

Introduction to Transportation Infrastructure Systems Planning and Design

By

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Transportation System

- A transportation system may be defined as a planned network of elements or physical components that play different roles in the transportation of goods and persons from one place to another.
- The elements or physical components of a transport system are referred to as the facilities.
- A transport system can therefore be considered as consisting of fixed facilities, the flow entities, and control system that permit people and goods to overcome the friction of geographical space efficiently in order to participate in a timely manner in some desired activity.

Fixed Facilities

- The fixed facilities are the physical components of the system that are fixed in space and constitutes the network of links and nodes of the transportation system.
- For example, the links could be roadway segment and railway track and the nodes could be intersections, interchanges, transit terminals, harbours, and airports
- The design of these fixed facilities has traditionally been within the realm of civil engineering.
- The design includes soil and foundation engineering design, structural engineering design, the design of drainage systems, and geometric design, which is concerned with the physical proportioning of the elements of fixed facilities.

Flow Entities

- Flow entities are the units that traverse the fixed facilities. These include people, vehicles, container units, railroad cars, and so on.
- In the case of a road system, the fixed facilities are expected to accommodate a wide variety of vehicle types, ranging from bicycles to large tractor-trailer combinations.

Control System

- The control system consists of vehicular control and flow control. Vehicular control refers to the technological way in which individual vehicles are guided on fixed facilities. Such controls can be manual or automated.
- The proper geometric design of fixed facilities must consider the characteristics of the vehicle and the characteristics of the vehicular control system.
- In the case of highway facilities, where the vehicles are manually controlled, these include driver's characteristics, such as time a driver takes to perceive and react to various stimuli. In the case of automated systems, similar, but more precisely definable response times exist as well.
- The flow control system consists of the means that permit the efficient and smooth operation of streams of vehicles and the reduction of conflicts between vehicles. This system includes various types of signing, marking, and signal systems and the underlying rules of operation.

Mobility & Accessibility

- Mobility refers to the ability to move between different activity sites
 - If a facility could move people and goods very fast then that facility provides very high mobility
- Accessibility refers to the number of activity sites connected by the facility
 - If a facility provides connection to large number of residences, commercial places and industrial places then it provides very high accessibility
- Mobility and accessibility are inversely related.

Major Transportation Systems

- Highways
- Railways
- Airways
- Waterways
- Pipeline
- Conveyor

Planning

- "... an activity or process that examines the potential of future actions to guide a situation or system toward a desired direction" (Papacostas & Prevedouros, 2001)
- Occurs in present but is oriented towards the future
- Purpose
 - Achieve positive goals
 - Avoid negative consequences
 - Or both

Scope of transportation planning

- All man-made projects should start with a plan
- The more significant the project, the more intensive and long term the planning
- For large transportation projects, planning starts 20 years before construction

Planning Process

Establishing the
Purpose & Need

Situation Definition

Problem Definition

Search for Solutions

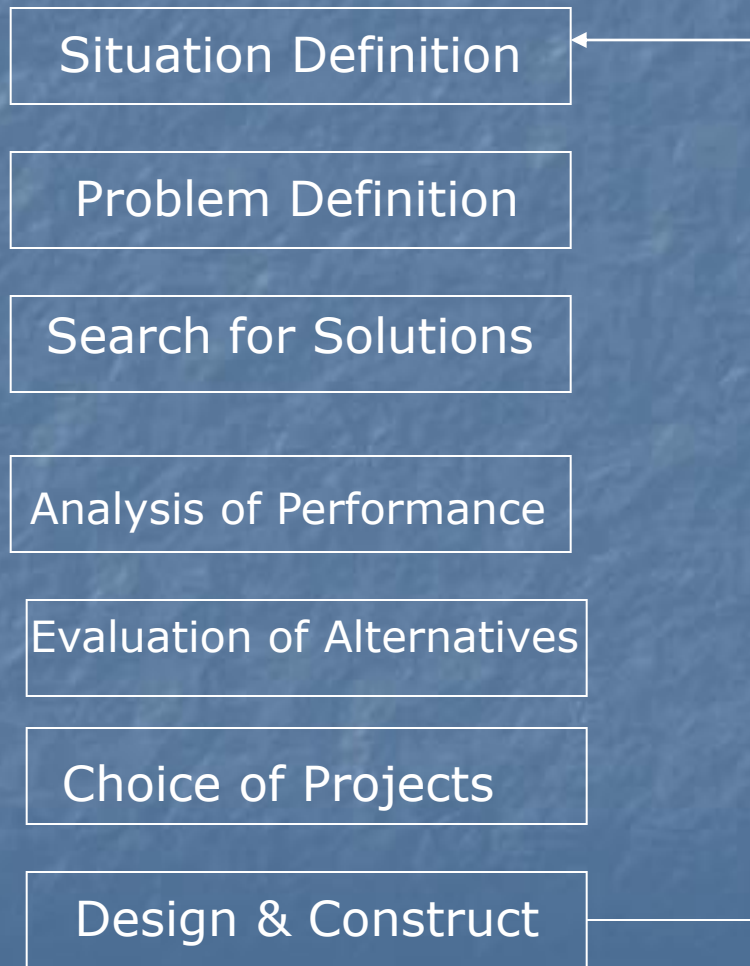
Analysis of Performance

Evaluation of Alternatives

Choice of Projects

Design & Construct

Feedback



Functional Classification of Highway Systems

- Primary System
 - Expressways
 - National Highways (Multilane highways)
- Secondary System
 - State Highways
 - Major District Roads
- Tertiary System
 - Other district Roads
 - Village Roads

Expressway

- **Expressway**: is a divided highway facility having two or more lanes in each direction for the exclusive use of traffic, with full control of access and egress

In the highway hierarchy, Expressway is the only facility that provides complete uninterrupted flow.

An Expressway is composed of three subcomponents: Basic freeway segment, weaving areas, and ramp junctions.

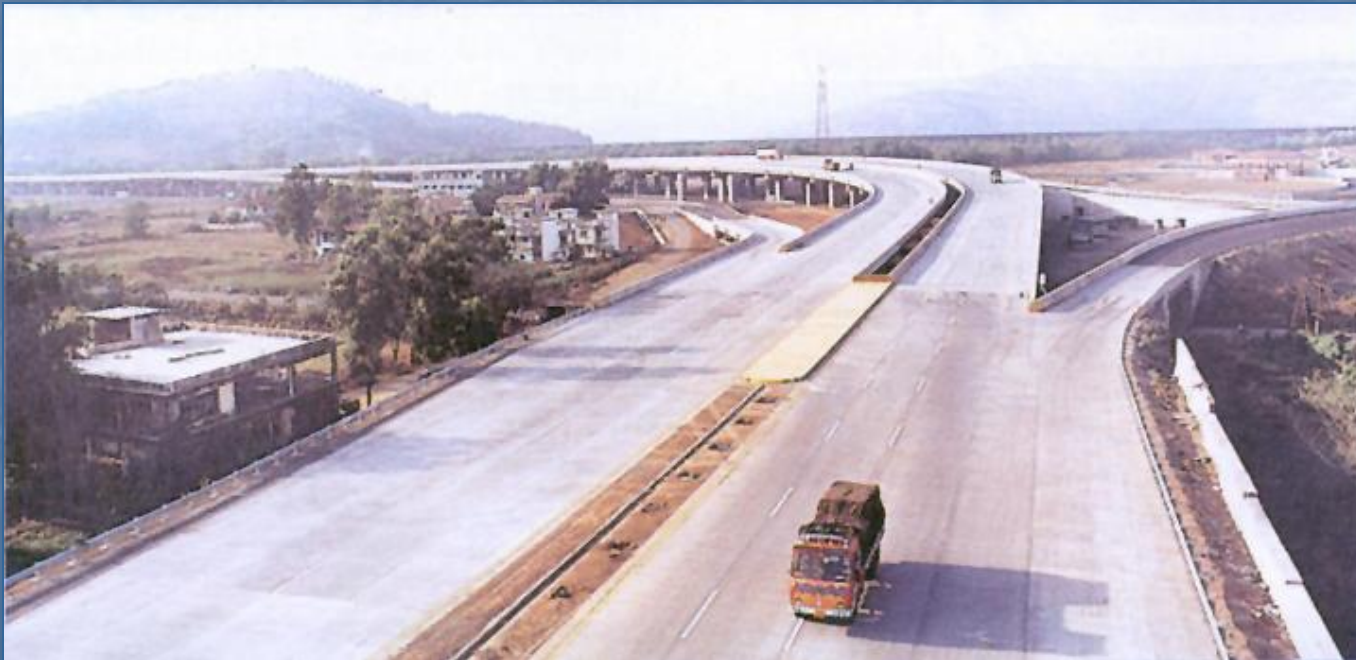
Mumbai – Pune Expressway



- First Expressway in India
- Total length 93.75 km
- A dual, 12.45-m wide carriageway, Central median verge 7.6 m
- 2.5-m black-topped shoulders
- Five twin-tunnels, and one single-tube tunnel, total length - 6,000 m

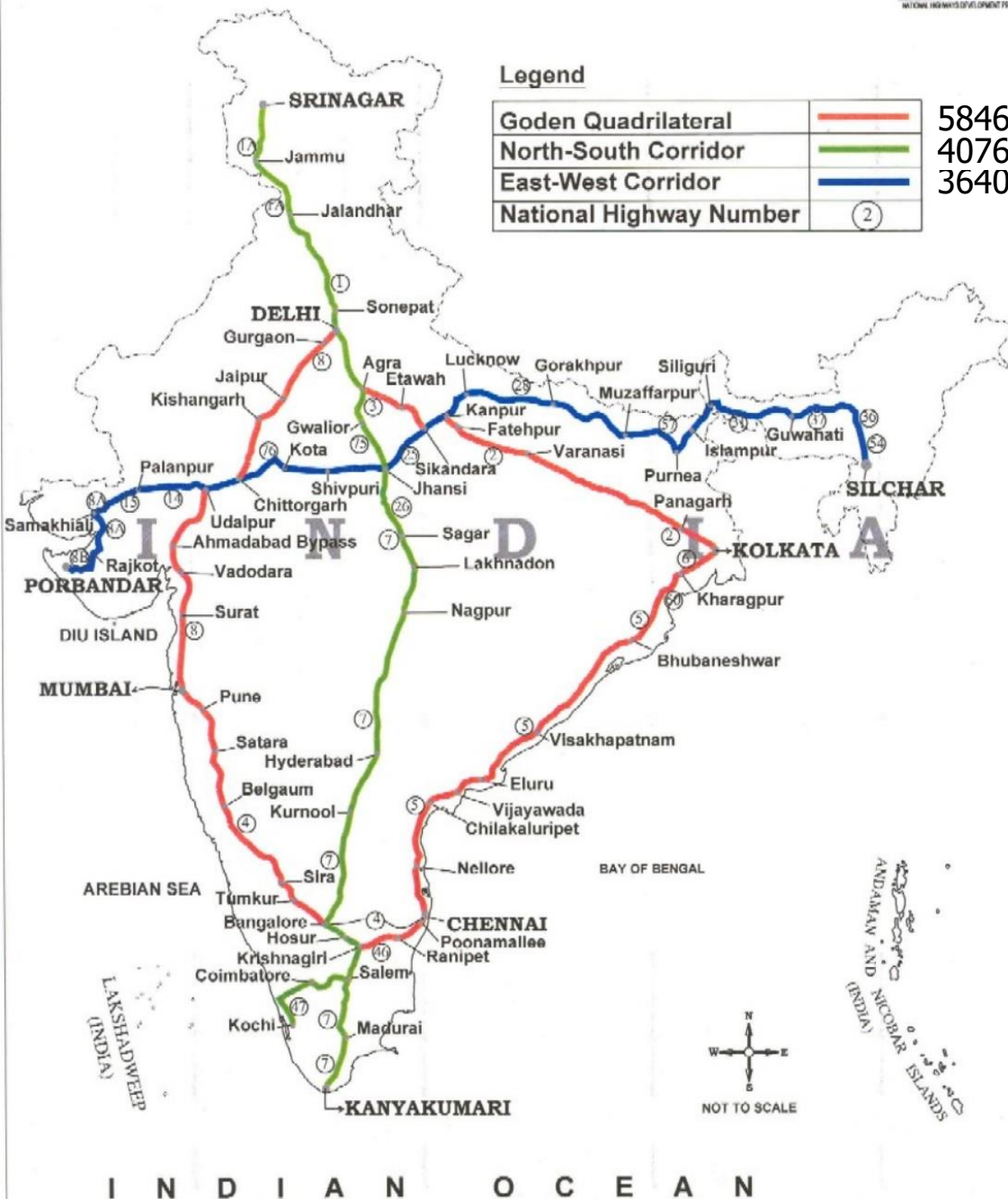
Mumbai – Pune Expressway

- 26 Underpasses
- 21 Overpasses
- 6 Major bridges/viaducts
- ◆ 21 Minor bridges
- ◆ 81 Box/slab culverts
- ◆ 2 Railway over bridges
- ◆ 4 Interchanges



Multilane Highways

- A highway with at least two lanes for the exclusive use of traffic in each direction, with no control or partial control of access, but that may have periodic interruptions to flow at signalized intersections no closer than 3.0 km.



National Highways Development Project is aimed at converting the national highways connecting the four metros and the North-South and the East-West corridors into a multilane highway network

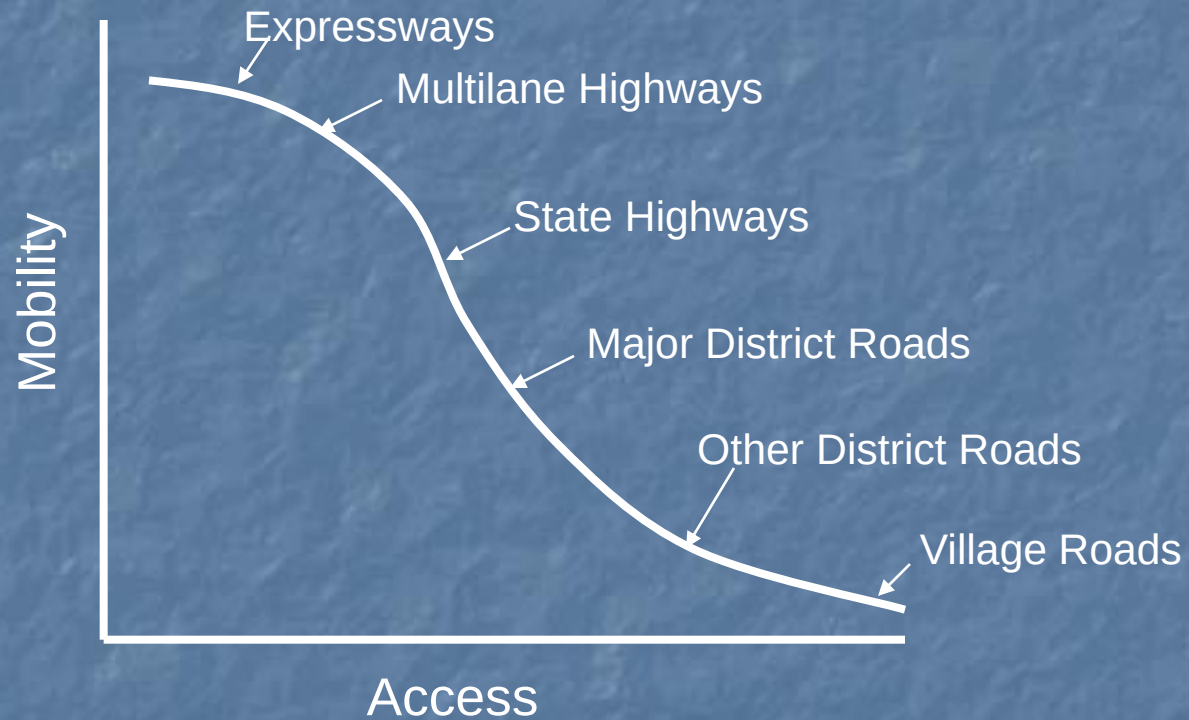
Multilane Highway in a Rural Environment



Multilane Highway in a Suburban Environment



Mobility & Accessibility



Classification of Urban Streets

- Urban Expressways
- Arterial streets
- Sub Arterial streets
- Collector streets
- Local streets

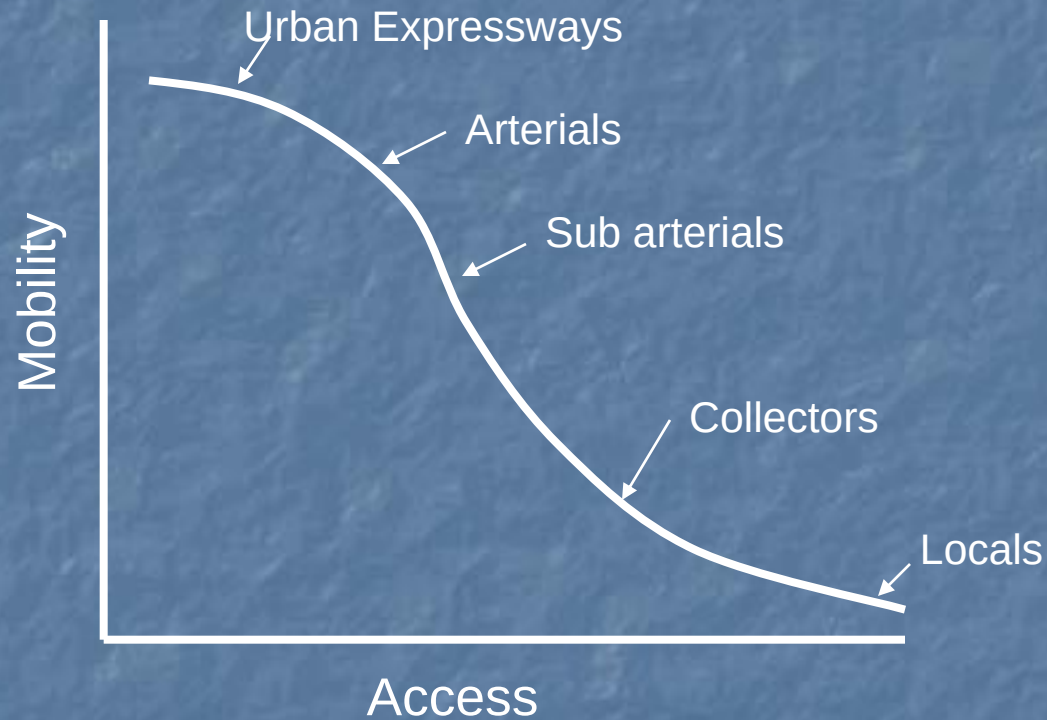
Arterials and Sub-arterials

- **Arterial** A major surface street with relatively long trips between major points, and with through-trips entering, leaving, and passing through the urban area.
- **Sub-arterial** A signalized street that primarily serves through-traffic and that secondarily provides access to abutting properties, with signal spacing of 3.0 km or less.

Collectors and Locals

- **Collector** A surface street providing land access and traffic circulation within residential, commercial, and industrial areas. The function of collector street is to collect traffic from local streets and feed it to the arterial and sub-arterial streets or vice-versa
- **Local Streets** These streets provide access to the abutting properties. Unrestricted parking and pedestrian movement is allowed on these streets

Mobility & Accessibility



Level of Service

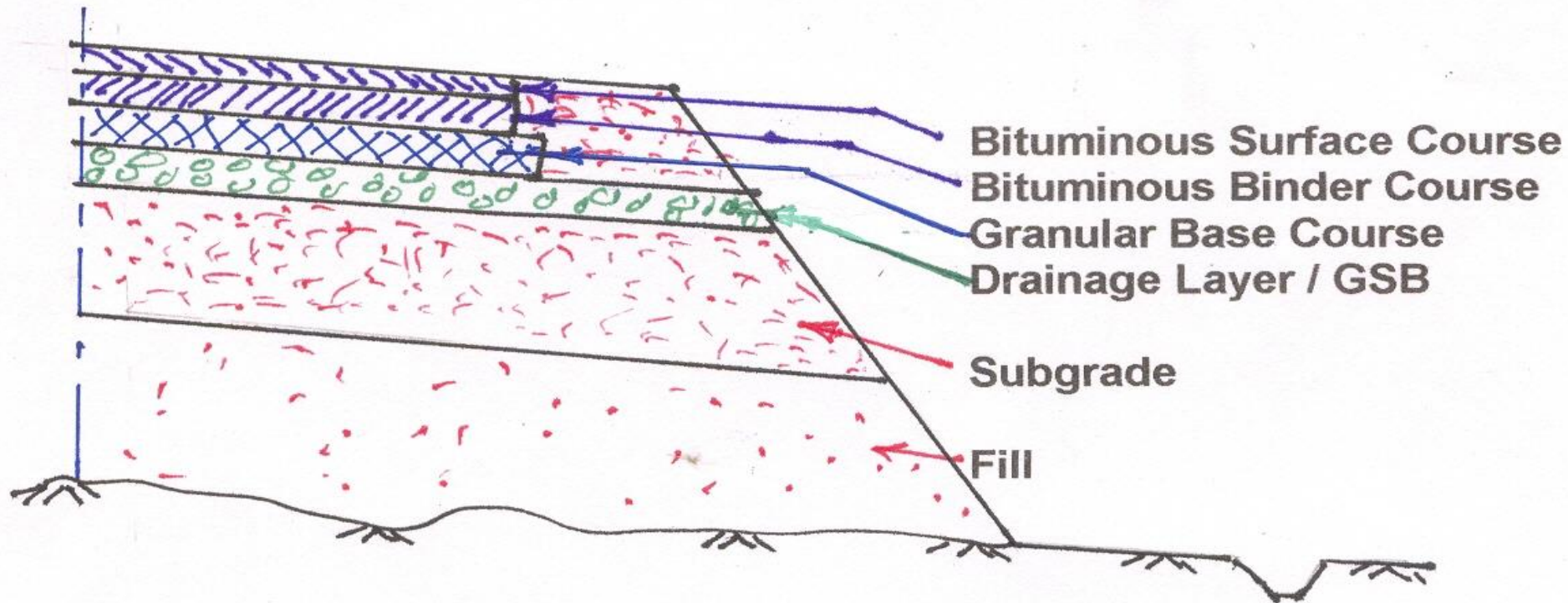
- A qualitative measure describing operational conditions within a traffic stream, based on service measures such as speed and travel time, freedom to maneuver, traffic interruptions, comfort, and convenience.

Urban Street Level of Service

(source: HCM- 2000)

Urban Street Class	I	II	III	IV
Range of free-flow speeds (FFS)	90 to 70 km/h	70 to 55 km/h	55 to 50 km/h	55 to 40 km/h
Typical FFS	80 km/h	65 km/h	55 km/h	45 km/h
LOS	Average Travel Speed (km/h)			
A	> 72	> 59	> 50	> 41
B	> 56–72	> 46–59	> 39–50	> 32–41
C	> 40–56	> 33–46	> 28–39	> 23–32
D	> 32–40	> 26–33	> 22–28	> 18–23
E	> 26–32	> 21–26	> 17–22	> 14–18
F	≤ 26	≤ 21	≤ 17	≤ 14

Typical Cross section of a Highway



Highway Design

- Geometric Design
- Design of Fill/Cut Section
- Pavement Design
- Drainage Design

Geometric Design

- Geometric Design

- Design of vertical and horizontal alignment of the highway

- Preparation of Plan

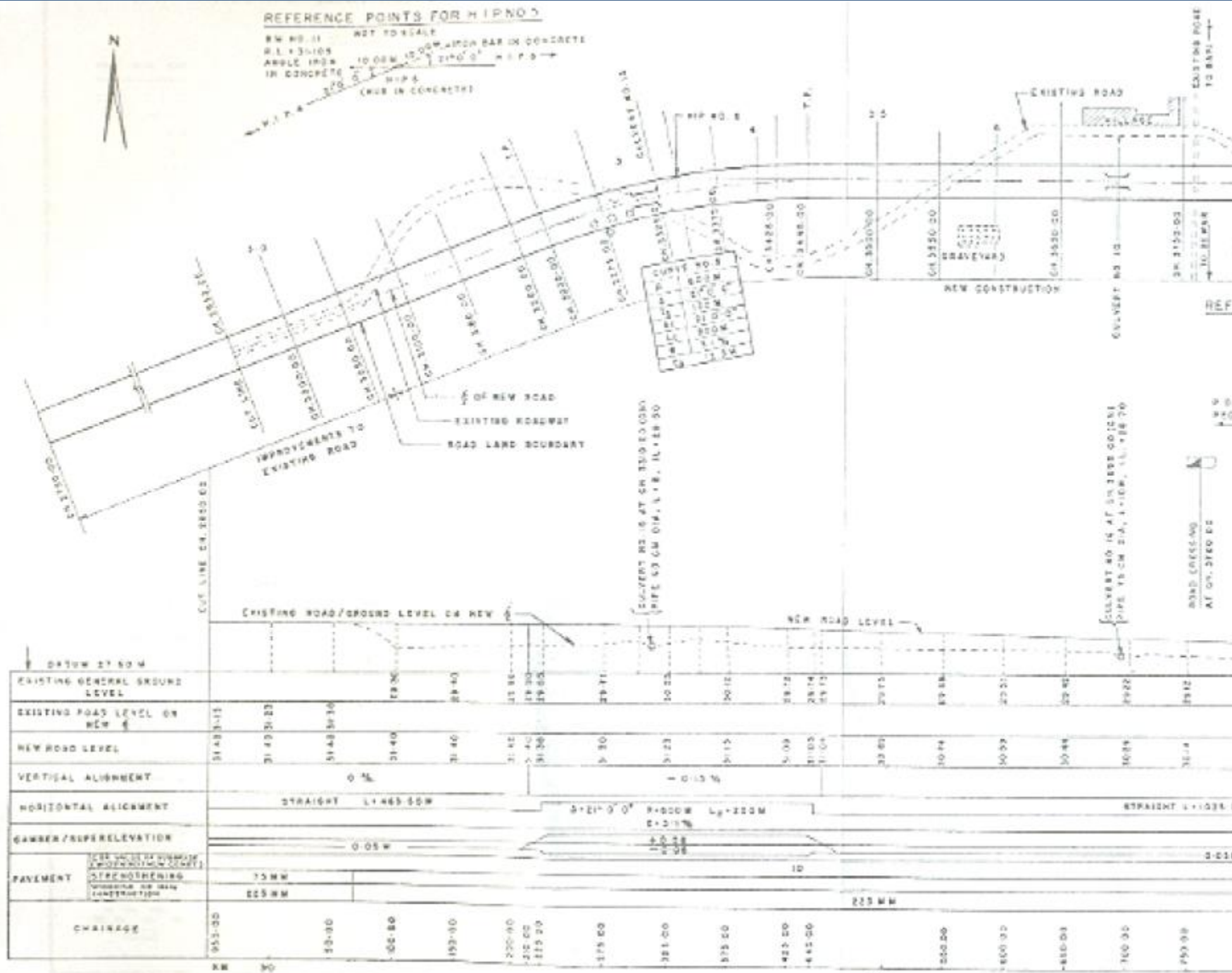
- Shows the horizontal alignment – straight sections, horizontal curves, width of carriageway, shoulders, side drains, right of way, etc.

- Preparation of Profile

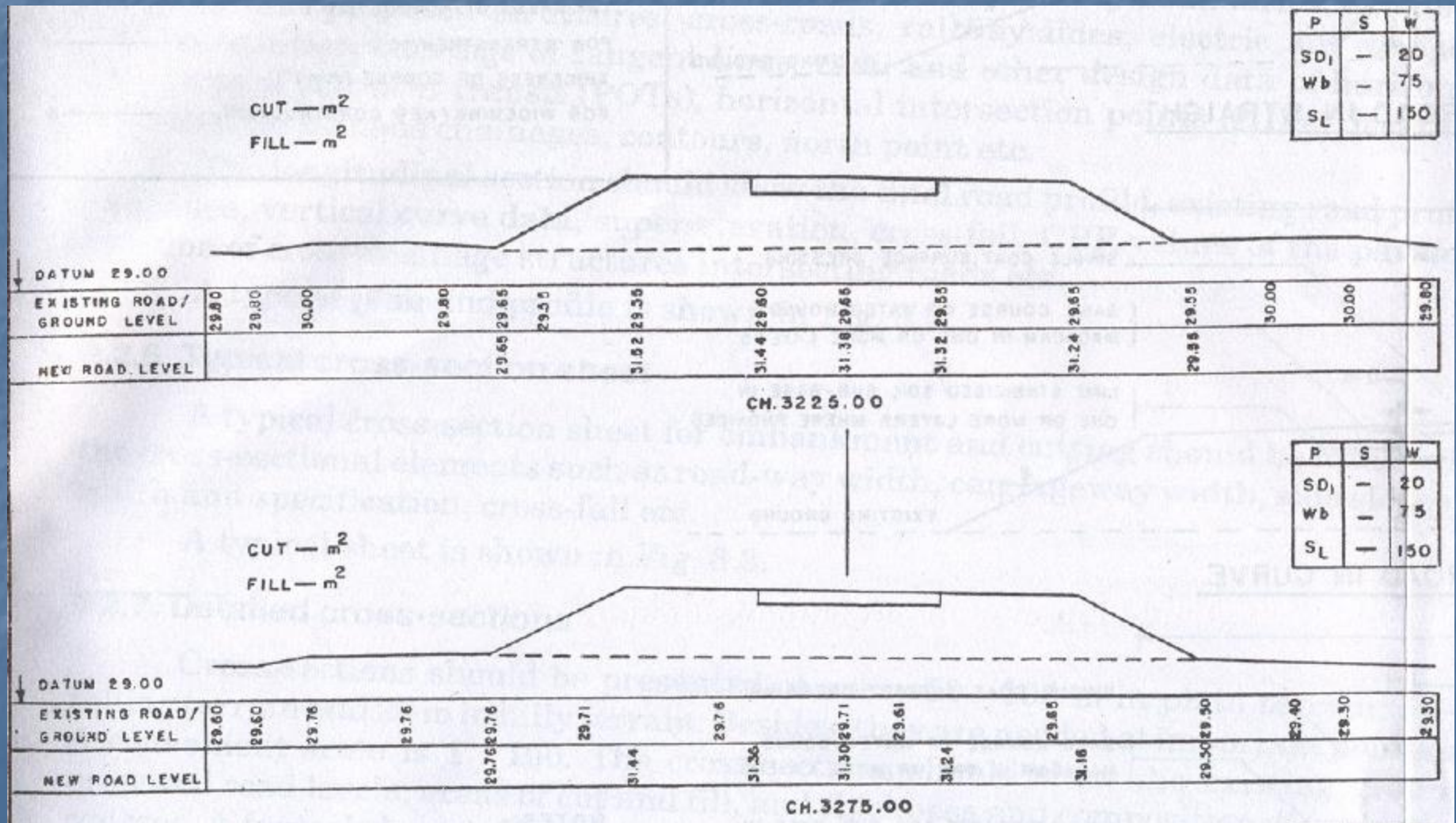
- Shows vertical alignment – grade line, vertical curves, high flood level, etc.

- Cross sections

- Show the camber, side slopes, area of fill/cut, etc.

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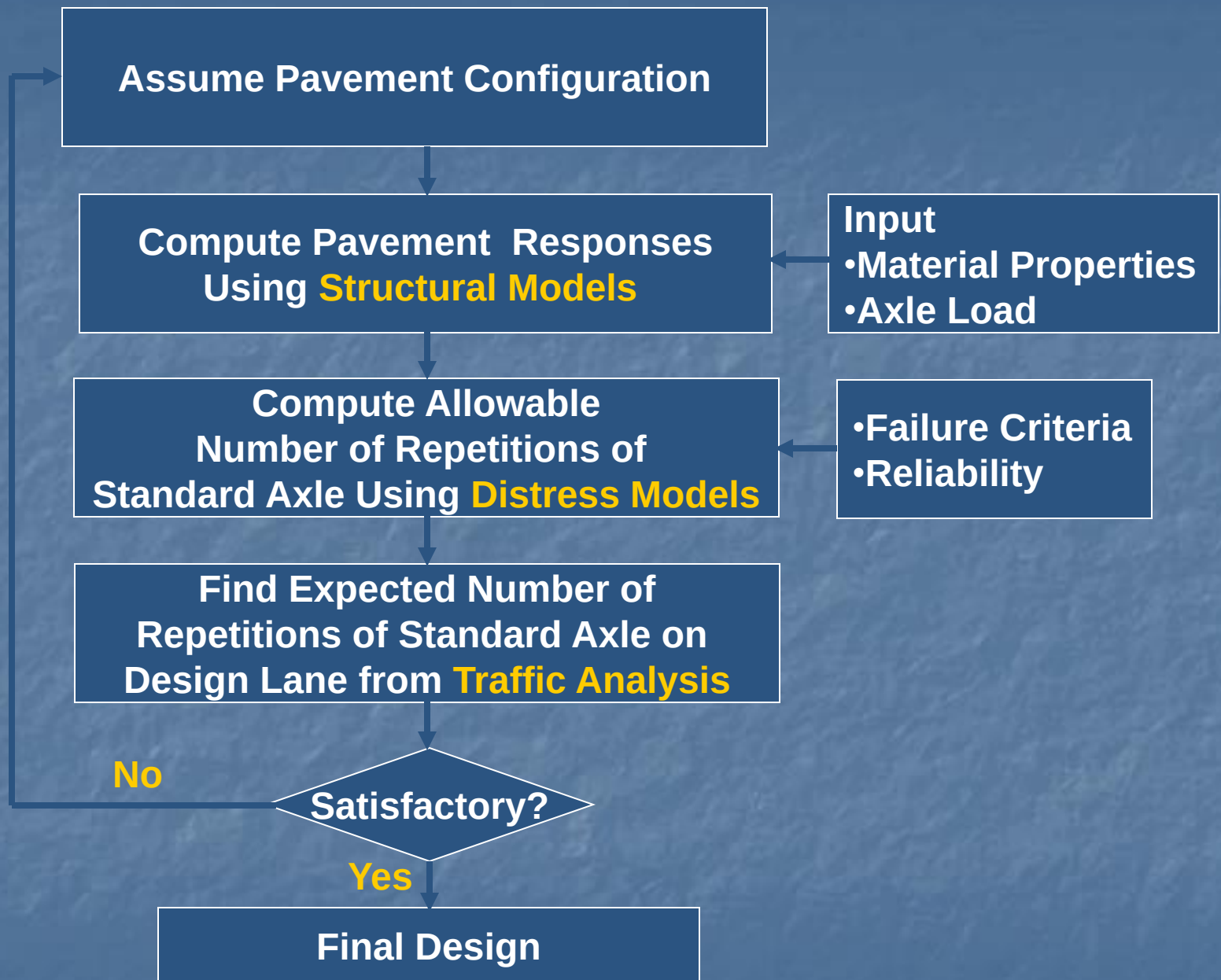
Cross Sections



Pavement Design

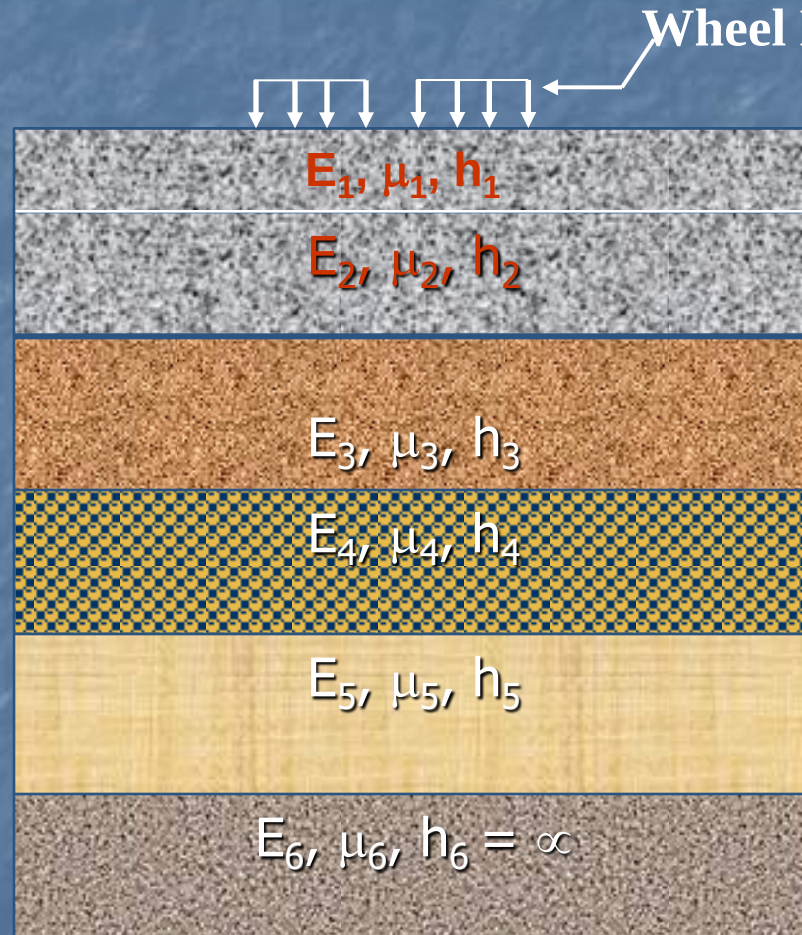
Layers in Flexible Pavement





Mechanistic Method of Pavement Design

Characterisation of Layers



Using Layer Theory the Stresses, Strains and Deflections at any Point in any Layer can be Computed

Axle Configurations



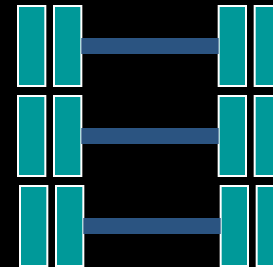
Single Axle With Single Wheel
(Legal Axle Load = 6t)



Single Axle With Dual Wheel
(Legal Axle Load = 10t)

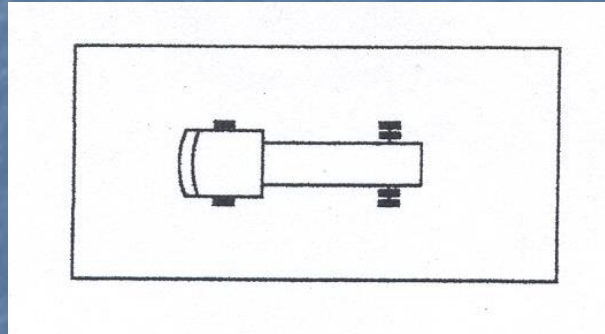


Tandem Axle
(Legal Axle Load = 18t)

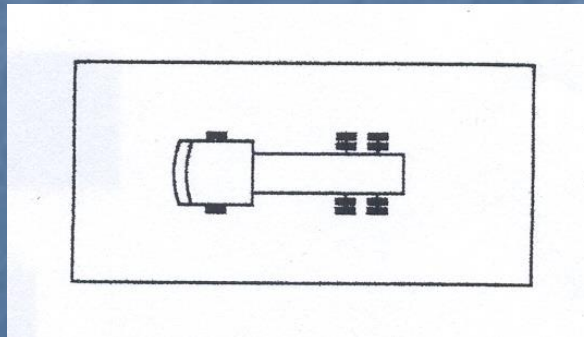


Tridem Axle
(Legal Axle Load = 24t)

Truck Configuration

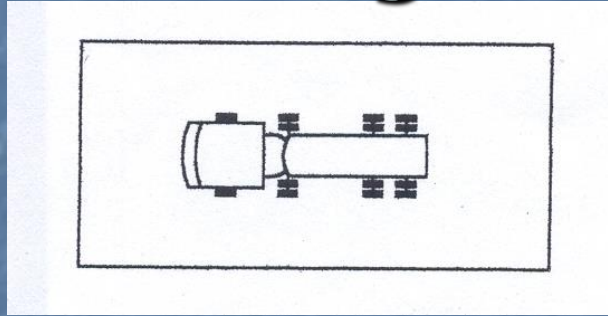


2 Axle Truck – 16t

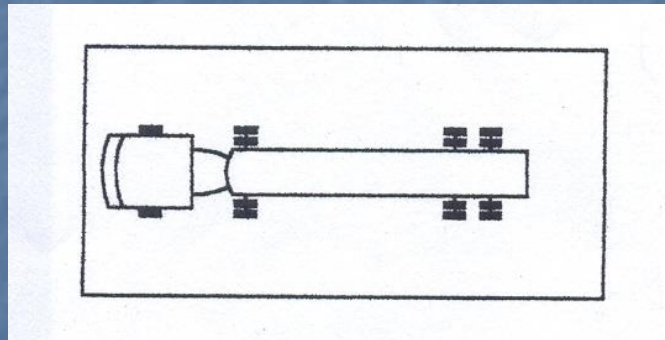


3 Axle Truck – 24t

Truck Configuration

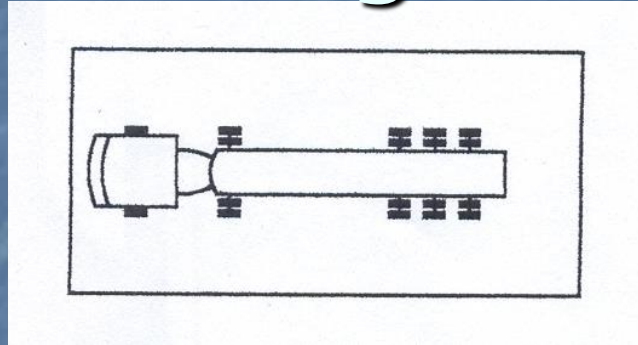


4 Axle Semi Articulated – 34t

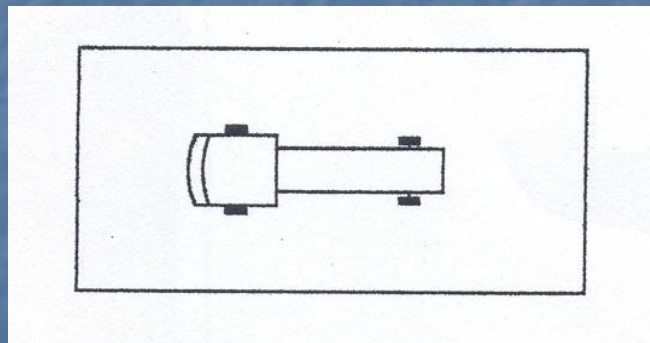


4 Axle Articulated

Truck Configuration



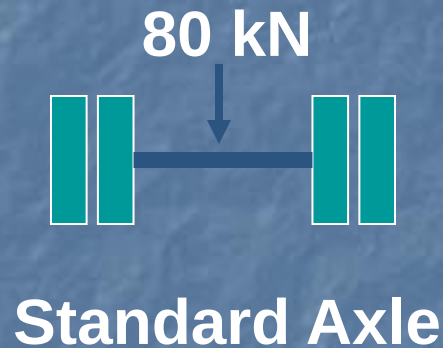
5 Axle Truck – 40t



LCV

Standard Axle

Single axle with dual wheels carrying a load of 80 kN (8 tonnes) is defined as standard axle



Vehicle Damage Factor (VDF)

- Instead of converting each axle pass into equivalent standard axle passes, It will be convenient to convert one truck pass into equivalent standard axle passes.
- The factor that converts the number of trucks into equivalent standard axle repetitions is termed as vehicle damage factor or truck factor
- Therefore, Vehicle damage factor is the number of standard axles per truck.

Steps in Highway Planning

- Situation Definition

- Inventory of existing facilities

- Current conditions and issues

- Congestion, very high travel time, very high road user costs

- Identification of other planning studies

- Earlier plans at National, regional and local level to arrive at a solution

Steps in Highway Planning

■ Problem Definition

- After understanding the present problems the problem could be defined as
- To achieve reasonable journey speeds, vehicle operation costs, comfort and convenience for travel between the four metros

Steps in Highway Planning

- Search for Solutions
 - Develop alternative concepts and solutions to reasonably satisfy the future needs considering their impact on environment, safety , economy and fiscal resources of the area
 - Examination of alternative alignments and development concepts is essential for the proper identification of viable alternatives

Steps in Highway Planning

- Analysis of Performance
 - Demand forecasting
 - Demand forecasting includes determination of daily volume of different classes of vehicles.
 - The forecast must also give the traffic volume during the busiest hour of the day
 - If the facility is tolled a relation between the volume levels and the toll levels should be established
 - Analysis of the interaction between demand and capacity of the facility
 - Use performance measures to shortlist the alternatives

Steps in Highway Planning

- Evaluation of Alternatives – Economic Feasibility
 - Conduct economic evaluation for the short-listed alternatives
 - Each of the alternative may be compared with the do nothing alternative
 - The benefits and cost for all the alternatives need to be worked out
 - Benefits include savings in travel time, reduction in operating cost, reduction in accidents, etc.
 - Cost include capital cost of construction, maintenance cost, environmental costs, etc.
 - Economic Internal Rate of Return (IRR) is worked out for all the alternatives
 - The alternatives can be ranked based on this IRR
 - IRR is that interest rate at which the Net Present Value of the Project is zero.

Steps in Highway Planning

- Evaluation of Alternatives – Financial Feasibility
 - Financial feasibility analysis is conducted in the hands of the sponsor
 - If the project is completely funded by the government, the sponsor is The Government
 - If the project is being implemented under public private participation or purely by private agencies, then the sponsor is the concerned private agency
 - A Financial Internal Rate of Return is worked out for each alternative by computing the cash flows in the hands of the sponsor
 - This financial analysis is also used to arrive at the best financial strategy for the project

Steps in Highway Planning

- Environmental Impact Assessment
 - The environmental impact of alternative concepts and recommended solutions must be considered and incorporated into the cost effectiveness analysis
 - The following impacts should be studied and a proper environment management plan mitigating the impacts should be prepared
 - Traffic
 - Pollution
 - Noise
 - Ecological
 - Social

Steps in Highway Planning

- Choice of project and Implementation
 - Prepare a Detailed Project Report (DPR) for the selected alternative
 - DPR includes all the technical design details, schedules for implementation, sources of revenue for the implementation of various phases of the proposed project
- Construction, Maintenance and Operation