

PRINCIPLES OF TRANSPORTATION ENGINEERING

Introduction To Transportation Engineering

Transportation contributes to

- Social development
- Economic development
- Cultural development

Various social effects of transportation

- Sectionalism and transportation
- Concentration of population in urban area
- Aspects of safety, law and order

Economic Development

Economic activity and transport

Two important factor are

1. Production or supply and
2. Consumption for humans wants or demand

Role of transportation for Development of Rural Areas

- Improved access to market area
- Commercialization of agricultural activity
- Better connectivity gives employment opportunities and increase standard of living
- Good public services

Issues and Challenges

- Congestion
- Safety
- Equity of access
- Environmental impacts
- New technologies

Different modes of Transportation

- Roadways or highways
- Railways
- Waterways
- Airways



TRANSPORTATION



Meaning and Definition

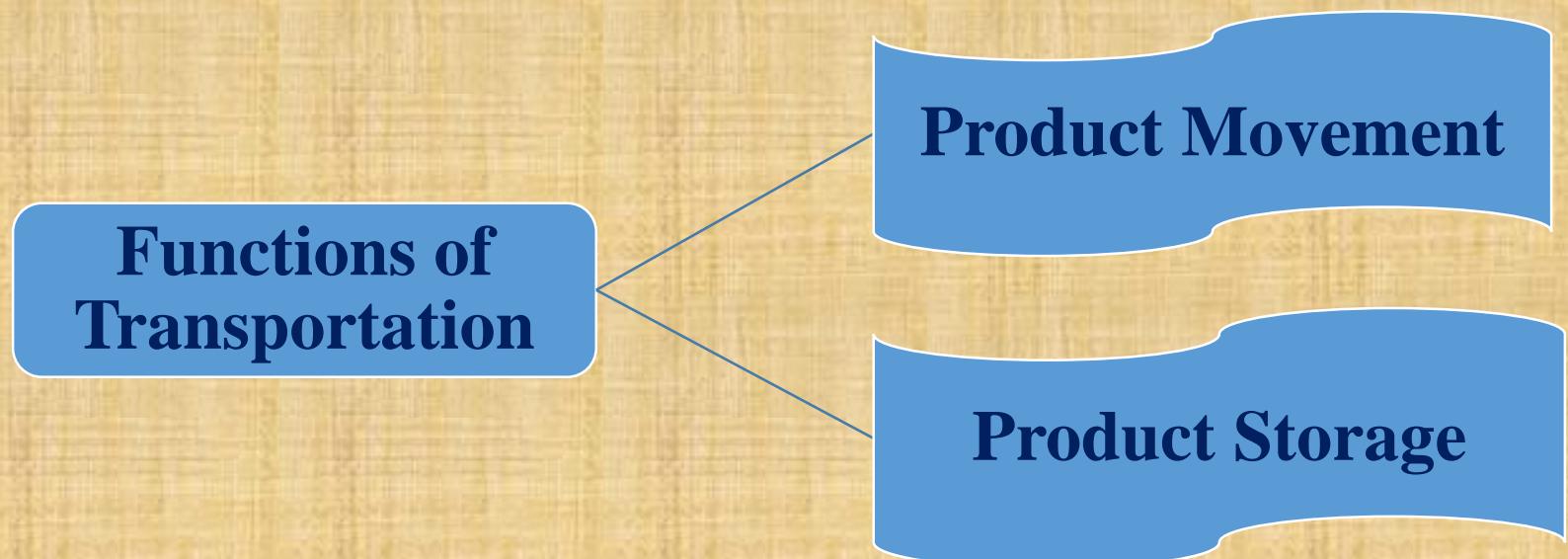
“The process of moving an item from point A to point B.”

“Safe, efficient, reliable, and sustainable movement of persons and goods over time and space”

Importance of Transportation:

- ✓ Without well-developed transportation systems, logistics could not bring its advantages into full play.
- ✓ A good transport system in logistics activities could provide better logistics efficiency, reduce operation cost, and promote service quality.
- ✓ A well-operated logistics system could increase both the competitiveness of the government and enterprises.
- ✓ Transport system is the most important economic activity among the components of business logistics systems

Transportation Functionality



Rail Transport:

Advantages of Rail transport:

- ✓ It is a convenient mode of transport for travelling long distances.
- ✓ It is relatively faster than road transport.
- ✓ It is suitable for carrying heavy goods in large quantities over long distances.
- ✓ Its operation is less affected by adverse weather conditions like rain, floods, fog, etc.

Limitations of Railway transport:

- ✓ It is relatively expensive for carrying goods and passengers over short distances.
- ✓ It is not available in remote parts of the country.
- ✓ It provides service according to fixed time schedule and is not flexible for loading or unloading of goods at any place.
- ✓ It involves heavy losses of life as well as goods in case of accident.

Road Transport

▪ Advantages

- ✓ It is a relatively cheaper mode of transport as compared to other modes.
- ✓ Perishable goods can be transported at a faster speed by road carriers over a short distance.
- ✓ It is a flexible mode of transport as loading and unloading is possible at any destination. It provides door-to-door service.
- ✓ It helps people to travel and carry goods from one place to another, in places which are not connected by other means of transport like hilly areas.

• Limitations of Road transport

- ✓ Due to limited carrying capacity road transport is not economical for long distance transportation of goods.
- ✓ Transportation of heavy goods or goods in bulk by road involves high cost.

Water Transport

• Advantages:

- ✓ It is a relatively economical mode of transport for bulky and heavy goods.
- ✓ It is a safe mode of transport with respect to occurrence of accidents.
- ✓ The cost of maintaining and constructing routes is very low most of them are naturally made.
- ✓ It promotes international trade.

■ Disadvantages:

- ✓ The depth and navigability of rivers and canals vary and thus, affect operations of different transport vessels.
- ✓ It is a slow moving mode of transport and therefore not suitable for transport of perishable goods.
- ✓ It is adversely affected by weather conditions.
- ✓ Sea transport requires large investment on ships and their maintenance.

Air Transport:

■ Advantages:

- ✓ It is the fastest mode of transport.
- ✓ It is very useful in transporting goods and passengers to the area, which are not accessible by any other means.
- ✓ It is the most convenient mode of transport during natural calamities.
- ✓ It provides vital support to the national security and defence

■ Disadvantages:

- ✓ It is relatively more expensive mode of transport.
- ✓ It is not suitable for transporting heavy and bulky goods.
- ✓ It is affected by adverse weather conditions.
- ✓ It is not suitable for short distance travel.
- ✓ In case of accidents, it results in heavy losses of goods, property and life.

What are Current Transportation Problems?

1. Financing
2. Congestion
3. Infrastructure
4. Safety
5. Population
6. Increased truck weights
7. Equity of access
8. Environmental Impacts
9. New technologies



Relative Opening Characteristics by Transportation Modes:

| Operating Characteristics | Rail | Truck | Water | Pipeline | Air | Remarks |
|---------------------------|------|-------|-------|----------|-----|--|
| Speed | 3 | 2 | 4 | 5 | 1 | Air is the fastest |
| Availability | 2 | 1 | 4 | 5 | 3 | Road is the best since they can drive from origin to destination |
| Dependability | 3 | 2 | 4 | 1 | 5 | Pipeline ranks best-As the service is continuous and there is no stoppage due to traffic or congestion |
| Capability | 2 | 3 | 1 | 5 | 4 | Sea is the best-Can handle all types and size of cargo |
| Frequency | 4 | 2 | 5 | 1 | 3 | Pipeline is ranked best-As the movement is continuous |
| Composite Score | 14 | 10 | 18 | 17 | 16 | Lowest rank is the Best- |

Cost Structure For Each Module:

| Mode | Fixed Costs | Variable Costs |
|----------|--|--|
| Rail | High- Equipments, Terminals , Tracks ,etc | Low |
| Road | Low-Highway provided by government | Medium-Fuel , Maintenance, etc |
| Water | Medium-Ships and Equipment | Low-As capacity is huge |
| Pipeline | Highest-Right of the way , construction, Equipment for control station and Pumping capacity | Lowest-Insignificant labour costs |
| Air | Low-Aircraft and cargo handling systems | High- Fuel, labour, Maintenance |

Characteristics of Road Transport

1. Road is used by various types of vehicles like bikes, cycles, four wheeler, earth movers etc. But railways only use wagons and locomotives, ships sail on waterways and airports are only restricted for the use of aircrafts.
2. Road infrastructure requires lowest initial investment in comparison to that for the infrastructure of other transportation modes.
3. Roads offer compete freedom to the road users to make of the roadway facilities at any time convenient to them or to change the lane from to another.
4. Door to door journey is possible only in road transportation.
5. Speed is directly related to the severity of accidents. Compared to other modes of transport, speed is less.
6. Road transport is the only mode that offers the facilities to the whole section of society.

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 recommendations

The Jayakar committee in the year 1928 submitted its recommendations

1. 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
2. An extra tax should be levied on petrol from the road users to develop a road development fund called **Central Road Fund**
3. 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
4. A research organisation should be instituted to carry out research and development work pertaining to roads and to be available for consultations

Jayakar committee implementation

Most of the recommendations of jayakar committee were accepted by the government and the some are implemented subsequently.

1. The Central Road Fund was formed by the year 1929
2. The semi official body called Indian Road Congress was formed in the year 1934
3. The Central Road Research Institute(CRRI) was started in the year 1950.
4. Motor Vehicle Act was bought in 1939, to regulate Traffic.

Central road fund

- It was formed on 1st march 1929
- The consumers of petrol were charged an extra levy of 2.64 paisa per litre of petrol to built up this road development fund.
- From this 20% of annual revenue is to be retain as a central revenue 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.

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 an 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.
- Land slide 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 channel is consultative services

Objects of Highway Planning

- To plan a road network for efficient and safe traffic operations, but at minimum cost. Hence the cost of constructions, maintenance and renewal of pavement layers and the vehicle operation costs are to be given due considerations.
- To arrive at the road system and lengths of different categories of roads which could provide maximum utility and could be constructed within the available resources during the plan period and under construction.
- To fix up date wise priorities for development of each road link based on utility as the main criterion for phasing the road development.

- To plan for future requirements and improvements of roads in view of anticipated developments.
- To workout financing systems.

Classification of Roads

Roads across the India are classified as follows.

Types of Roads

Depending upon whether, they can be classifies into two categories.

1. All whether roads:

These are available for traffic in all seasons.

2. Fair weather roads:

Movement of traffic may be interrupted during monsoon.

Based upon the carriageway or the road pavement, the classification would be,

1. Paved roads

Water bound macadam layer must be provided.

2. Unsurfaced roads

Earthen roads and Gravel roads without provision of water bound macadam.

Based upon the type of pavement surface,

1. Surfaced roads

Pavement surfaces would be provided with Bituminous or Concrete layers.

2. Unsurfaced roads

Pavements will not be provided with any of the top coats i.e. Bitumen or Concrete layers.

Methods of classification of roads

The roads are generally classified into following basis:

1. Traffic volume
 2. Load transported or tonnage
 3. Location and function
- Classification based upon 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 groups.

- Based upon 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.
- Classification based upon 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.
- Classification based upon location and function should therefore be a more acceptable classification for a country as they may be defined-clearly.

➤ The Nagpur Road Development Plan classified the roads in India based upon location and function into following five categories.

1. National Highways(NH)
2. State Highways(SH)
3. Major District Roads(MDR)
4. Other District Roads(ODR)
5. Village Roads(VR)

1. National Highways (NH)

- These are main highways running through the length and breadth of India, connecting major parts of the country.
- NH-1 connects Delhi, Ambala, Jalandhar and Amritsar(up to Pakistan border)
- NH-4 connects Thane, Pune, Belagavi, Hubbli, Bengaluru, Chittoor and Chennai



Yamuna Expressway



Yamuna Expressway



Pune- Mumbai expressway



Hyderabad ORR

2. State Highways (SH)

- These 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.
- The NH and SH have the same design speed and geometric design specifications.



State Highway

3. Major District Roads (MDR)

- These are the roads within the district, serving areas of production and markets and connecting those with each other or main highways of district.
- The MDR has lower speed and geometric standards than NH / SH.



Major District Roads

4. Other District Roads (ODR)

- These roads are serving rural areas of production and providing them with outlet to market canters, taluk head quarters, block development head quarters or other main roads.

5. Village Roads (VR)

- These are the roads connecting villages or groups of villages with each other to nearest road of a higher category.

A general notes was assigned by Nagpur Road Conference regarding the economics of road construction that all roads whatever type or class, should be constructed that maintenance and capital costs over a period of 20 years will be minimum.



Village Roads

Nagpur Road Conference and Plan:

- A conference of chief engineers of all states and provinces was convened in 1943 by Government of India at Nagpur, at initiative of the Indian Road Congress to finalize the first road development plan for the country as a whole.
- “First 20-year Road Development Plan” in India was finalized for the period 1943-63.
- The total target road length aimed at the end of this plan period was 16km per 100 square area of the country.
- Target was achieved about two years ahead, in 1961.

Second 20-Year Road Development Plan:

- It was initiated for period of 1961-81 by IRC at Mumbai.
- The target road length at the end of this road development plan was 32 km per 100 square km area.

Third Twenty Year Road Plan(1981-2001)

- It was held in Lucknow.
- The future road development should be based on the revised classification of road system.
- All the villages with population over 500 should be connected by all weather by the end of this century.
- The overall road density should be increased to 82km per 100sq.km area by the year 2001. The corresponding values of planned road densities are 40 km for hill areas of altitudes up to 2100 m above msl and 15km/sq.km area for altitude above 2100m.
- The national highway should be expanded to form square grids of 100km sides so that no part of the country is more than 50km away from a NH.

Modified Classification of Road System by Third 20-Year Road Development Plan 1981-2001

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

1. Primary system

a. Expressways

b. National Highways

2. Secondary system

a. State highways

b. Major District roads

3. Tertiary system

- a. Other District roads
- b. Village roads

Classification of Urban Roads

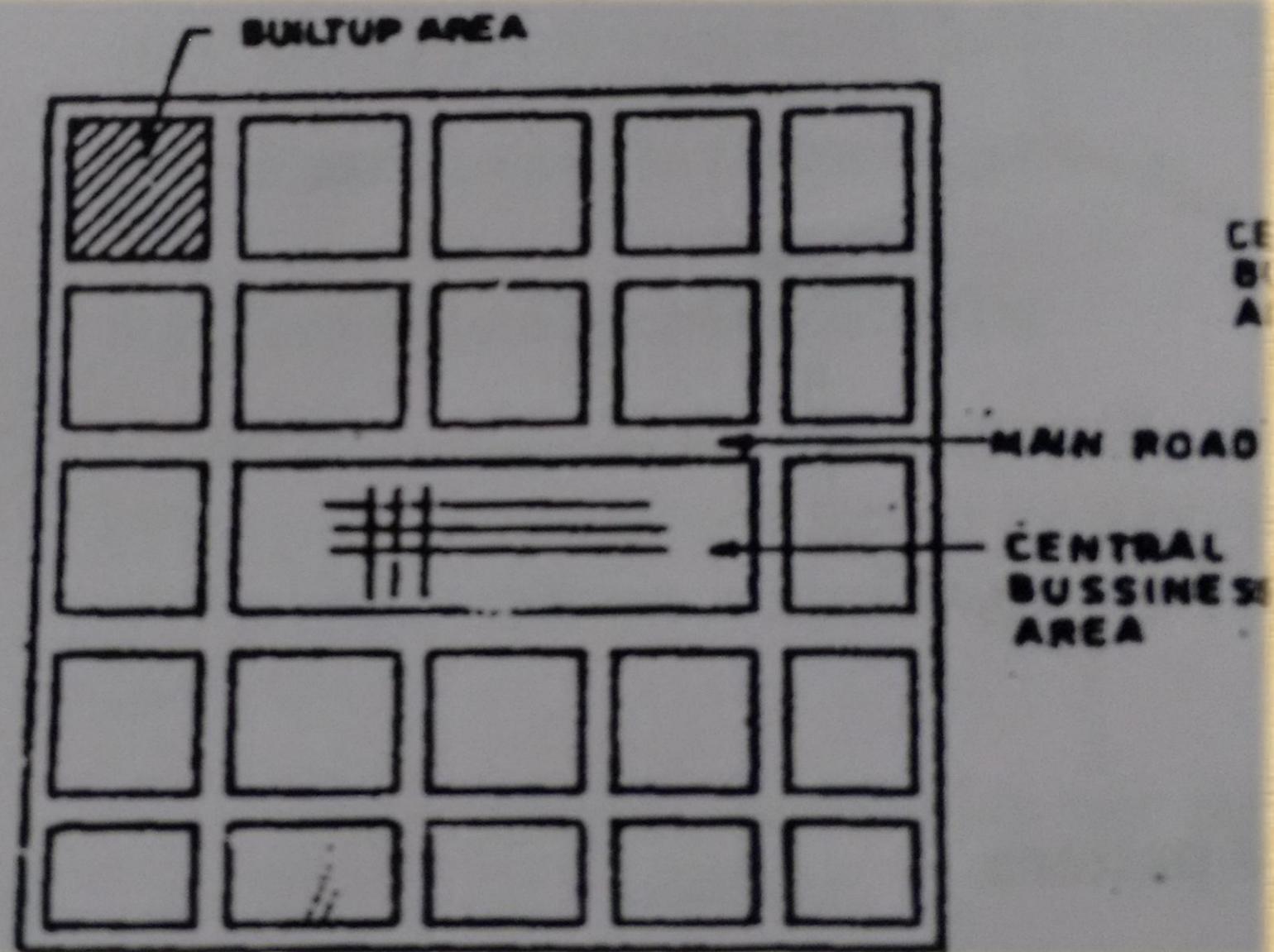
The road system within urban areas are classified as Urban Roads and will form a separate category of roads to be taken care by respective urban authorities.

- 1. Arterial roads
- 2. Sub-arterial roads
- 3. Collector streets
- 4. Local Streets

Road Patterns

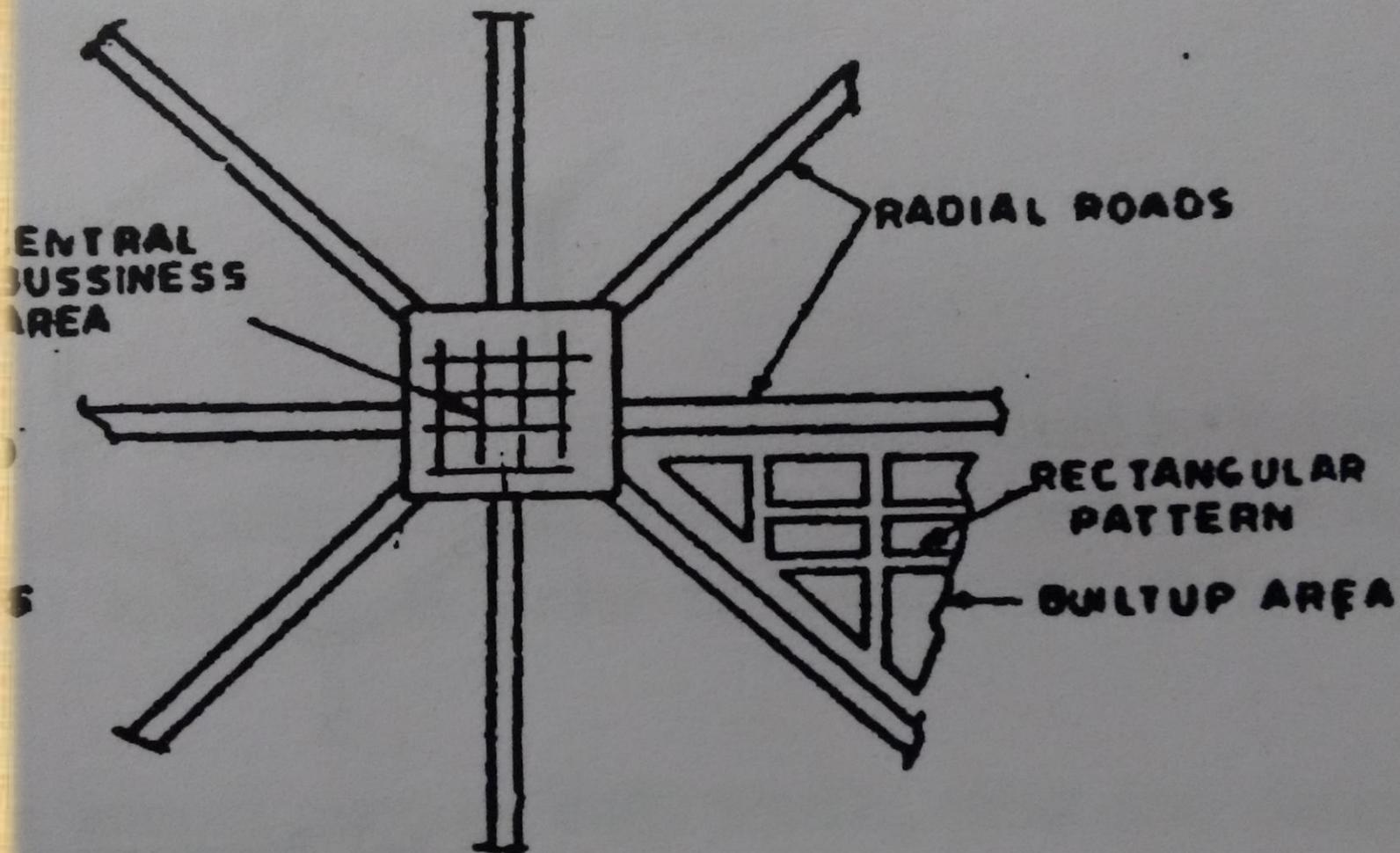
Various road patterns may be classified as

1. Rectangular or block pattern
2. Radial or Star and block pattern
3. Radial or Star and circular pattern
4. Radial or Star and grid pattern
5. Minimum travel pattern



Rectangular or Block Pattern

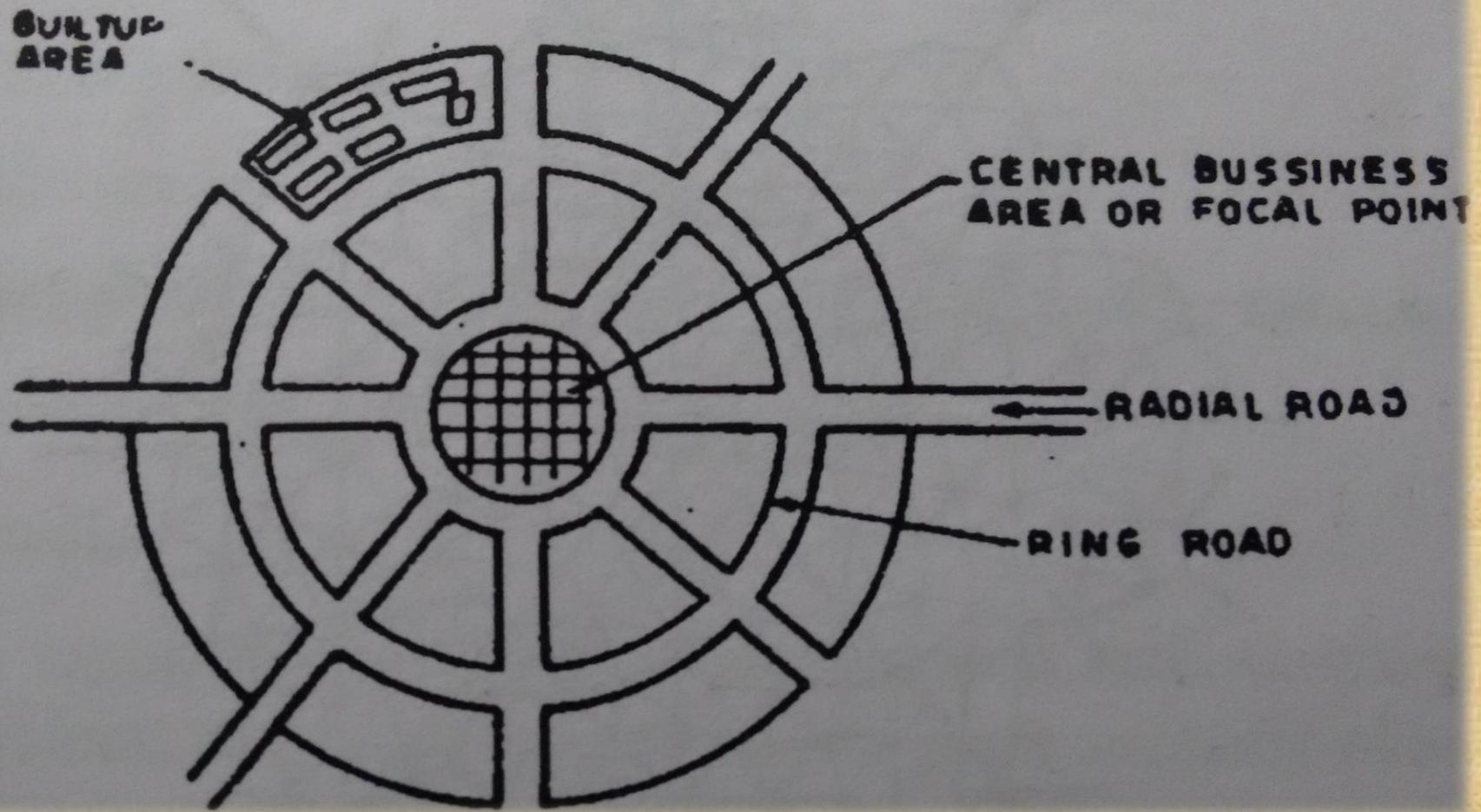




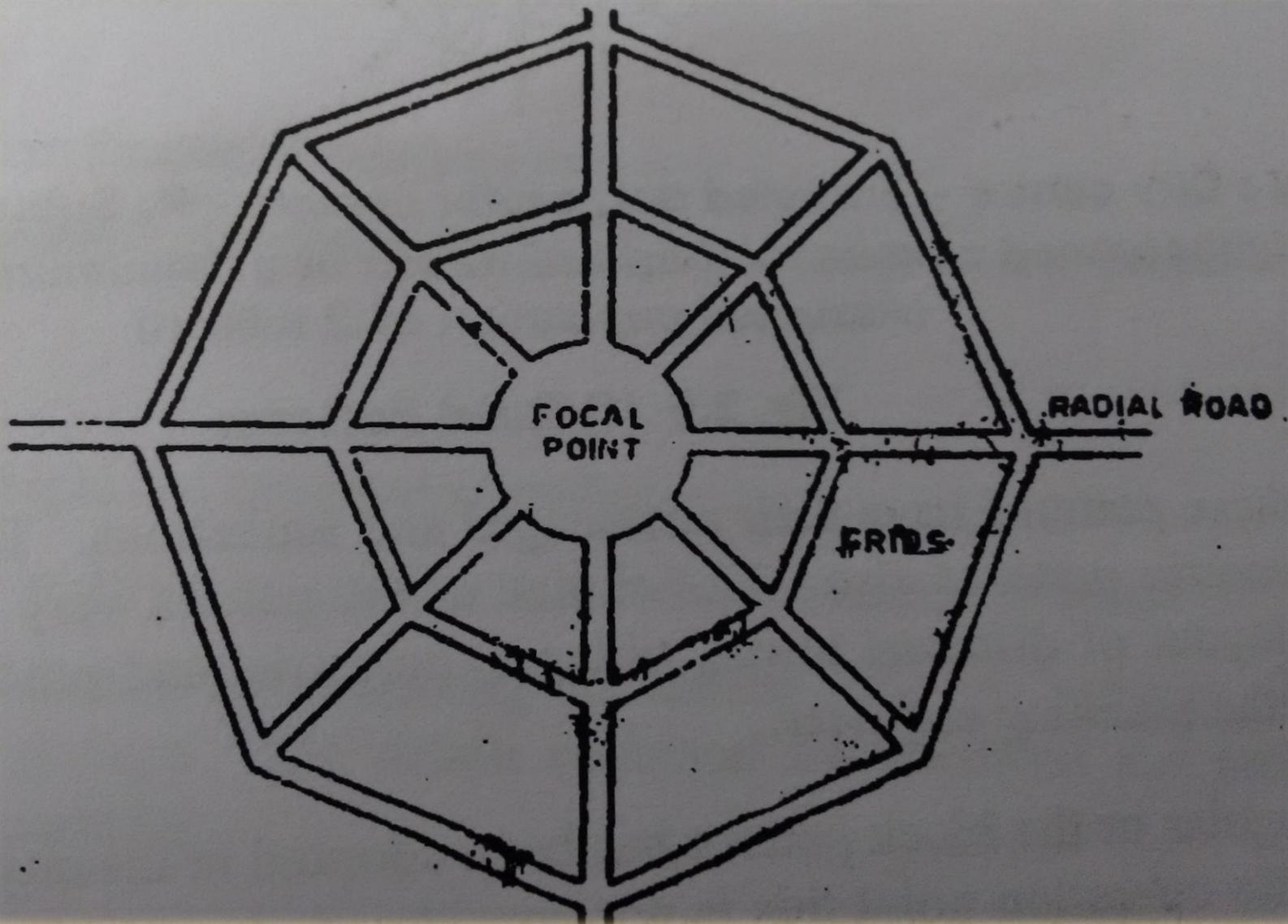
Radial or Star and Block Pattern



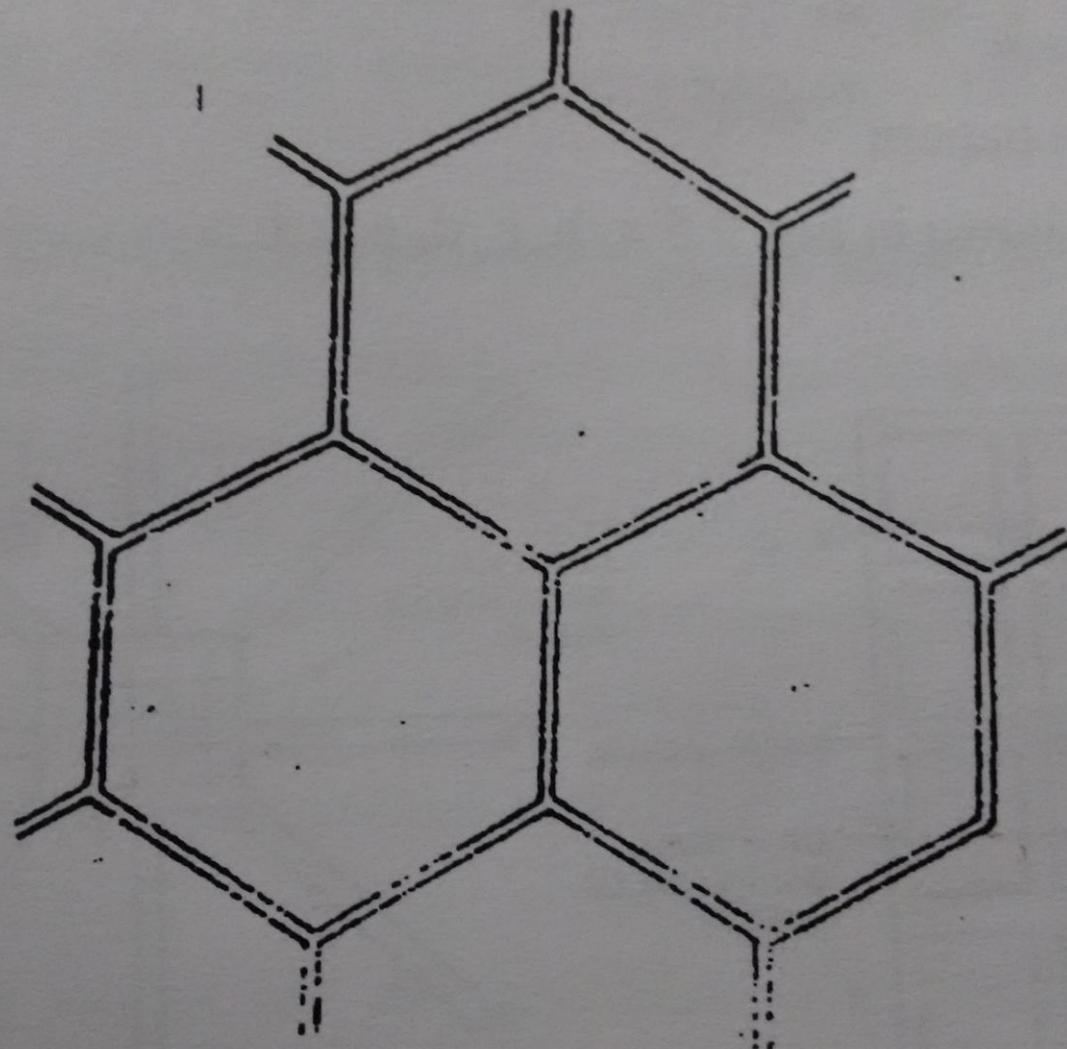
© Jeffrey Milstein/REX



Radial or Star and Circular Pattern



Radial or Star and Grid Pattern



Hexagonal Pattern



Connaught place, New Delhi

- Each of these road patterns have their advantages and limitations.
- There can be a number of other geometric patterns also.
- It depends upon locality, layout of towns, villages , industrial areas, production centers and Engineer.
- The rectangular or block pattern has been adopted in city roads of Chandigarh.
- The radial and circular pattern is the road network of Connaught Place in New Delhi.

Planning Surveys

Highway planning phase includes,

1. Assessment of road length requirement for an area
(It may be a district, state or the whole country)
2. Preparation of master plan showing the phasing of plan in annual and or five year plans.

Field surveys required for collecting the factual data may be called as planning surveys or fact finding surveys.

Planning surveys consists of following studies,

1. Economic studies
2. Financial studies

3. Traffic or road use studies

4. Engineering studies

1. **Economic studies**

- a. Population and its distribution in each village, town, or other locality with area classified in groups
- b. Trend of population growth
- c. Agricultural and industrial developments
- d. Existing facilities with regard to communication, recreation and education
- e. Per capita income.

2. Financial Studies

- a. Sources of income and estimated revenue from taxation on road transport
- b. Living standards
- c. Resources at local level, toll taxes, vehicle registration and fines
- d. Future trends in financial aspects

3. Traffic or Road studies

- a. Traffic volume in vehicles per day
- b. Origin and destination studies
- c. Traffic flow pattern
- d. Mass transport facilities

- e. Accidents, their cost analysis and causes
- f. Future trend and growth in traffic volume and goods traffic etc.,
- g. Growth of passenger trips and the trend in choice of modes.

4. Engineering studies

- a. Topographic surveys
- b. Soil surveys
- c. Location and classification of existing roads
- d. Estimation of possible developments in all aspects due to the proposed highway development.

Preparation of plans

Details during the planning surveys are tabulated and plotted on the maps of the area under planning.

Usually following drawings are prepared

Plan 1: general area plan showing existing details and cross drainage structures

Plan 2: plan showing the distribution of population groups

Plan 3: plan showing the locations of places with their respective productivity

Plan 4: plan showing existing road network with traffic flows

Preparation of master plan

- Master is the final road development plan for the study area which may block , taluk , district , state level.
- Based on the master plan different possible network of new roads and improvement of some of the existing roads are proposed.
- Some target length has been fixed for the country on the basis of area or population and productivity
- Target road length is fixed in 20 year road plan

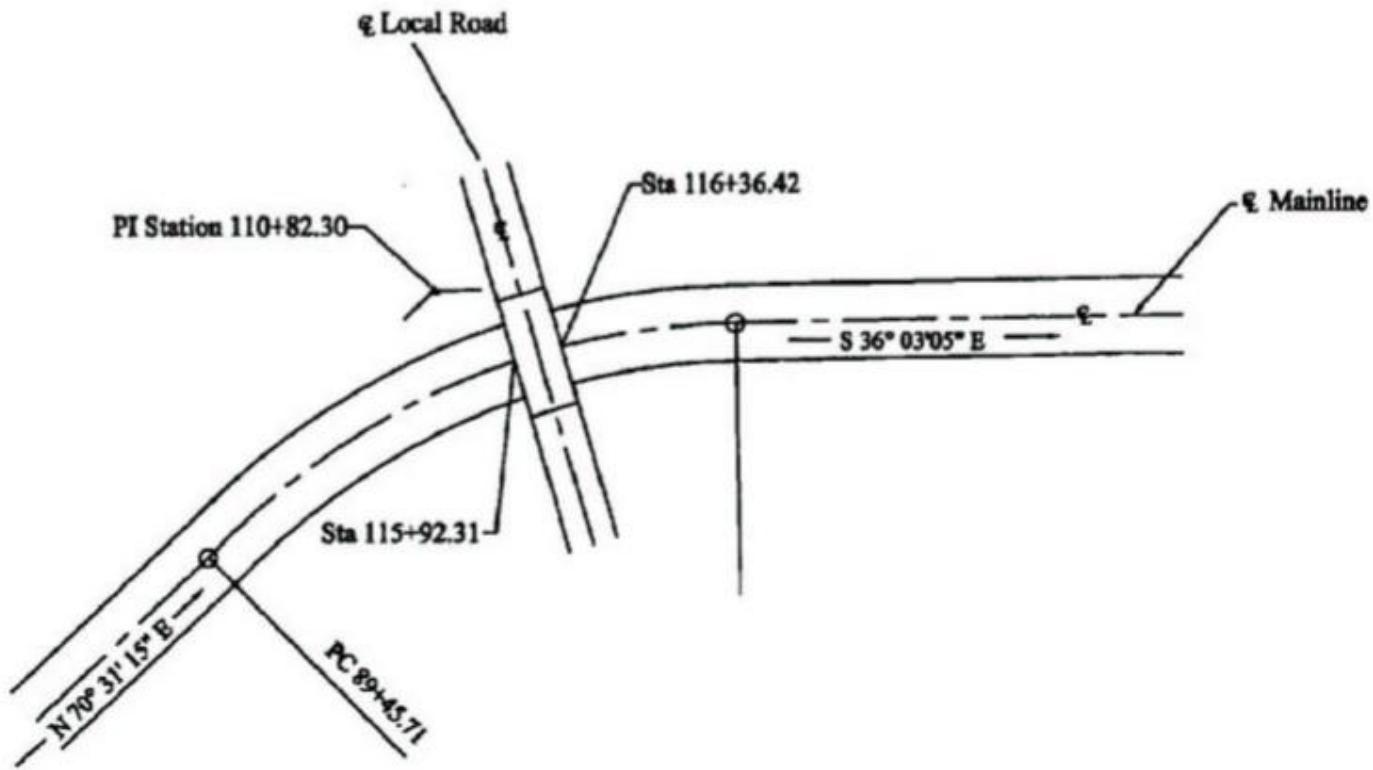
Saturation System

- In this system the optimum road length is calculated for a area , based on the concept of obtaining maximum utility per unit length of road .hence it is called as maximum utility system
- Factors to be considered for obtaining the utility per unit length
 1. Population served by road network
 2. Productivity served by network

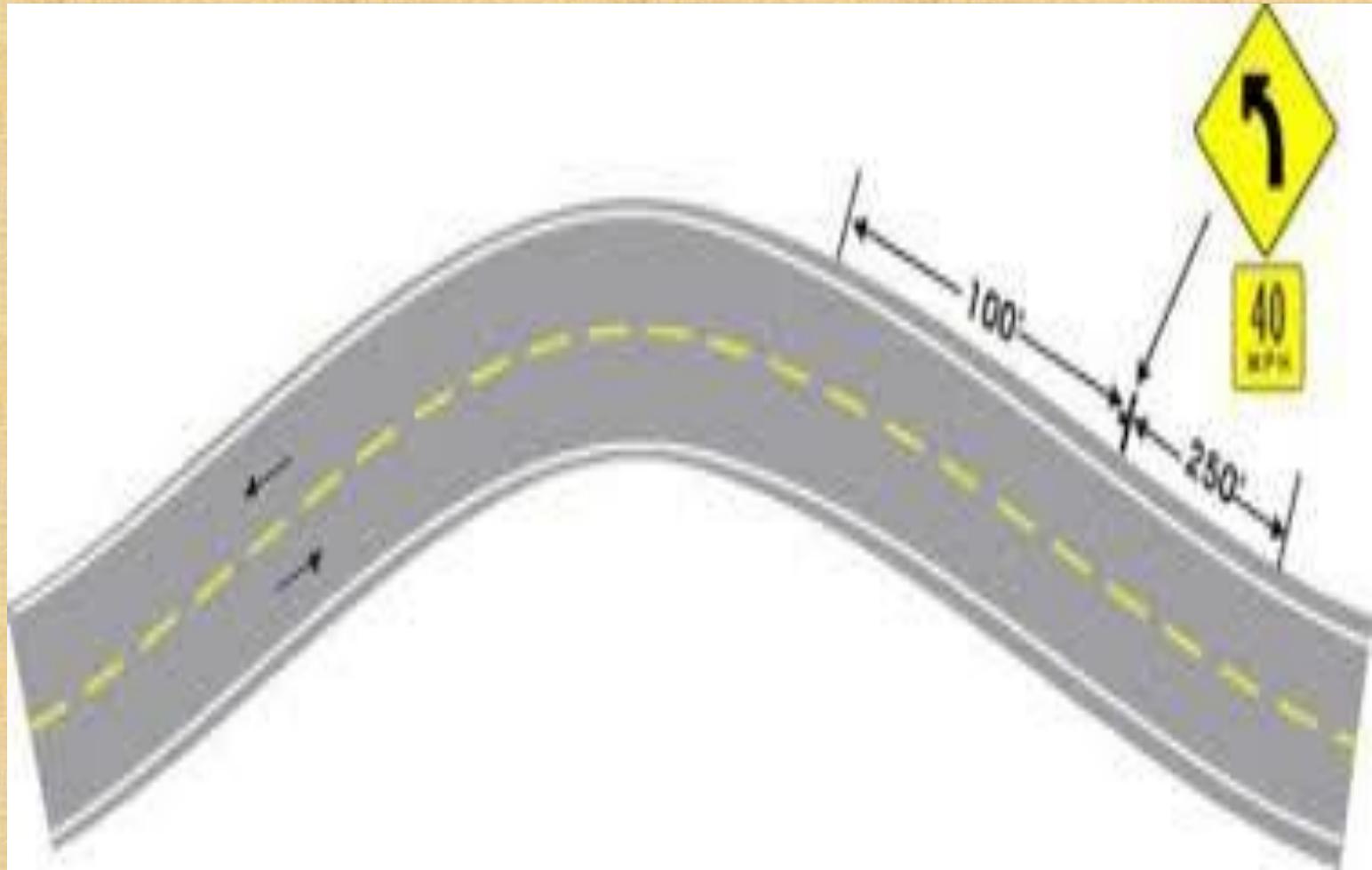
Road alignment

- The position or the layout of the centreline of the highway on the ground is called the alignment . Highway alignment includes both horizontal and vertical alignments of the roadway .

Horizontal alignment



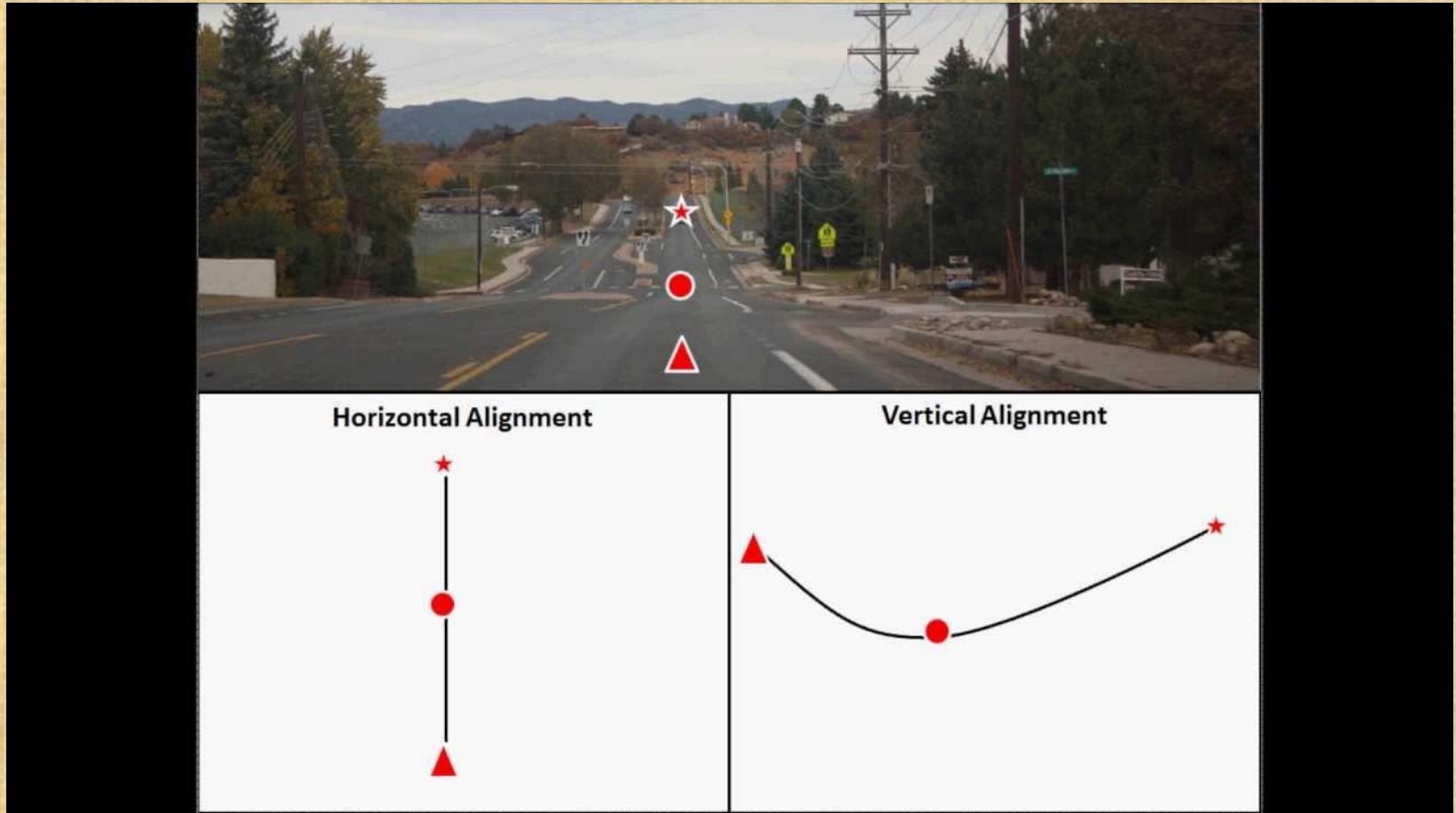
Horizontal alignment



Vertical alignment



Comparison



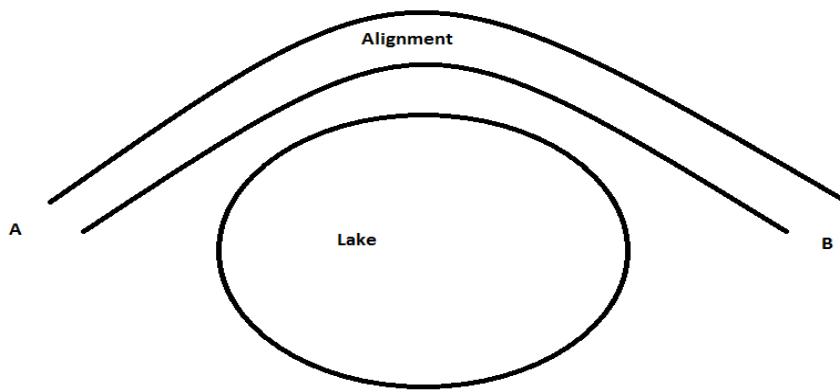
Factors affecting the alignment

Various factor affecting the alignment are

- Obligatory points
- Traffic
- Geometric design
- Economics
- Other considerations

Obligatory points

- Broadly divided into two categories
- Points through which the alignment is to pass
- Points through which the alignment should not pass



Traffic

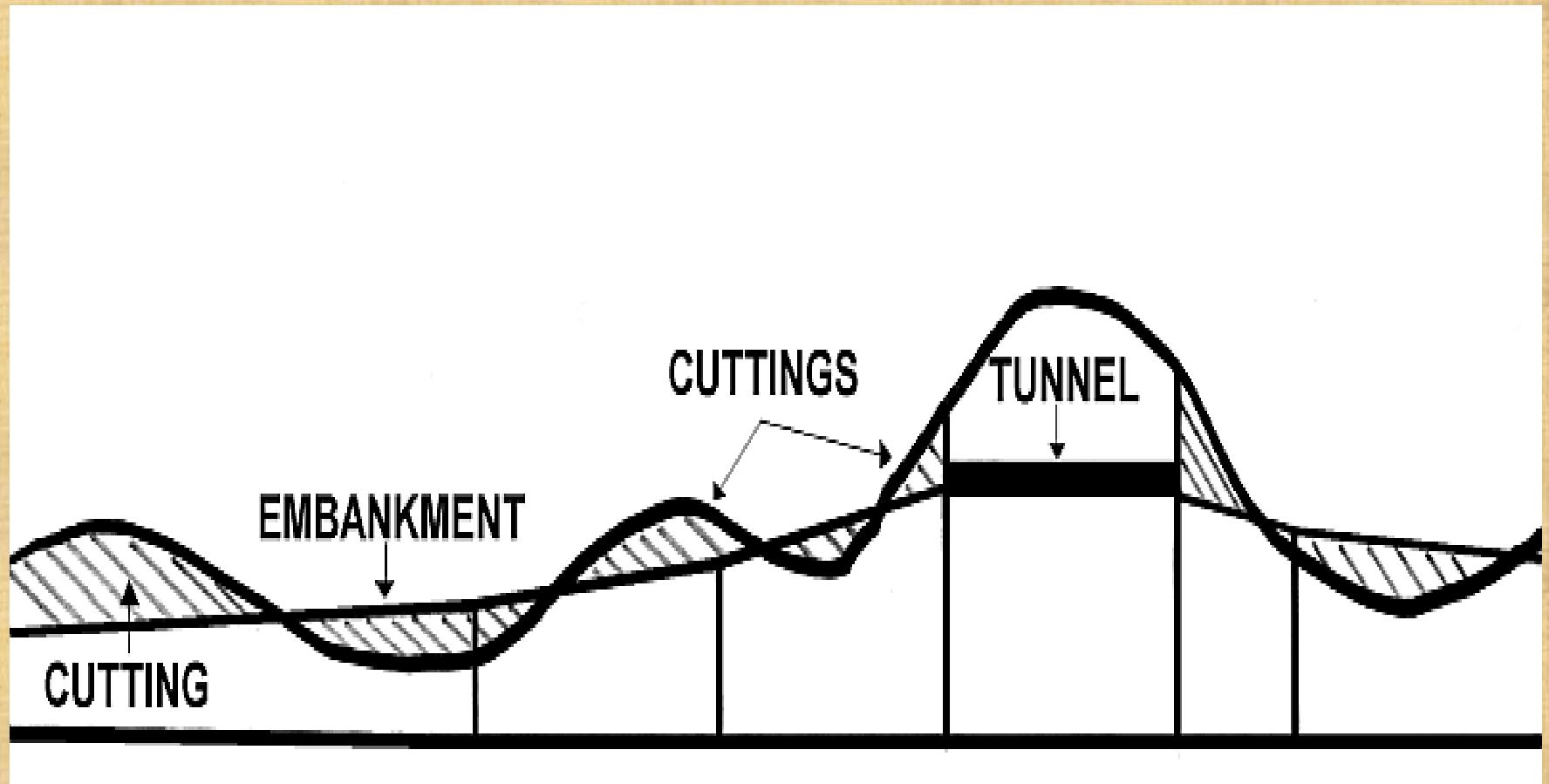
- The road alignment should be decided based on the requirements of road traffic .
- Origin and destination study should be carried out in the area and the desire lines be drawn showing the trend of traffic flow .
- The new road should keep in view of classified traffic volume their growth and future trends

Geometric Design

Geometric design factors are

1. Gradient
2. Radius of curve
3. Sight distance

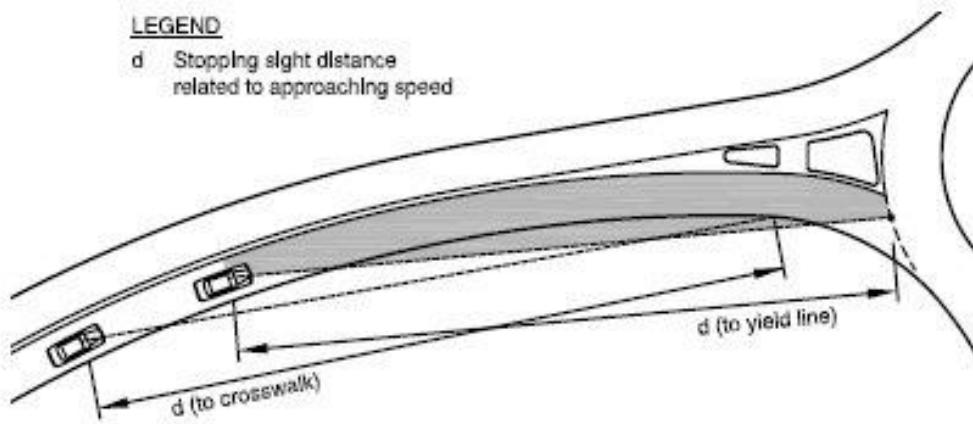
Gradient



Sight Distance

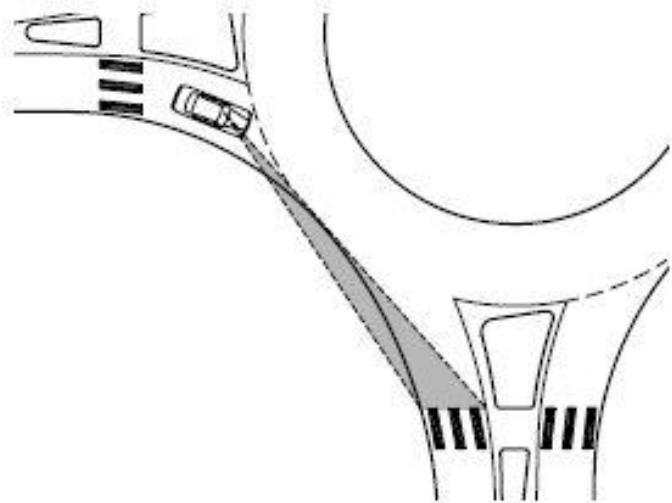
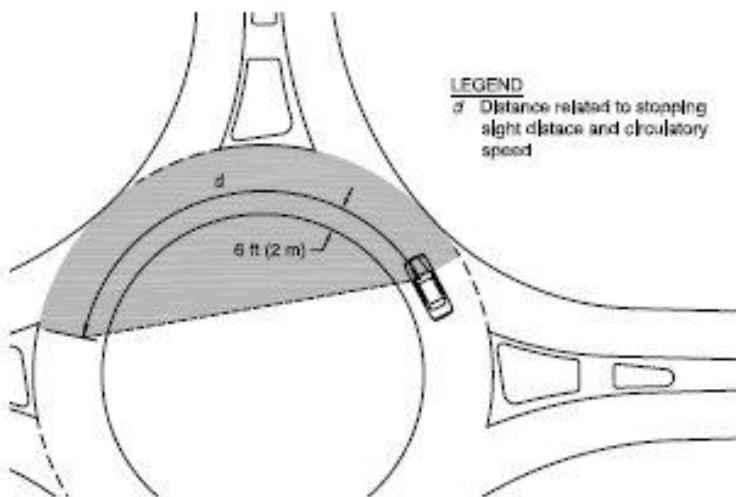
LEGEND

d Stopping sight distance
related to approaching speed



LEGEND

d' Distance related to stopping
sight distance and circulatory
speed



Economics and other considerations

1. Initial construction cost of the road
2. Regular and periodic maintenance cost of the road
3. Vehicle operation cost in future years
4. Drainage factor
5. Monotony factor

Alignment of road on hilly areas

Factors to be considered are

- Stability of hill side slopes
- Drainage of surface and sub surface water flowing from hill side
- Special geometric standard for hill road
- Resisting length

Hill road



Engineering surveys for new Highway alignment

Stages of engineering surveys

1. Map study
2. Reconnaissance study
3. Preliminary surveys
4. Final location and detailed surveys