TRANSPORTATION ENGINEERING

Transportation engineering is the application of technology and scientific principles to the planning, design, construction, maintenance, and operation of transportation facilities in order to provide for the safe, efficient, rapid, comfortable, convenient, economical and environmentally compatible movement of people and goods. The facilities include highway, railroad, water, pipelines and air transportation.

Modes of transportation:
There are three modes of transportation:

1. **Land**: Bicycle, motorcycle, car, wagon, bus, truck and train.
2. **Air:** Hot air balloon, aircraft, helicopter, rocket, and space shuttle.
3. **Water:** Boat, Canoe, ferry, steamboat, ship and sub-marine. Waterways include oceans, rivers, canals and lakes.

Elevators, belt conveyors, cable cars and monorails also functionas minor transportation systems.
Transportation engineering in general covers the following areas:

- Highway engineering
- Railroad engineering
- Airport engineering
- Port and harbor engineering

In this course we shall study highway engineering and railroad engineering:

HIGHWAY ENGINEERING

Highway engineering involves planning, design, construction, operation and maintenance of roads, bridges and tunnels to ensure safe and effective transportation of people and goods.

HISTORY
The beginning of road construction could be dated back to the time of the Romans. The cut stones fitting together tightly were placed on the natural ground to form surface of the road.The roads with brick drains on both sides were built during Indus Valley Civilization.The first major road in the Indo-Pak sub-continent was constructed during the time of ShershahSuri (1540-1545 AD) from Calcutta (Kolkata) to Lahore. The present G.T. (Grand Trunk) road has been constructed along this road.The road foundation for highway construction in the U.K. was developed by John Macadam and Telford in 1827.

HIGHWAY PLANNING
Highway planning involves planning of an economical road network for efficient and safe traffic operation. The growth of the motor vehicle industry and economic growth has generated a demand for safer, better performing and less congested highways. Highway planning depends on quality data to provide input into the many different steps of the

planning process.It consists of collection of information system and involves forecasting decision related to key factors such as land use, price of fuel, growth in employment and estimation of existing and future traffic volumes on a road network.
Transportation planners use a variety of methods for **collecting the data** needed for input into the planning process. Some of these studies are given as follows:

The planning surveys include the following:

1. Economic studies
2. Financial studies
3. Traffic volume studies
4. Road-use studies
5. Pavement-life studies
6. Engineering studies
7. Environmental impact assessment
8. Highway safety

Economic studies

These studies include population, population growth, agricultural & industrial products, industrial growth and future trends, existing facilities with regard to communication, recreation, education and per capita income.

Financial studies

Developed counties are constantly faced with high costs of new highways and maintenance of aging highways. Financial studies include various financial aspects such as 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 road transport; toll taxes, registration fees and fines etc.
ii. Living standards of people

Traffic volume studies

Traffic volume studies provide with information on the number of vehicles using the highway system. Such information is needed for determining design standards, the systematic classification of highways and the development of programs for improvement and maintenance of the road network.
From traffic volume studies, planners may estimate the Vehicle-Kilometers of Travel (VKT) on the various classes of rural and urban roadways. Such travel data indicate a measure of service provided by the system and facilitate the appraisal of safety programs and the development of highway finance and taxation programs.
The fundamental measure for traffic volume studies is annual average daily traffic (AADT). By using empirical formulae, AADT values can be converted to peak hourly volumes. The traffic studies include:

i. Traffic volume in vehicle per day, annual average daily traffic (AADT) and peak hourly traffic volume.
ii. Origin & destination (O & D) studies
iii. Mass transit facilities
iv. Accidents, their cost analysis and causes
v. Growth of passenger trips

Road-use studies

These studies are performed to determine the relative use of various parts of a highway system. Introduction may be obtained by personal interviews of the drivers within the highway jurisdiction.

Pavement-life studies

The primary objective of such studies is to determine the remaining service life for each type of pavement. Information is also assembled on costs of construction, maintenance and depreciation.

Engineering studies

These studies include:

i. Topographic surveys
ii. Soil surveys
iii. Location and classification of existing roads
iv. Road life studies
v. Estimation of possible developments due to proposed highway
vi. Problems in drainage, construction and maintenance of roads.

Environmental Impact Assessment

The economic growth of community is dependent upon highway development to enhance mobility. Highway infrastructure must be constructed and maintained to high qualities and standards. However, improperly planned, designed, constructed and maintained highways can disrupt the social and economic characteristics of a community. Common adverse impacts to highways development include damage of habitat and bio-diversity, creation of air & water pollution, noise/vibration generation and damage of natural landscape.

There are three key steps for integrating environmental considerations into the planning, construction and maintenance of highways. This process is known as an environmental impact assessment (EIA).

1. Identification of the full range of possible impacts on the natural and socio-economic environment.
2. Evaluation and qualification of these impacts.

3. Formulation of measures to avoid, mitigate and compensate for the anticipated impacts.

Highway Safety

Highway systems are cause of considerable injury and death. There are about 50 million injuries and 1.2 million deaths in traffic accidents every year. Management of highway safety is systematic process that strives to reduce the occurrence and severity of traffic accidents. Technological advancements in highway engineering have improved the design, construction and maintenance methods which have increased the safety of highway systems.

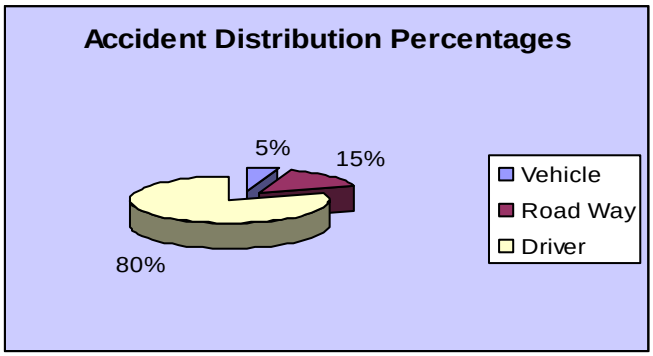
ELEMENTS OF TRANSPORTATION

There are three main elements of automobile transportation

- Human (drivers & pedestrians)
- Vehicle
- Roadway

These three basic elements of transportation have the following accident distribution percentages:

- Human (drivers & pedestrians) 80%
- Vehicle 5%
- Roadway 15%



CLASSIFICATION OF ROADS

The roads in Pakistan are classified as **urban roads** and **rural roads**. A road within a city is called urban road whereas a road outside the city is called rural road.

A. Based on location and function

The urban roads are classified as follows:

1. **Expressways**

   The road for high speed vehicles is known as expressway or motorway. The expressways are provided with divided carriageways, controlled access, grade

separations at cross roads and fencing. The pedestrian crossing, parking, loading and unloading of goods are not allowed on the expressways.

2. **Arterial streets**
   The streets meant for through traffic. There are also divided highways to connect areas within the towns or cities with the expressways.

3. **Sub-arterial streets**
   The roads which provide lower level of travel mobility than the arterial streets.
4. **Collector streets**
   The roads which collect and distribute the traffic to and from local streets. These are located in residential, industrial and commercial areas. These are connected to sub-arterial streets.
5. **Local streets**
   The roads which provide an access to residential and commercial buildings. A local street may be residential, industrial or commercial.
6. **CUL-DE-SAC**
   It is Dead End street with only one entry access for entry and exit, usually in residential areas.

The rural roads are classified as follows:

1. **National highways**
   These are major or important roads of a country. The highways connecting commercial or industrial centers with airports or sea-ports, provincial capitals and tourist centers. These are constructed and maintained by National Highway Authority.
2. **Provincial highways**
   The highwaysconnecting district headquarters with provincial headquarters or from province to province.These are constructed and maintained by National Highway Authority.
3. **Major District roads**
   The roads traversing each district serving areas of production and markets connecting each other or with National or Provincial highways. The construction and maintenance of these roads is the responsibility of the provincial government.
4. **Village roads**
   The roads connecting village to village and village to district road. The construction and maintenance of these roads is the responsibility of local government.

B. Based on the traffic volume

Heavy
Medium
Light

C. Based on load or tonnage

Class-1 or Class-2 or Class-A or Class-B

D. Based on weather

All weather road

Fair weather road

E. Based on type of carriageway

Paved roads

Unpaved roads

F. Based on type of pavement surface

Surfaced roads

Un-surfaced roads

National Highways of Pakistan

- The **National Highways of Pakistan**is a network of highways in Pakistan that are distinct from its motorways.
- The main difference between the two is that, unlike motorways, national highways are not controlled-access or limited access,as in the case of motorways.
- National Highway Authority owns, maintains and operates all national highways.
- Famous National Highways include the Grand Trunk Road, the Indus Highway, the Karakoram Highway and the Makran Coastal Highway
- All National Highways in Pakistan are pre-fixed with the letter 'N' (for "National") followed by the unique numerical designation of the specific highway (with a hyphen in the middle), e.g. "N-5". Each numerical designation is separated by five numerals, i.e. N-5, N-10, N-15, etc.

Motorways of Pakistan

- The **Motorways of Pakistan** are a network of high-speed, limited-access or controlled-access highways in Pakistan, which are owned, maintained and operated federally by Pakistan's National Highway Authority
- M1 is from Islamabad to Peshawar. It is a 155 km access-controlled motorway with 6 lanes.
- M2 is from Lahore to Islamabad. It is a 367 km access-controlled motorway with 6 lanes. It was completed in November 1997.
- M3 is from PindiBhattian to Faisalabad. It is a 53 km access-controlled motorway with 4 lanes, which, in future, can be increased to 6 lanes.
- M4 is from Faisalabad to Multan with a total length of 200 km. It has 4 lanes, which, in future, can be increased to 6 lanes.
- M5 is from Multan to Dera Ghazi Khan with a total length of 65 km and 4 lanes, which, in future, can be increased to 6 lanes.
- M6 is from Dera Ghazi Khan to Ratodero with a total length of 450 km and 4 lanes, which, in future, can be increased to 6 lanes.
- M7 is from Kakkar via Dureji to Karachi with a total length of 303 km and 2 lanes.
- M8 is from Gwadar to Ratodero with a total length of 1072 km and 2 lanes.

- M9 is from Karachi to Hyderabad with a length of 136 Km and 6 lanes.
- M10 is the Karachi Northern Bypass, which has a total length of 56 km and 6 lanes

NHA Road Network

Sr. No.	Route No	Road Description	Punjab	Sindh	KP	Balochistan	Gilgit - Baltistan	AJK	Total
1	N-5	Karachi-Lahore-Peshawar-Torkham	1,021	671	127	-	-	-	1,819
2	N-10	Liari-Ormara-Gwadar-Jiwani	-	-	-	653	-	-	653
3	N-15	Mansehra-Naran-Jalkhad-Chilas	-	-	180	-	60	-	240
4	N-25	Karachi-Kalat-Quetta-Chaman	-	23	-	790	-	-	813
5	N-30	Basima - Khuzdar	-	-	-	110	-	-	110
6	N-35	Hassanabdal-Thakot-Khunjrab	15	-	360	-	431	-	806
7	N-40	Lakpass-Dalbandin-Taftan	-	-	-	610	-	-	610
8	N-45	Nowsehra-Dir-Chitral	-	-	309	-	-	-	309
9	N-50	Kuchlak-Zhob-D.I.Khan	-	-	143	388	-	-	531
10	N-55	Kotri-Larkana-D.G.Khan-D.I.Khan-Peshawar	373	495	396	-	-	-	1,264
11	N-65	Sukkur-Sibi-Quetta	-	90	-	295	-	-	385
12	N-70	Multan-D.G.Khan-Loralai-Qila Saifullah	181	-	-	266	-	-	447
13	N-75	Islamabad-Satra Mile-Lower Topa-Kohala	90	-	-	-	-	-	90
14	N-80	Tarnol-Fateh Jang-Jand-Kohat	108	-	38	-	-	-	146
15	N-85	Hoshab-Panjgur-Nag-Baseema-Sorab	-	-	-	487	-	-	487
16	N-90	Khwazakhela - Besham	-	-	64	-	-	-	64
17	N-95	Chakdara - Kalam	-	-	135	-	-	-	135
18	N-105	Larkana - Naudero - Lakhi	-	61	-	-	-	-	61
19	N-110	Gharo - Keti Bunder	-	90	-	-	-	-	90
20	N-120	Hyderabad - Mirpurkhas - Umarkot - Khokhrapar (Indian Border)	-	220	-	-	-	-	220

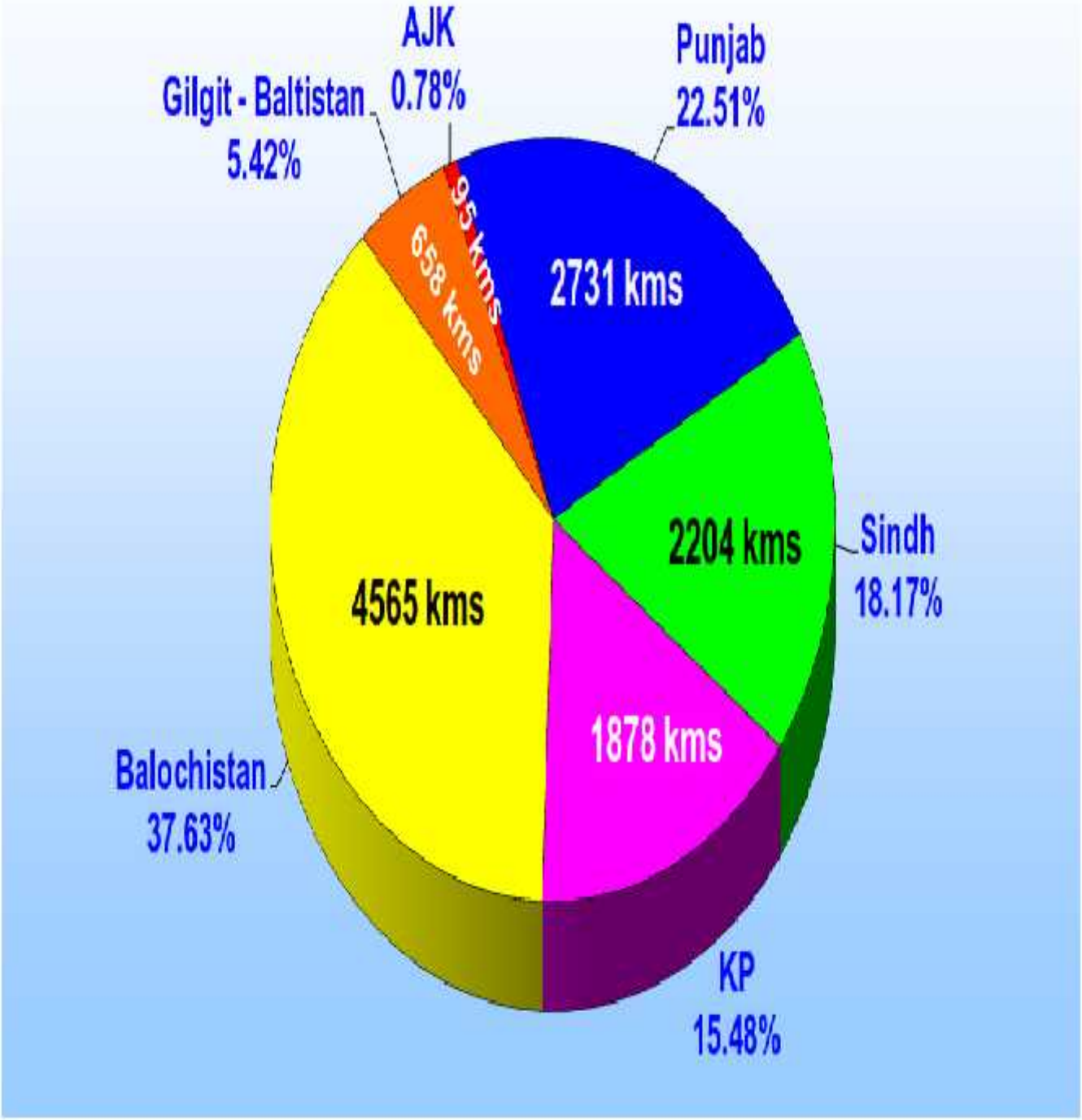
Cont'd on next slide

NHA Road Network

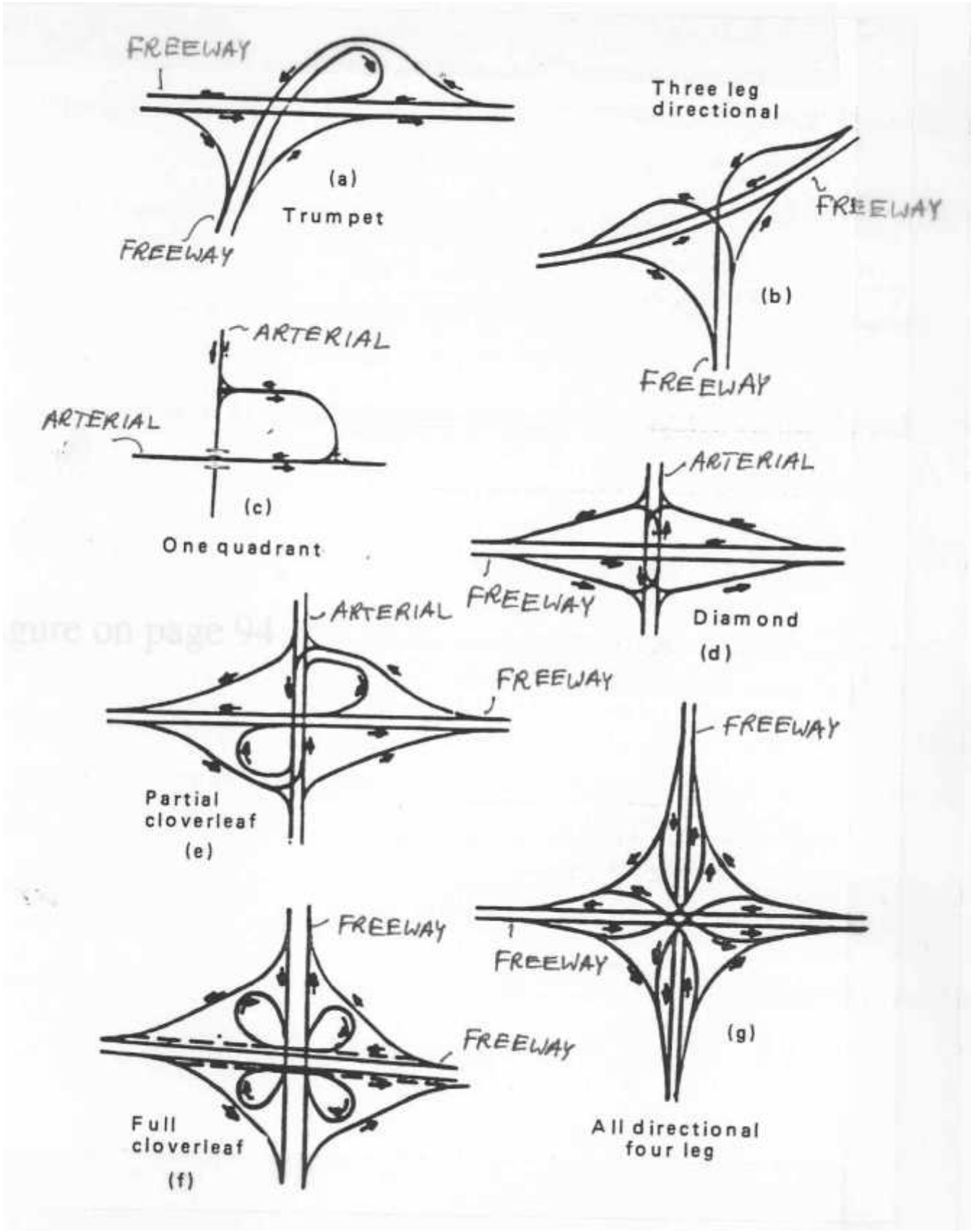
Sr. No.	Route No	Road Description	Punjab	Sindh	KP	Balochistan	Gilgit - Baltistan	AJK	Total
21	N-125	Taxila - Khanpur - Haripur	6	-	38	-	-	-	44
22	N-155	Larkana - Moenjo Daro Road upto Airport	-	28	-	-	-	-	28
23	N-255	Larkana - Nasirabad via Rasheed Wagan	-	34	-	-	-	-	34
24	N-305	Sakrand - Shaheed Benazirabad	-	35	-	-	-	-	35
25	N-455	Larkana - Kamber - Shahdadkot	-	50	-	-	-	-	50
26	N-655	Ratodero - Naudero Road incl. Internal Road of about 2 Km	-	18	-	-	-	-	18
27	S-1	KKH-Skardu Road (Strategic Road)	-	-	-	-	167	-	167
28	S-2	Kohala-Muzaffarabad	-	-	-	-	-	40	40
29	S-3	Muzaffarabad - Chakothi	-	-	-	-	-	55	55
30	E-3	Kot Sarwar - Hafizabad - Wazirabad	100	-	-	-	-	-	100
31	M-1	Islamabad-Peshawar Motorway	67	-	88	-	-	-	155
32	M-2	Lahore-Islamabad Motorway incl. 32 Km Link roads	367	-	-	-	-	-	367
33	M-3	Pindi Bhattian-Faisalabad Motorway	53	-	-	-	-	-	53
34	M-4	Faisalabad - Khanewal - Multan	241	-	-	-	-	-	241
35	M-5	Khanewal - Bahawalpur (Lodhran)	109	-	-	-	-	-	109
36	M-7	Dadu-Dureji-Hub	-	132	-	138	-	-	270
37	M-8	Gwadar-Hoshab-Khuzdar-Ratodero	-	64	-	828	-	-	892
38	M-9	Karachi-Hyderabad Motorway		136	-	-	-	-	136
39	M-10	Karachi Northern Bypass	-	57	-	-	-	-	57
TOTAL			2,731	2,204	1,878	4,565	658	95	12,131

Road Length of National Highways

Province-wise Breakup



Interchanges



Urban Location Controls

- Location controls are basically the factors which effects the selection of location of a highway.

In an urban area, it is almost impossible to locate a new major highway or improve an existing street/highway to carry out the required functions.

Factors which affect the location of a highway are summarized below:

- The location of a new highway or the substantial improvement of an old one results in the elimination of , or change in, portions of the established city culture, which complicates the problem of finding a suitable location.
- Anticipated traffic is a major factor controlling the location of a highway as it effects the land use requirements.

Town planning considerations should also be evaluated for highway location. Town planning relates the present and future needs of the business, industrial, residential and recreational elements.

In most cities, parking problem is acute, so it is desirable to locate a new highway as close as possible to the existing or potential parking areas. This is particularly important in central areas, where congestion is to be minimized. If the selected route location does not meet this criterion then congestion can be reduced by providing ramps at the locations which connects the major highway to the town streets

- The most important controls effecting the location and type of urban arterial highways is the existing transportation system. Any new facility must be integrated with the existing road system for optimum usage.
- Topography and physical features of a town can be the major controls influencing the location of a highway in **rural** areas.
- Soil and ground water conditions also effect location, e.g. poor soil conditions, high water table and rock close to the subgrade effect the location.
- In an urban area, existing public facilities (e.g. storm and sewer pipes, electric lines, gas and water lines etc.) can present many difficulties which may effect the location of a major highway.
- In the case of a specific highway the changes or need for complete utility relocation may make another site more attractive. So the highway engineer engaged in locating a new roadway must have sufficient information regarding utilities to assure that the plans being considered are practical and workable.

COMPONENTS OF ROAD

Right of way

It is the area of land acquired for construction and future development of a road symmetrically about the central alignment. The width of land depends upon the importance of the road and possible future development.

Formation width

It is the top width of the highway embankment or the bottom width of highway cutting excluding the side drains.

Carriageway

It is the portion of the road surface which is used for vehicle traffic. The width of carriageway depends upon the width and number of lanes. The width of single lane is generally kept 3.75m.

Crown

It is the highest point on the road surface.

Camber or cross slope

It is the slope provided to the road surface in the transverse direction to drain off the rain water from the road surface. Usually camber is provided on the straight roads by raising the centre of the carriageway with respect to the edges. At horizontal curves the outer edge of pavement is raised with respect to the inner edge.It is known as super-elevation. Its value is about 1 in 50.

Separator or divider

It is the narrow continuous structure provided for dividing the two directions of the traffic flow**.**

Shoulder

It is the portion of the road between the outer edges of the carriageway and edges of the top surface of the embankment or inner edges of the side drains in cutting of the road. The shoulders are generally in level with road surface, having aslope outwards. The shoulders and foot paths prevent the edges of the road from wear and tear. The minimum width of shoulder is about 2.5m.

Kerb

It is the boundary between the pavement and shoulder or foot path on urban roads. It is also provided between the pavement and the separator or divider.

Side slope

It is the slope of the side of earthwork of embankmentand cutting to ensure stability. It is about 1:1.5.

Berm

It is width of land left in between the toes of the embankment and the inner edges of the borrow pits.

Components of Road Pavement

In order to give satisfactory service throughout the year, the road surface should remain dry and a good wearing surface. It should have a good carriage-way and smooth gradient.

The following are the *various components of a road surface:

1. **Sub-grade**. The top of the ground on which the foundation of a road rests, is called sub-grade. It is provided by digging up the sub-soil. The level of the sub-grade is decided by subtracting the total thickness of the pavement from the finished level of the road pavement. The strength and durability of a road depends upon its sub-grade.
2. **Sub-base**. When the bearing capacity of the soil is poor and the intensity of traffic is high, an additional layer is provided between the soling and sub-grade. This additional layer is called sub-base.
3. **Base**. The foundation of a road is also called soling or base. The thickness of base, in no wearing course. The load of the traffic is transferred to the sub-base and sub-grade through the base course.
4. **Wearing course**. The super structure of a road is called wearing course or road surfacing or wearing layer. It should be stable, durable and impervious. The wearing course may be laid in one or two layers according to the total designed thickness and the thickness of each layer should not exceed 10 cm. the thickness of the road surfacing depends upon the type of traffic, intensity of traffic and the type of material.