Highway and Traffic Engineering

Course Outline

- ***Introduction to Road Systems:*** Location Survey in Rural and Urban Areas; Urban Location Controls; Highway Planning. Roads in Hilly Areas
- ***Highway Engineering:*** Highway Components, Elements of a typical cross-section of road. Types of cross-section; Highway location; Classification of Highways; Highway Materials, Types & Characteristics, Specifications & tests, Introduction to resilient behavior
- ***Geometric Design:*** Design controls and criteria; Sight distance requirements; Horizontal curves; Super elevation; Transition curve; Curve widening; Grade line; Vertical curves
- ***Pavement Design:*** Types of pavements. Wheel loads. Equivalent single axle load, Repetition and impact factors. Load distribution characteristics; Design of flexible and rigid pavements, Highway drainage, Pavement failures, Introduction to non-destructive testing, Pavement evaluation; Construction, Maintenance and rehabilitation

Tests, Exams & Graded Marks

- Mid Term Exam = 30 marks
- Final Term Exam = 50 marks
- Quizzes and Assignments = 10 marks
- Mini Project/Presentation = 10 marks

Recommended Books

- Traffic and Highway Engineering 4th Edition by Nicholas J. Garber, Lester A. Hoel
- Introduction to Transportation Engineering 2nd Edition by James H. Banks

Transportation Engineering

- Transportation engineering or transport 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.

Modes of Transportation

- Transport modes are the means by which passengers and freight achieve access and mobility between origin and destination. They fall into one of three basic categories depending over what median is used to travel upon.

1. Land (road, rail and pipelines)
2. Water (shipping)
3. Air (Aircrafts)

Modes of Transportation

- **Highways**

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

- **Railways**

  Passenger and Goods (Freight trains)

- **Airways**

  Aircraft, Helicopters & Hot-air balloon

- **Waterways**

  Ships, boats, submarine… etc.

- **Continuous Flow systems**

  Pipelines, belts, elevator, ropeway…etc.

Modes of Transportation

- **Airways**
  i. Fastest among all other modes
  ii. More comfortable
  iii. Time saving
  iv. Uneconomical
- **Waterways**
  i. Slowest among all other modes
  ii. It needs minimum energy to drag unit load through unit distance.
  iii. This can be possible between ports on the sea routes or along the river
  iv. Economical

Modes of Transportation

- **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 drag a unit load through unit distance by the railway is only $^1/_4$ to $^1/_5$ of that required by road
- Safety (minimum crash rate if handled carefully else sever crash can occur)

Modes of Transportation

- **Highways**

- It gives the maximum service to one and all
- It gives maximum flexibility for travel with reference to route choice, direction, time and traveling speed.
- 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 engines
- It saves the time for short distance
- High degree of accident due to flexibility of movement

Highway Engineering

- Highway engineering is an engineering discipline that involves the planning, design, construction, operation, and maintenance of roads, bridges, and tunnels to ensure safe and effective transportation of people and goods.

Historical Development of Road Construction

Old Roman Roads 500 BC (Stone Dumping)

Historical Development of Road Construction

Modern Road (Asphalt Roads)

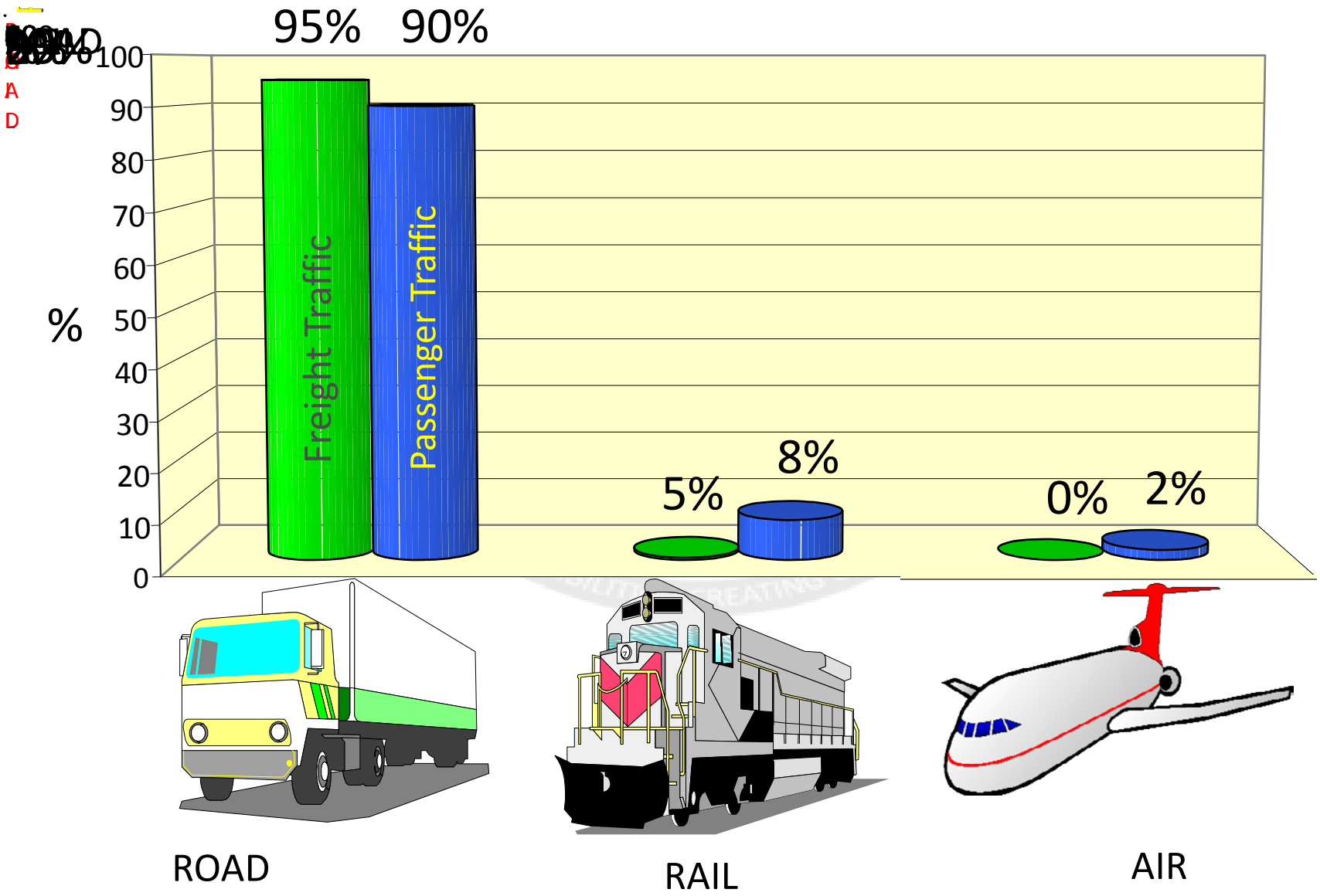
TRANSPORTATION SECTOR

- Accounts for 12 % of GDP
- Growth rate Freight – 3%
- Growth rate Passenger – 4.5%

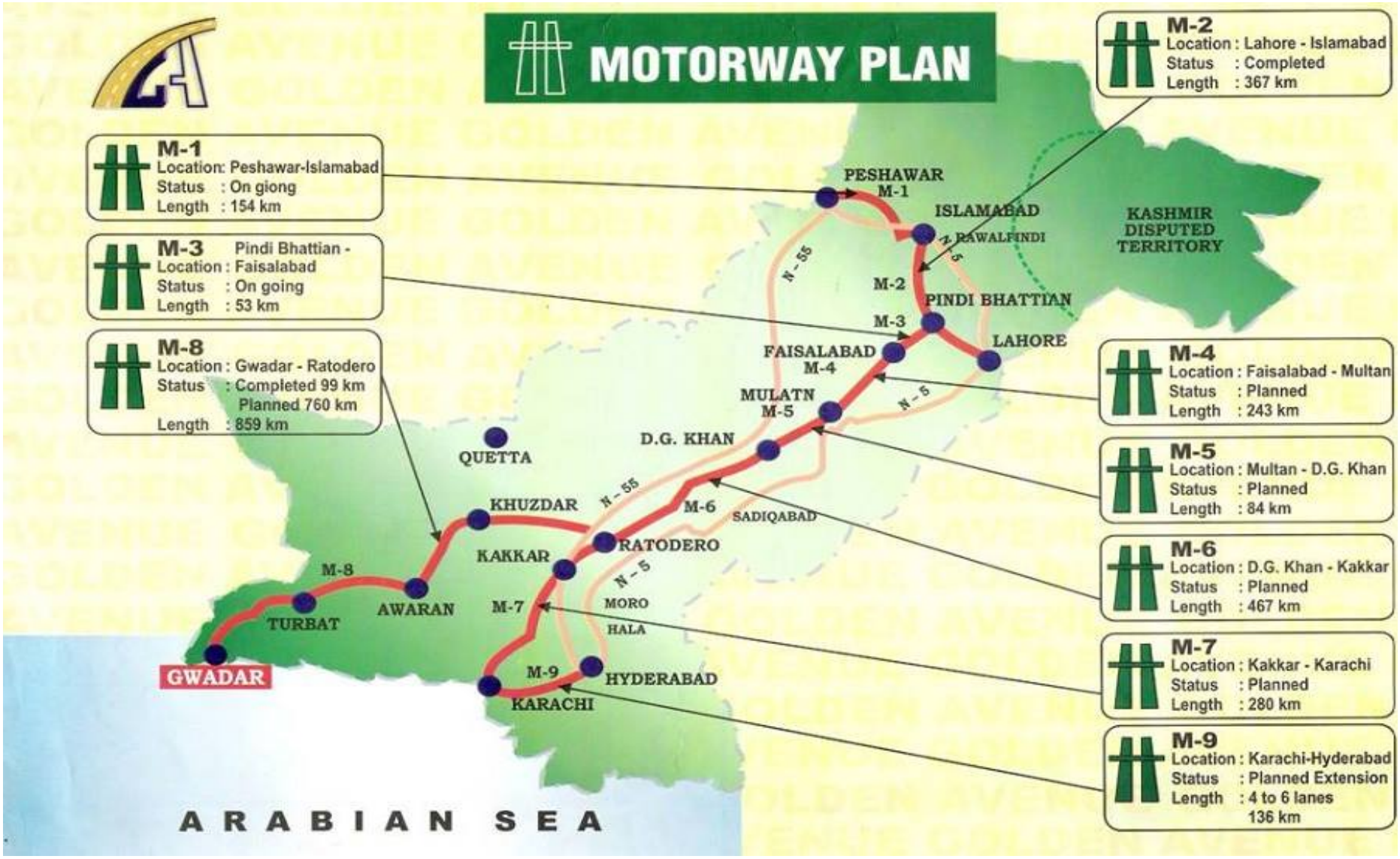
Road Sector Accounts for:

- Passenger Traffic – 90%
- Freight Traffic – 95%

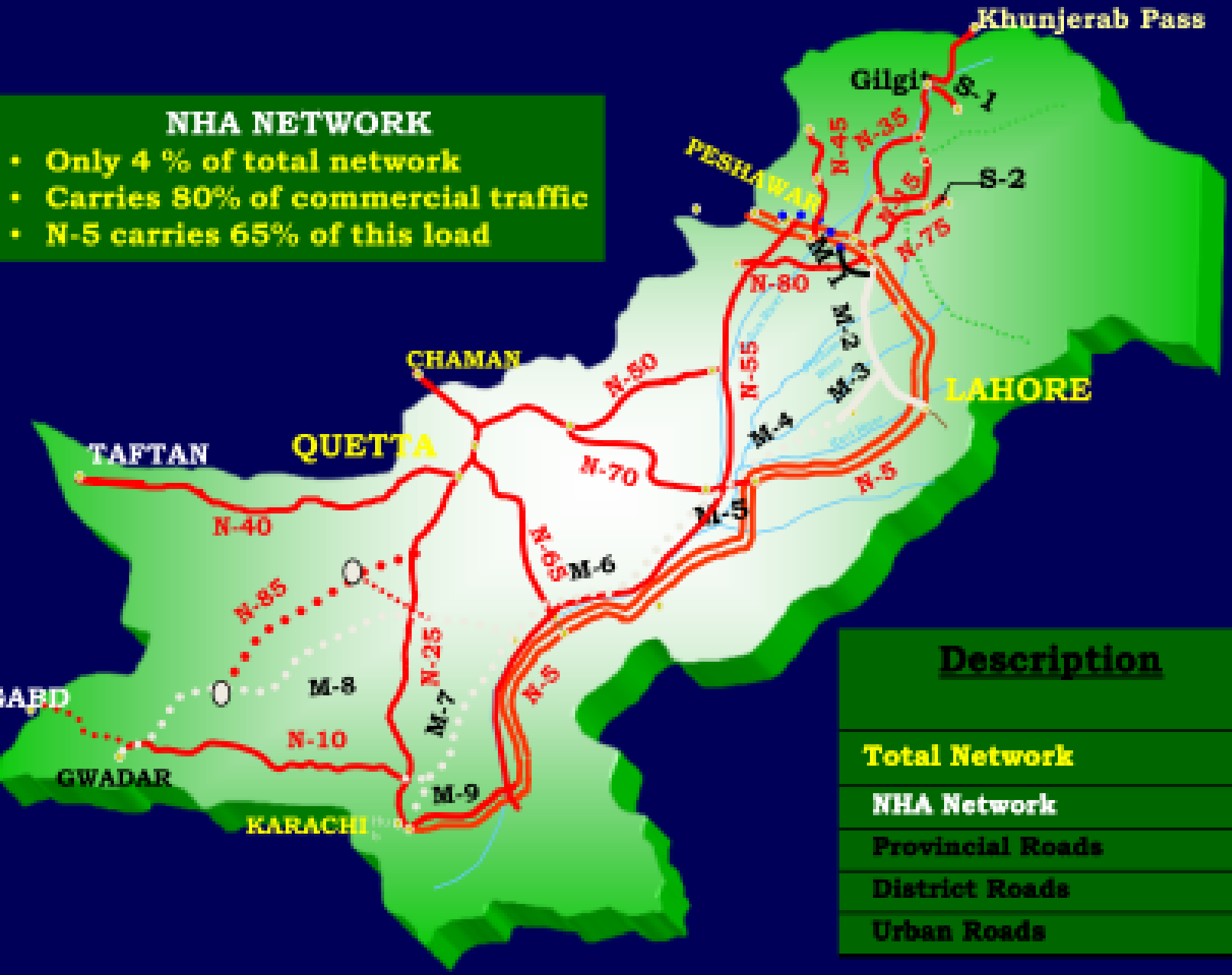
Passenger Transport in Pakistan



Motorway Plan of Pakistan



NATIONAL HIGHWAY NETWORK



NHA NETWORK

- Only 4 % of total network
- Carries 80% of commercial traffic
- N-5 carries 65% of this load

Description	Km
Total Network	260,000
NHA Network	11,900
Provincial Roads	101,000
District Roads	94,150
Urban Roads	54,000

National Highways Authority

- The National Highway Authority (NHA) was established, in 1991.
- NHA is responsible of 39 national highways / motorways / expressway / strategic routes
- N-5 which is blood-line of Pakistan, carries 65% of this load in the country.

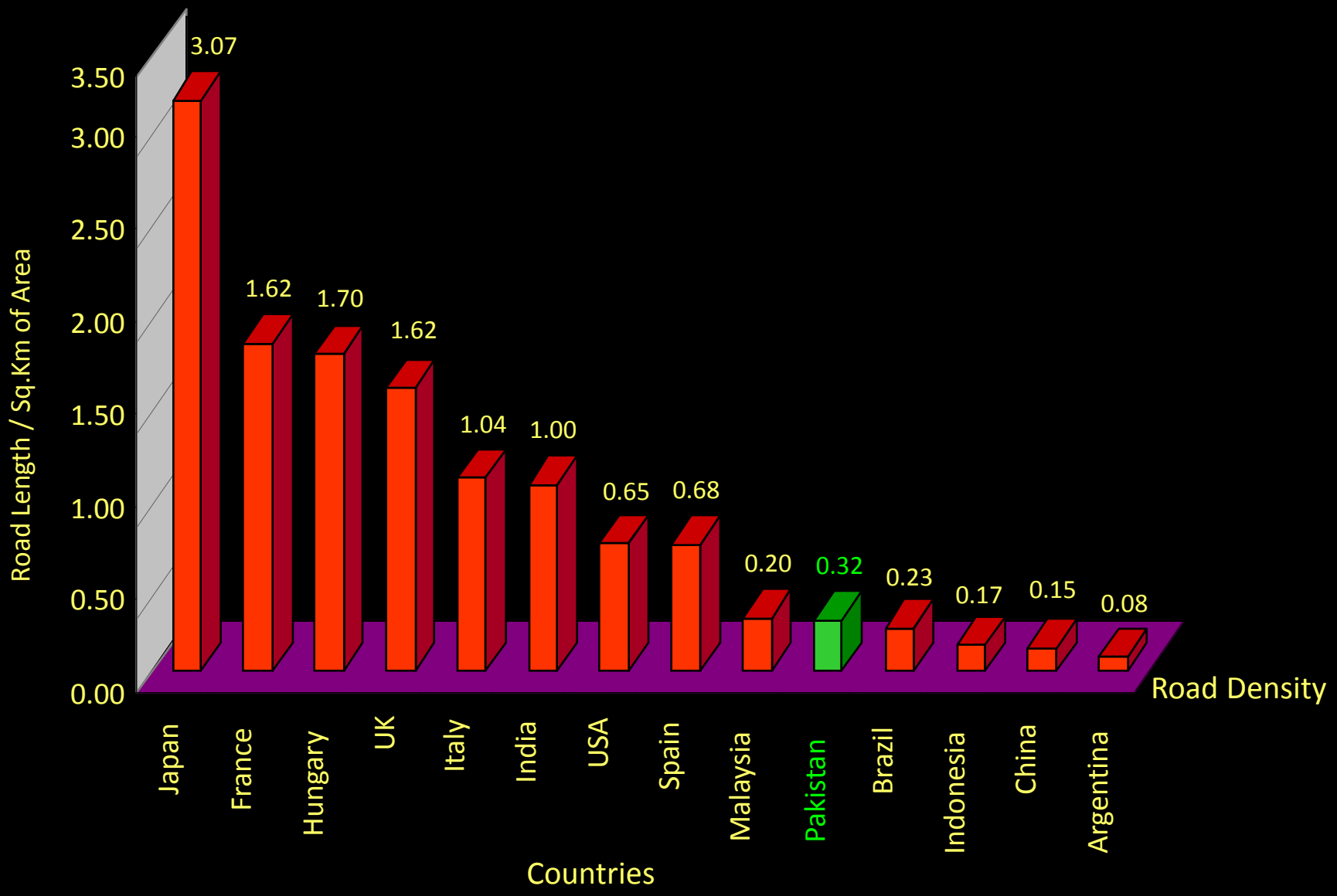
NATIONAL HIGHWAYS OF PAKISTAN

- N-5 Karachi – Peshawar 1819 Km
- N-10 Liari – Gwadar 653 Km
- N-15 Mansehra – Naran 240 Km
- N-25 Karachi – Quetta 813 Km
- N-35 HasanAbdal – Khunjrab 806 Km
- N-40 Lakpass – Taftan 610 Km
- N-45 Nowshera – Chitral 309 Km
- N-50 Kuchlak – DI Khan 531 Km
- N-55 Kotri – Peshawar 1264 Km
- N-65 Sukkar – Quetta 385 Km
- N-70 QilasaifUlah – Multan 447 Km

Transportation Sector

Description	Unit	1947	2017
Total Roads	Km	50,367	260,000 +
Regd Vehicles	No	21,209	7,000,000 +
Motorways	Km	Nil	679.5
Highways	Km	Nil	11321
Density	Km/Km^2	0.06	0.32

ROAD DENSITY COMPARISON



Functional Classification of Roads

- **Functional classification** is the process by which streets and highways are grouped into classes, or systems, according to the character of traffic service that they are intended to provide.
- The classification based on ***mobility and accessibility*** is the most generic one
- As the accessibility of road increases, the mobility reduces
- Accordingly, the roads can be classified in the order of increased accessibility and reduced mobility.

Functional Classification of Roads

- **Freeways:** A freeway may be defined as a divided highway with full *control of access* and two or more lanes for the exclusive use of traffic in either directions and are designed for *high speed limits*. Most freeways are four lanes, two lanes each direction, but many freeways widen to incorporate more lanes as they enter urban areas. ***Access is controlled through the use of interchanges*** (Motorway)
- **Expressways:** They are superior type of highways and are designed for high speeds (120 km/hr is common), high traffic volume and safety. They are generally provided with grade separations at intersections. Parking, loading and unloading of goods and pedestrian traffic is not allowed on expressways (Islamabad Expressway)

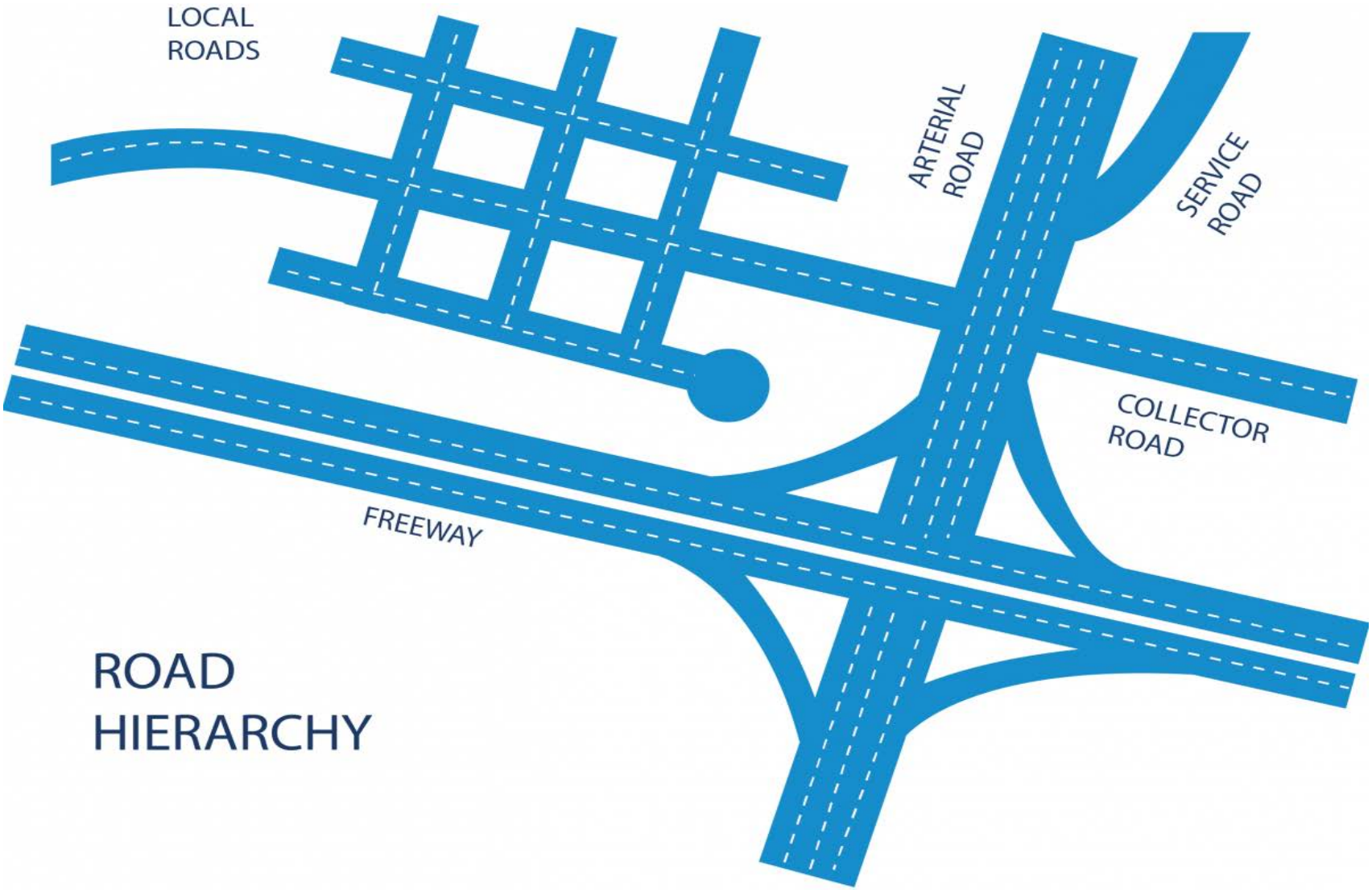
Functional Classification of Roads

- **Highways:** They represent the superior type of roads in the country. Highways are of two types – rural highways and urban highways. Rural highways are those passing through rural areas (country side) and urban highways are those passing through large cities and towns, ie. urban areas. Highways are designed for speeds less than freeways and expressways (less mobility, 80km/hr.) and with partially controlled access. (N5 - GT Road)
- **Arterials:** It is a general term denoting a street primarily meant for through traffic usually on a continuous route. They are generally divided highways with partially controlled access and safe speed of about 70km/hr. Parking, loading and unloading activities are usually restricted and regulated. Pedestrians are allowed to cross only at intersections/designated pedestrian crossings. (Ring Road)

Functional Classification of Roads

- **Collector streets:** These are streets intended for collecting and distributing traffic to and from local streets and also for providing access to arterial streets. Normally full access is provided on these streets. There are few parking restrictions except during peak hours. They are designed for speeds of 50km/hr.
- **Local streets:** A local street is the one which is primarily intended for access to residence, business or abutting property. It does not normally carry large volume of traffic and also it allows unrestricted parking and pedestrian movements. Local streets are designed for speeds with 30km/hr. - 40km/hr.

Road Hierarchy



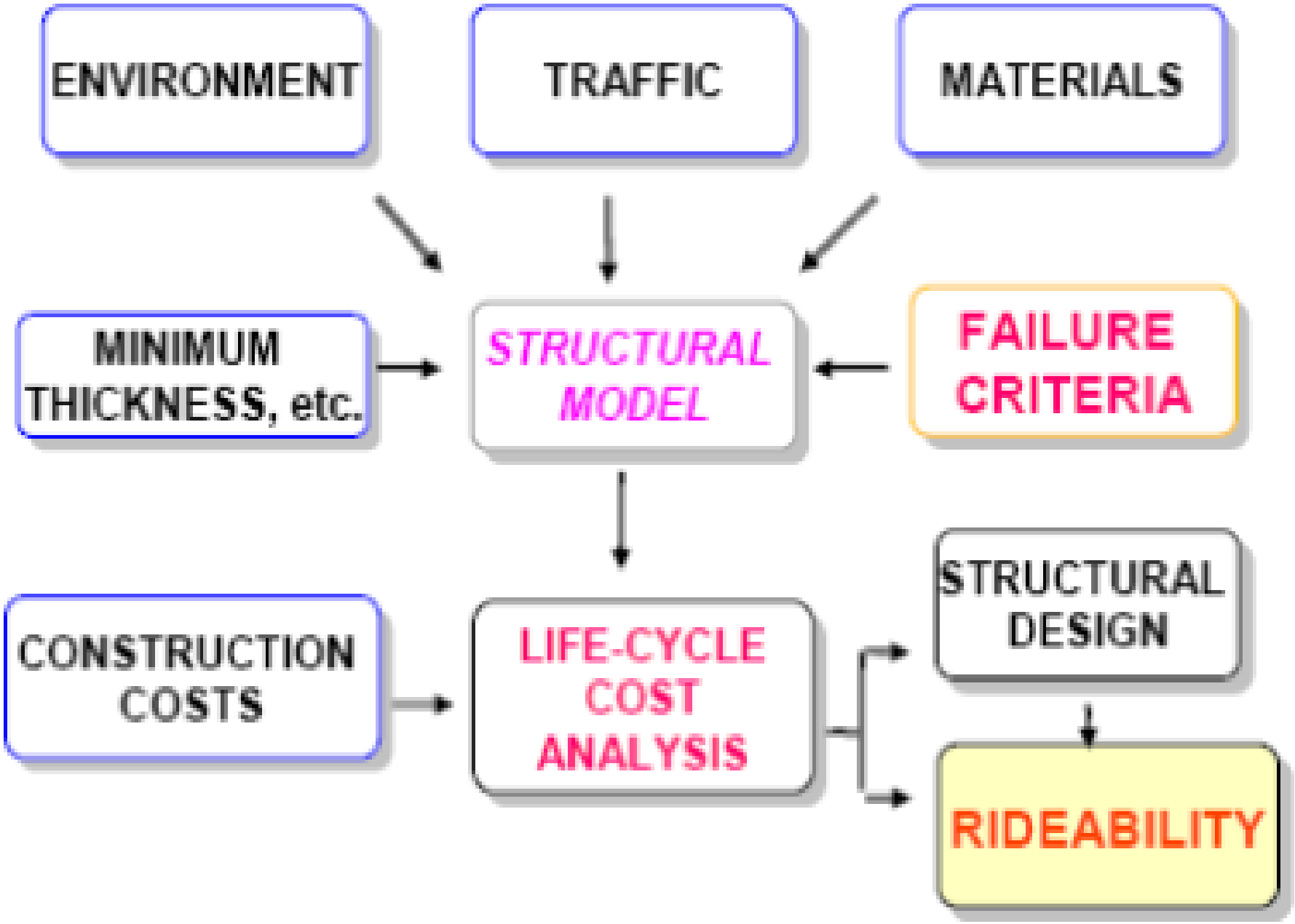
PAVEMENT DESIGN

- Structural Design (Thickness Design)

  Pavements are design for carrying structural loads the objective is to find the thickness of different layers and material types.

- Geometric Design (Functional Design)

  Design consists of congestion free and safe traffic flow the objective is to find overall road width, and curve radius


ENVIRONMENT
TRAFFIC
MATERIALS
MINIMUM THICKNESS, etc.
STRUCTURAL MODEL
FAILURE CRITERIA
CONSTRUCTION COSTS
LIFE-CYCLE COST ANALYSIS
STRUCTURAL DESIGN
RIDEABILITY

PAVEMENT TYPES

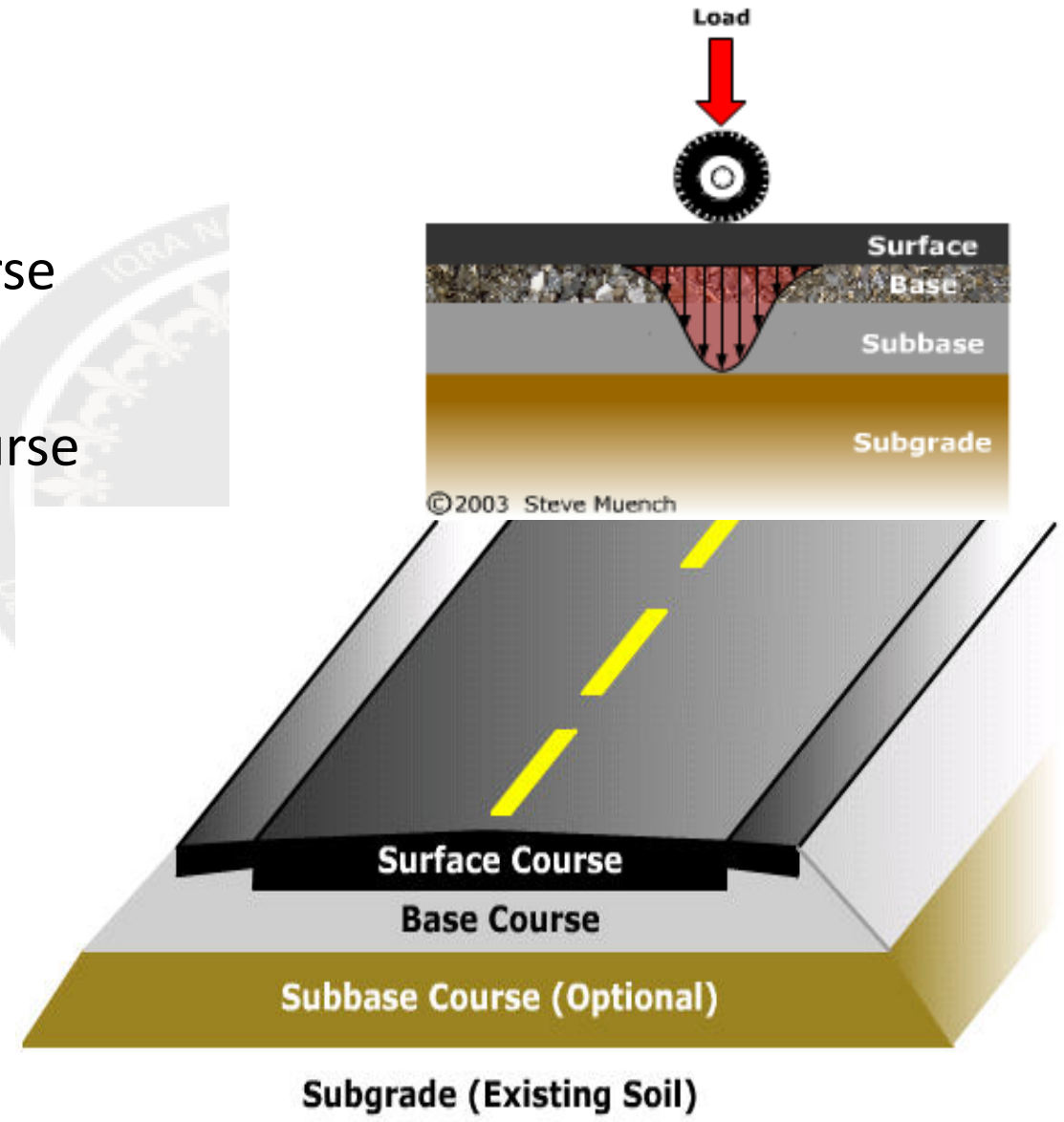
- Flexible Pavements
- Rigid Pavements

FLEXIBLE PAVEMENT

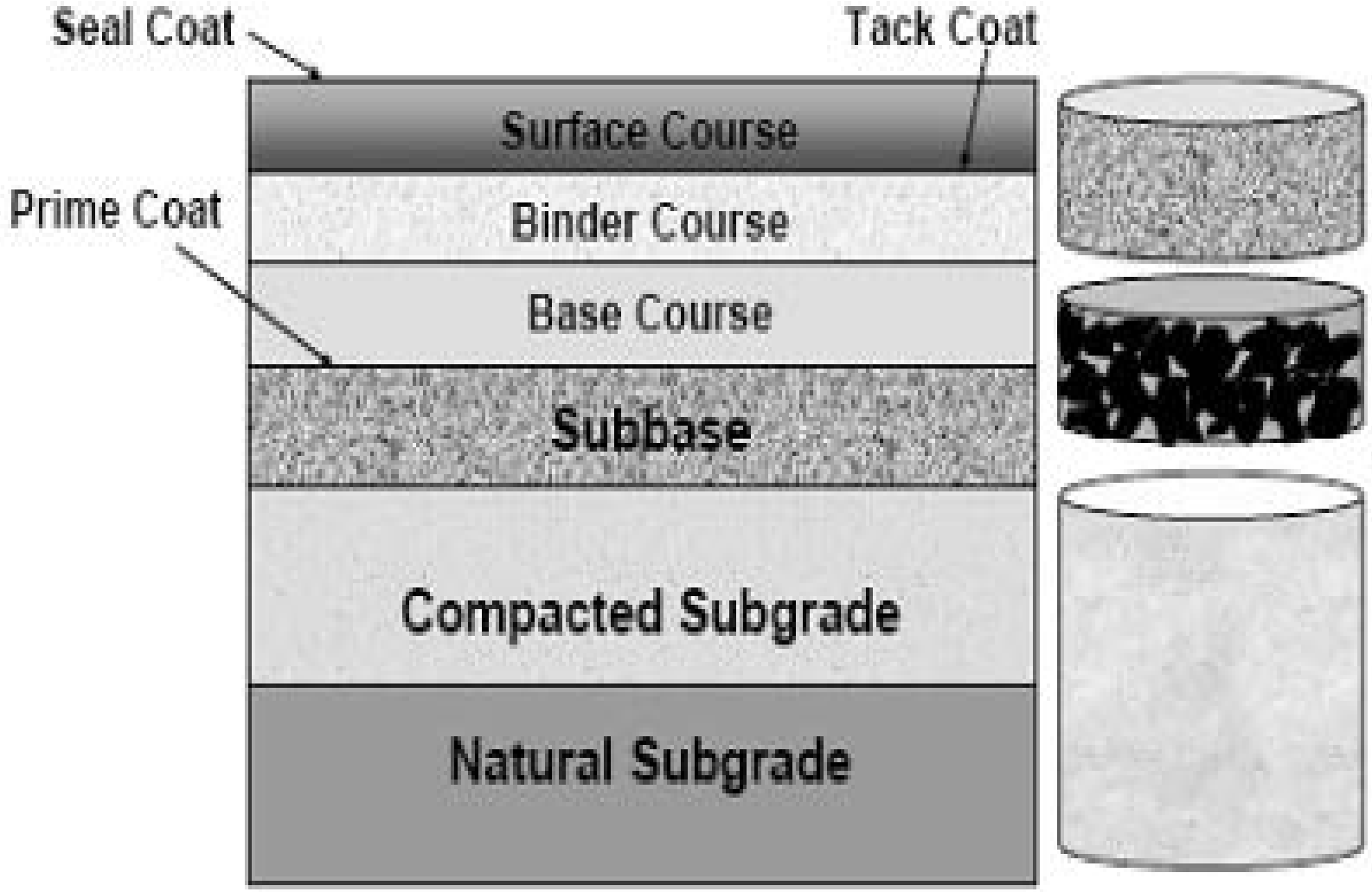
- Based on Structural Response flexible pavements normally use asphaltic concrete (AC) as the surface, and sometimes underlying layers.
- Flexible pavements are made of a series of layers with the strongest material layers at or near the surface.
- The load-carrying capacity of flexible pavements is brought about by the load-distributing characteristics of the layered system, thereby, distributing the load over the subgrade, rather than by the bending action of the slab.

FLEXIBLE PAVEMENT

- Structure
  - Surface course
  - Base course
  - Subbase course
  - Subgrade



COMPONENTS OF FLEXIBLE PAVEMENT



RIGID PAVEMENT

- Rigid pavements are made up of Portland Cement Concrete and may or may not have a base course between the pavement and the subgrade.
- The rigid pavement, because of its rigidity and high modulus of elasticity, tends to distribute the load over a relatively wide area of soil; thus, a major portion of the structure capacity is supplied by the slab itself.

RIGID PAVEMENT

- The major factor considered for the design of rigid pavements is the structural strength of concrete. Minor variations in the subgrade strength have little influence on the structural Capacity of Concrete Pavements.
- Base course are provided under rigid pavements for various reasons:

1.Control of Pumping 2.Control of Frost Action

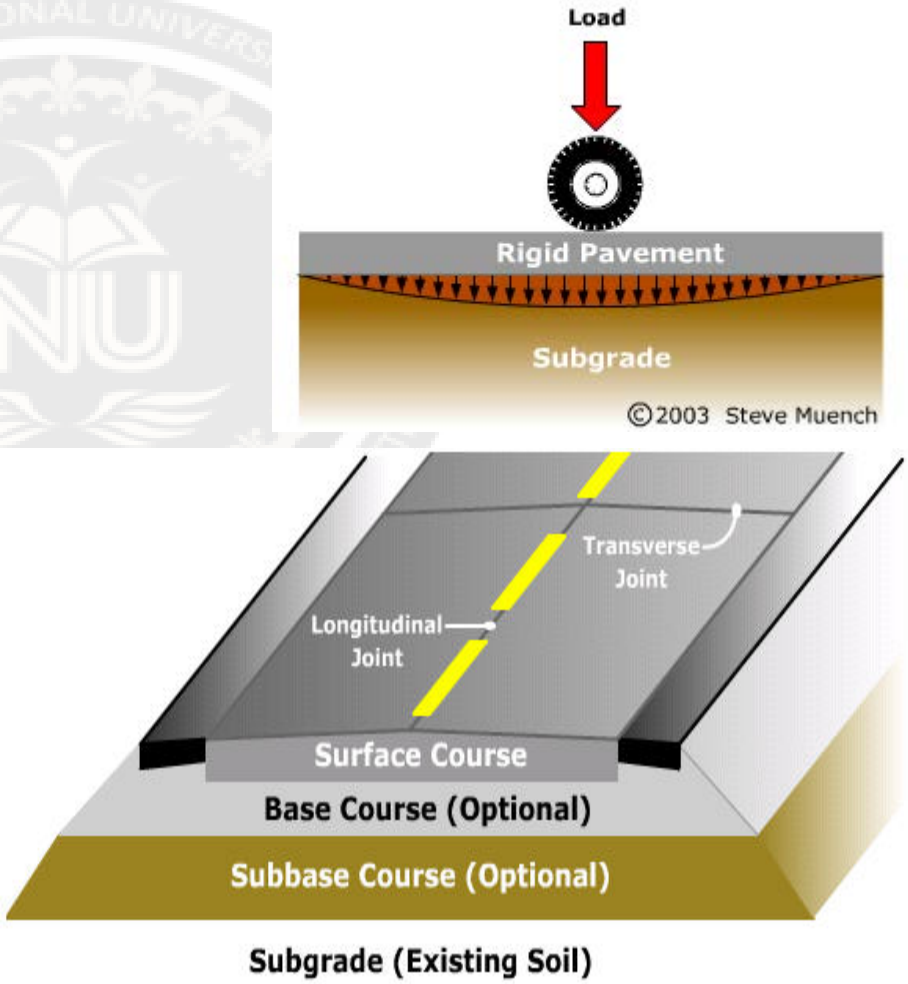
3.Drainage 3.Control of Shrinkage & Swell potential of the subgrade 4.Construction facilitation

RIGID PAVEMENT

- Provision of Base/Subbase Course lends some structural capacity to the pavement. However, its contribution to the load carrying capacity may be relatively minor.
- Load Carrying Capacity of rigid pavements is due to BENDING of slabs.

RIGID PAVEMENT

- Structure
  - Surface course
  - Base course
  - Subbase course
  - Subgrade



HIGHWAY AND AIRFIELD PAVEMENTS

- Highways are generally 24 feet wide
- Runways are 150 feet wide
- Taxiways 75 feet wide
- Runways are always crowned, whereas, highways may or may not be crowned.
- Taxiways and runway ends are constructed using thicker section than the central portion, due to high concentration of traffic.

HIGHWAY AND AIRFIELD PAVEMENTS

- Rigid Highways, if without base/subbase layer, due to heavy distresses always show pumping(Removal of material from subgrade).
- Airfield pavements comparatively show less pumping.
- Highways; more distresses at the edge of the pavement.
- Airfield pavements do not show edge distresses.

HIGHWAY AND AIRFIELD PAVEMENTS

- Major difference are repetition of load, distribution of traffic and geometry of pavement.
- For a given wheel load and tire pressure, Highway Pavements are thicker than Airfield Pavements. Due to high repetition of load on highway pavements and due to close application to the edges.
- However, as the gross weight of aircraft is very high with the result that airfield pavements are actually thicker in practice.

FRAMEWORK OF PAVEMENT DESIGN

TYPES of FAILURES

- Structural Failure
- Functional Failure

STRUCTURAL FAILURE

- Collapse or a breakdown of one or more of the pavement components of such magnitude to make the pavement incapable of sustaining loads imposed on the surface.

FUNCTIONAL FAILURE

- May or may not include structural failure, however, the pavement will not carry out its intended function without causing distress and discomfort to passengers or high stresses to the vehicle due to surface roughness.

CAUSES OF FAILURES/DISTRESS

- Overloading
- High load repetitions
- High tire pressure
- Climatic and environmental conditions
- Freeze-Thaw or Dry-Wet

Highway Alignment and Surveys

- Highway location involves the acquisition of data concerning the terrain upon which the road will traverse and the economical siting of an alignment
- Important factors needing consideration: earthwork, geologic conditions, and land use
- Geometric design principles are used to establish the horizontal and vertical alignment, including consideration of the driver, the vehicle, and roadway characteristics
- Design of parking and terminal facilities must be considered as they form an integral part of the total system
- Since the new highway will alter existing patterns of surface and subsurface flow, thus careful attention to the design of drainage facilities is required

Highway Alignment and Surveys

- Roadway elements such as curvature and grade must blend with each other to produce a system that provides for the easy flow of traffic at the design capacity, while meeting design criteria and safety standards
- The highway should cause a minimal disruption to historic and archeological sites and to other land-use activities
- Environmental impact studies are therefore required in most cases before a highway location is finally agreed upon

Highway Alignment and Surveys

- The position or lay out of centerline of the highway on the ground is called the alignment.
- It includes straight path, horizontal deviation and curves.
- Due to improper alignment ,the disadvantages are,
  - ❖ Increase in construction
  - ❖ Increase in maintenance cost
  - ❖ Increase in vehicle operation cost
  - ❖ Increase in accident cost
- 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 structure.

Highway Alignment and Surveys

Highway Alignment and Surveys

Highway Alignment and Surveys

Requirements of Highway Alignment

- Short
- Easy
- Safe
- Economical

- **Short:** Desirable to have a short alignment between two terminal stations.
- **Easy:** Easy to construct and maintain the road with minimum problem also easy for operation of vehicle.
- **Safe:** Safe enough for construction and maintenance from the view point of stability of natural hill slope, embankment and cut slope also safe for traffic operation.
- **Economical:** Total cost including initial cost, maintenance cost and vehicle operation cost should be minimum

Factors Controlling Highway Alignment

- **Factors Controlling Alignment**
  - ✓ Obligatory points
  - ✓ Traffic
  - ✓ Geometric design
  - ✓ Economics
  - ✓ Other considerations
- **Additional Care in Hill Roads**
  - ✓ Stability
  - ✓ Drainage
  - ✓ Geometric standards of hill roads

Factors Controlling Highway Alignment

- **Obligatory Points**

  Obligatory points through which alignment is to pass

  ✓ Examples:-bridge site, intermediate town etc.…

  Obligatory points through which alignment should not pass.

  ✓ Examples:-religious places, costly structure, unsuitable land etc.…

- **Traffic**

  - Origin and destination survey should be carried out in the area and the desire lines be drawn showing the trend of traffic flow.
  - New road to be aligned should keep in view the desired lines, traffic flow patterns and future trends.

Factors Controlling Highway Alignment

- **Geometric Design**
  - Design factors such as gradient, radius of curve and sight distance also govern the final alignment of the highway.
  - Gradient should be flat and less than the ruling gradient or design gradient.
  - Avoid sudden changes in sight distance, especially near crossings
  - Avoid sharp horizontal curves
  - Avoid road intersections near bend

Factors Controlling Highway Alignment

- **Economy**

  - Alignment finalized based on total cost including initial cost, maintenance cost and vehicle operation cost.

- **Other Consideration**

  - Drainage consideration
  - Political consideration
  - Surface water level, high flood level
  - Environmental consideration

Factors Controlling Highway Alignment

- **Topographical Control Points (Controlling factors in Hilly Areas)**

  - The alignment, where possible should avoid passing through :
    - Marshy (water logged) and low lying land with poor drainage
    - Flood prone areas
    - Unstable hilly features

- **Materials and Constructional Features**

  - Deep cutting should be avoided
  - Earth work is to be balanced; quantities for filling and excavation
  - Alignment should preferably be through better soil area to minimize pavement thickness
  - Location may be near sources of embankment and pavement materials

Factors Controlling Highway Alignment

- **Stability**
  - A common problem in hilly roads is land sliding
  - The cutting and filling of the earth to construct the roads on hilly sides causes steepening of existing slope and affect its stability.
- **Drainage**
  - Avoid the cross drainage structure
  - The number of cross drainage structure should be minimum.
- **Geometric Standard of Hilly Road**
  - Gradient, curve and speed
  - Sight distance, radius of curve


Q
A
Answer