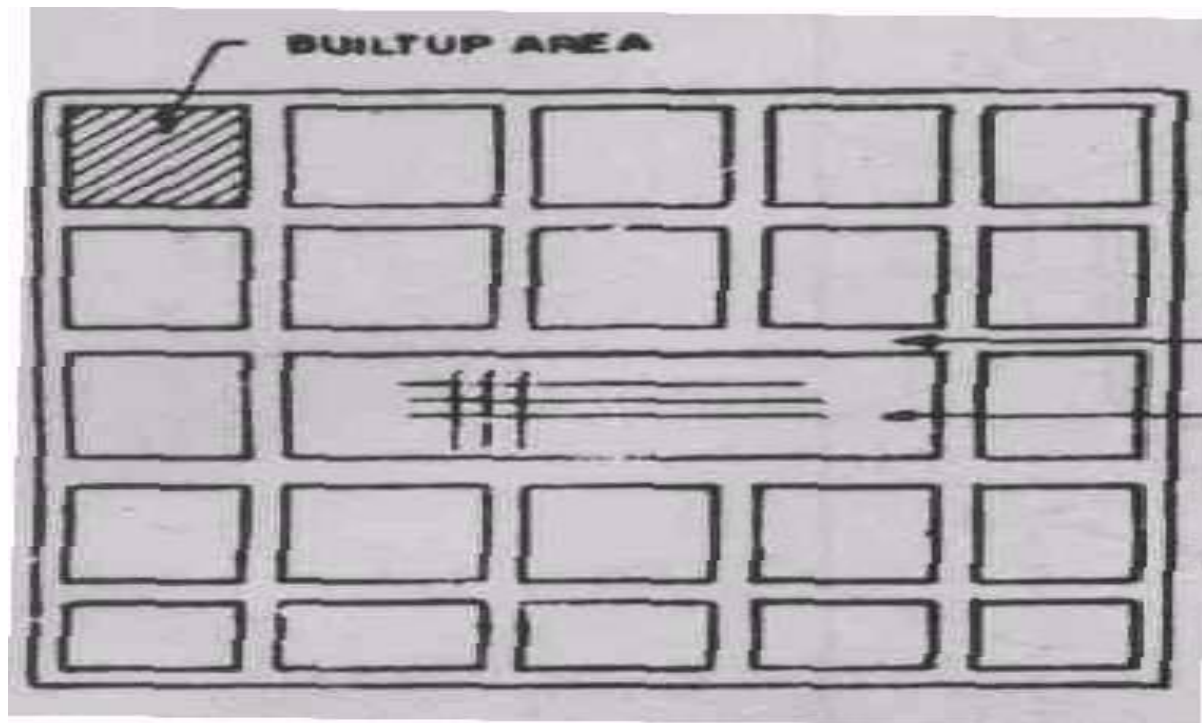
- **Advantages:**
- The rectangular plots may be further divided into small rectangular blocks for construction of buildings placed back to back, having roads on their front.
- The construction and maintenance of roads of this pattern is comparatively easier.
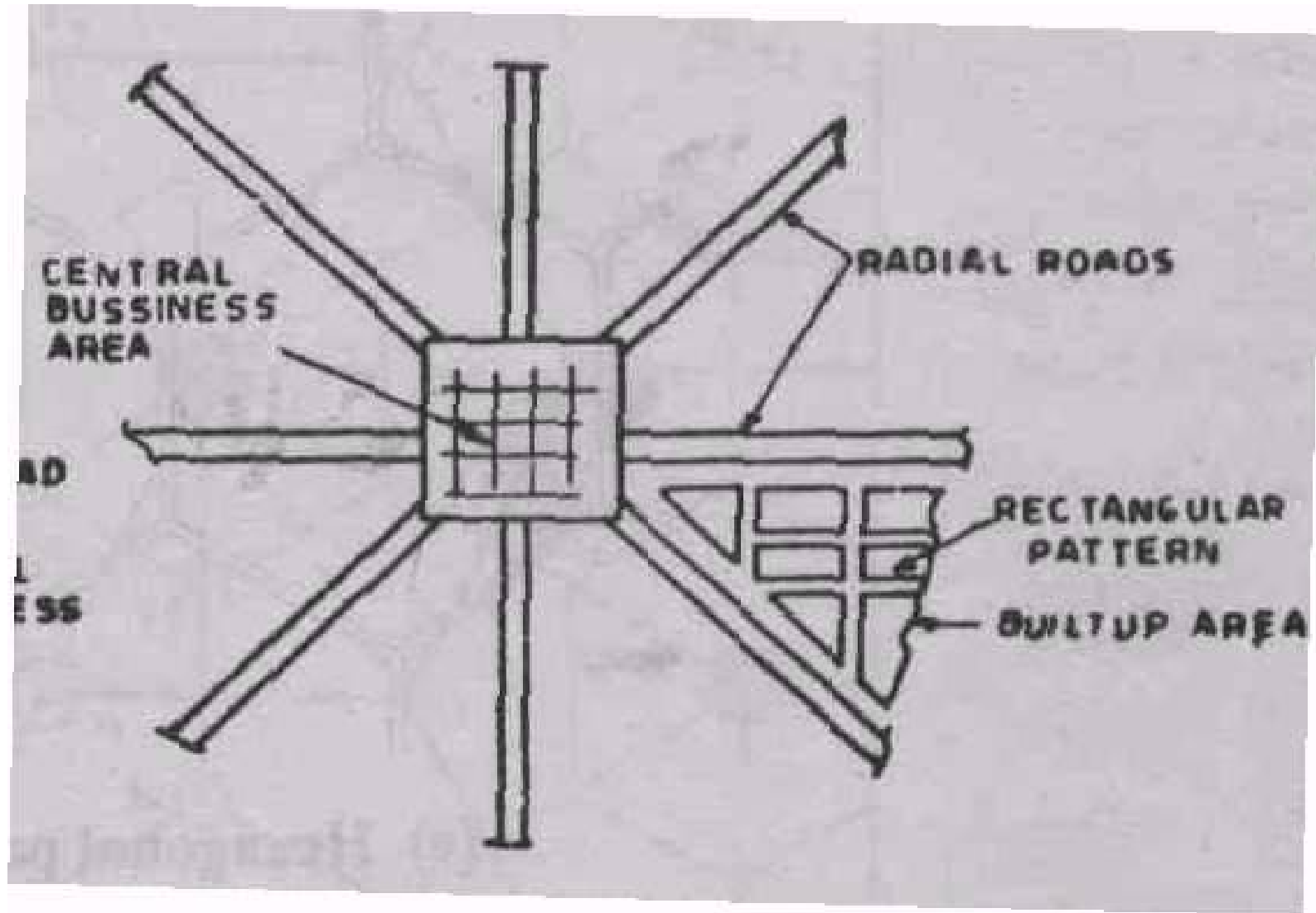- The main road is provided a direct approach to outside the city
- **Limitations:**
- This pattern is not very much convenient because at the intersections, the vehicles face each other.

Rectangular or Block Pattern

Star and Block Pattern

Star and Block Pattern

- In this pattern, the entire area is divided into a network of roads radiating from the business outwardly.

- In between radiating main roads, the built-up area may be planned with rectangular block.

- <u>Advantage:</u>

- Reduces level of   congestion at the primary bottleneck location.

- Vehicles face each other less than block pattern.

Star and Circular Pattern

- In this system, the main radial roads radiating from central business area are connected together with concentric roads.

- In these areas, boundary by adjacent radial roads and corresponding circular roads, the built-up area is planned with a curved block system
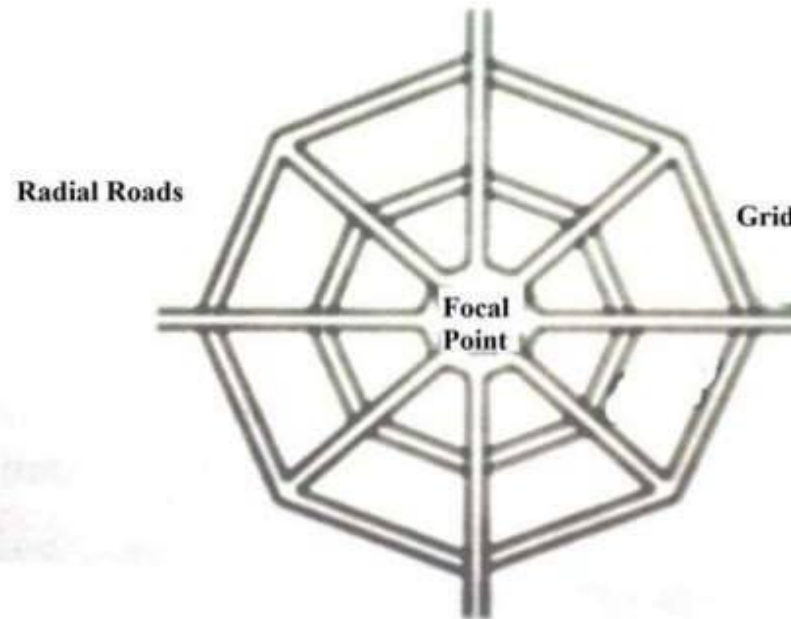
Star and Circular Pattern
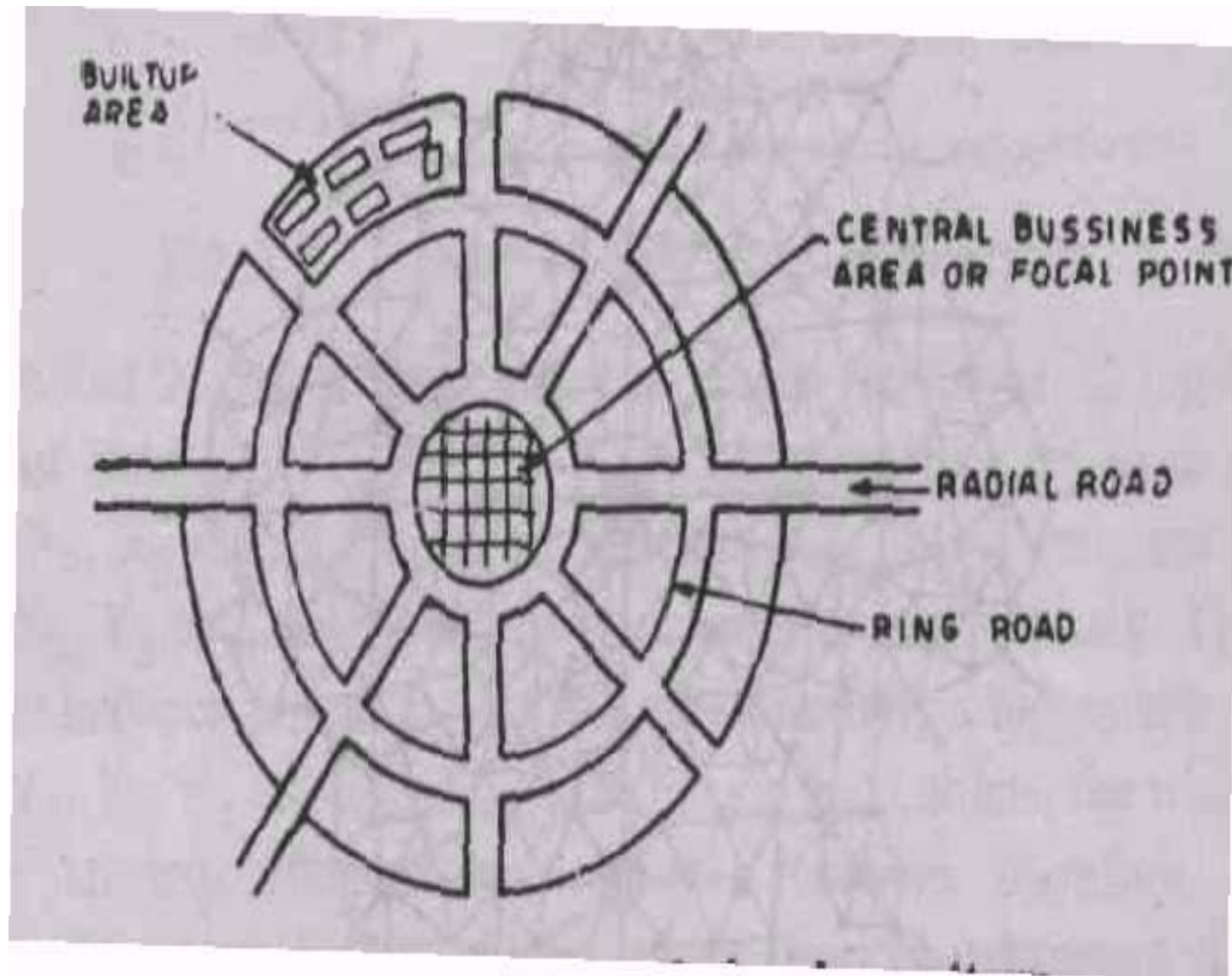
Star and Circular Pattern

Star and Grid Pattern

Radial (Star) and Grid Pattern

Star and Grid Pattern

- **Advantages:**

- Keep vehicular traffic safe.

- Improve traffic flow in both directions using cellular structure.

- Improve land use efficiency and unit density.

- **Limitations:**

- Islands separating the approach and exit lanes, known as splitter islands, should extend far enough.

- **Examples:**

- The Nagpur road plan formulae were prepared on the assumption of Grid pattern.

Hexagonal Pattern

Hexagonal Pattern

PMGSY-Phase I

PMGSY – Phase I was launched in December, 2000 as a 100 % centrally sponsored scheme with an objective to provide single all-weather road connectivity to eligible unconnected habitation of designated population size(500 and above in plain areas and 250 persons and above in North-East, hill, tribal and desert areas,

Also, upgrading (to prescribed standards) of the existing roads in those Districts where all the eligible Habitations Of the designated population size have been provided all-weather road connectivity was to be taken up.

However, up gradation is not central to the Programme. In Up gradation works, priority was to be given to Through Routes of the Rural Core Network, which carry more traffic.

Under the scheme, 1,35,436 habitations were targeted for providing road connectivity and 3.68 lakh km. for upgrading existing rural roads (including 40 % renewal of rural roads to be funded by the States) in order to ensure full farm to market connectivity

PMGSY – Phase II

The Phase II of PMGSY was approved during May, 2013. While the ongoing PMGSY – I continued, under PMGSY phase II, the roads already built for village connectivity was to be upgraded to enhance rural infrastructure.

For the 12th Five Year Plan period a target of 50,000 Km length under PMGSY-II. 75 percent of the cost of the upgrade was by the Centre and 25 per cent by the state. For hill states, desert areas, and Naxal-affected districts, 90 percent of cost was borne by the Centre

PMGSY – Phase III

•Phase III was approved by the Cabinet during July 2019. It involves consolidation of Through Routes and Major Rural Links connecting habitations to Gramin Agricultural Markets (GrAMs), Higher Secondary Schools and Hospitals.

•Under the PMGSY-III Scheme, it is proposed to consolidate 1,25,000 Km road length in the States.

•The duration of the scheme is 2019-20 to 2024-25.The funds would be shared in the ratio of 60:40 between the Centre and State for all States except for 8 Northeastern and 3 Himalayan States (Jammu & Kashmir, Himachal Pradesh & Uttarakhand) for which it is 90:10.Major source of funds for PMGSY is Central Road Fund