1. Introduction to Transportation Planning and Engineering (4 hrs)

1.1 Introduction
1.2 Modes of Transportation
1.3 Comparison between various modes of Transportation
1.4 Historical Development of Roads: Roman, Tresaguet, Telford, Macadam
1.5 Road Construction in Nepal
1.6 Transportation Planning including Objectives of Planning
1.7 Classification of Roads: Strategic Road Network, Rural/Local Road Network, Urban Road

1.1 Introduction to Transportation System

A transportation system may be defined as consisting of the fixed facilities, the flow entities, and the control systems 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.

The transportation system as defined by ITE-Institute of Transportation Engineers can be summed up as the application of technology and scientific principles to the planning, functional design, operation and management of facilities for any mode of transportation to provide safe, rapid, comfortable, convenient, economical and environmentally compatible movement of people and goods.

Components of Transportation System

A transportation system consists of different components which together allow people and goods to overcome the hindrance of geography. The different components are:

1. **Fixed facilities**

These are the physical components of the system that are fixed in space and constitute the network of links and nodes. Road, railway track, ocean or waterways, airports harbor etc. are fixed facilities of their respective modes.

2. **Flow entities**

These are the components that traverse (travel through) the fixed facilities. They mainly include vehicles and are considered on the basis of shape, size, weight, acceleration and deceleration abilities. For example, road vehicles, trains, aircraft, ships etc.

3. **Control system**

This system consists of vehicle control and flow control.

Vehicle control refers to the technological way in which the vehicles are guided either automatically or manually. Flow control consists of the means that permit the efficient and smooth operation of stream of vehicles and the reduction of conflicts between them. Eg: traffic control using traffic lights, at the intersection, road signs and markings, air traffic control etc. help in the smooth flow of vehicles.

Role of Transportation in Society

Transportation is an inseparable part of a society. In fact, the measure of the development of any society is characterized by how developed transportation system is. Advancement in transportation has made a vast change in the quality of life of people. Impact of transportation can be summarized as below:

1. **Economic role**: Transportation plays an important role in developing the economic aspect of a society. Economics involves production, distribution, and consumption of goods and services which are inevitable without the transportation facility. In a country like Nepal which has a wide gap between production and consumption, an effective mode of transportation can always be helpful for its economic growth. Rice of terai need to be transported to the hills and the apples of Humla and Jumla need to be brought up to the terai.
2. **Social role**: Development of transportation system influences the formation of urban society. It links rural areas with urban ones transporting goods from one place to other, eventually helping in overall development. Transportation also promotes cultural and social exchanges. It provides employment opportunities.
3. **Political role**: The world being divided into different political units for mutual protection, economic advantages and development of common culture is linked by transportation of both people and goods through different modes. Transportation plays a vital role in functioning of these political units.
4. **Environmental role**: The environment is highly affected by transportation. Its harmful aspect is more prominent than its useful aspects. Air pollution, noise pollution, overuse of non-renewable energy etc. are some of its impacts on the environment. Transportation safety (mainly road safety) is of major concern.

1.2 Modes of Transportation

a) Primary Mode
   - Land Transportation (Highway, Railway)
   - Air Transportation
   - Water Transportation
   - Pipeline Transportation

b) Secondary Mode
   - Ropeway
   - Belt conveyors
   - Canal

Primary Mode

Land Transportation

1. **Highway**: The major advantage of the highway is that it has high accessibility to almost all potential destinations, direct service with very low door-to-door travel times, moderate speeds and capacities. Capital cost for physical facilities is also moderate. Vehicles are small and readily available at a low cost. However operating cost tends to be higher. Environmental impacts of the system as a whole are high and are a major social concern.

2. **Railway**: The railway system provides moderate speeds and levels of accessibility. Accessibility is only limited to railway stations. A heavy capital must be invested in both physical facilities and flow entities. This mode is very effective for transportation of a lot of goods through land.

Air Transportation

The main advantage of air transport is its high speed and less time consumption. Accessibility is limited but is of less importance as greater lengths of trips are made. Capital investment as well as operating and maintenance cost for both fixed and flow entities are higher than other modes. Environmental impacts are significant, air and noise pollution of commercial aviation but are of less concern than that of highways.

Water Transportation

Water transportation provides low speed and relatively low accessibility, but extremely high capacities. The capital cost of vehicles, especially ships are very high but operating cost is low for a large distance. So, if a lot of goods is required for transportation, this mode can be used for best results. Environmental effects are relatively low but the chances of water pollution due to leakage of oil and petroleum products are high.

Pipeline Transportation

The transport of daily use products and wastes to the desired location encompass pipeline transportation. They provide very low speed, but the high capacity constant flow and involves a large amount of working storage. Environmental impacts are generally low.

Secondary Mode

A variety of other modes also exists although they do not contribute in major transportation, however, are inevitable.

Ropeway refers to special type of carriers suspended from or simply attached to an overhead rope. Ropeway is an effective, economic and environmentally friendly way of crossing hills. Belt conveyors are belt supported on rollers that provides steady movement of materials. Cable and belt are systems extensively used in industries for transportation of goods. Canals are also used in transportation for irrigation system in rural areas.

In the Context of Nepal

Nepal is a landlocked country. The possibility of waterways is less due to the presence of fast flowing rivers. So, water transport is only limited to small distances for fishing and crossing the rivers. Also, most of the area is covered by hills and mountains. So, the potentiality of any mode of transport becomes less. But road transport is the best option Nepal has carried out so far. However, there is a lot of potential for ropeways and railways. Although it is difficult to provide railways at every place it can be a useful mode of transport. The government of Nepal has established a Department of Railways giving more priority on the development of railway tracks. Similarly, ropeways program is also being started at different places in Nepal.

1.3 Comparison between Various Modes of Transportation:

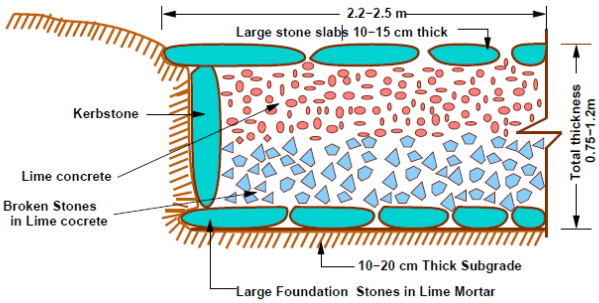
	Roadway	**Railway**	**Airway**	**Waterway**	**Pipeline**
Accessibility	High	Moderate	Low	Low	Low
Speed	Moderate	Moderate	High	Low	Very Low
Capacity	Moderate	Higher than roads.	Capacity per vehicle is limited.	High capacity per vehicle.	High capacity.
Initial Capital Cost	Moderate	High	High	High	Moderate to High
Operating Cost	High	Moderate to High	High	Low	Low (Depends mainly upon pumping cost).
Efficiency	Not high	High	Low	Very High	High

1.4 Historical Development of Roads:

- The first mode of transportation was by foot. This led to the development of footpaths.
- The next major mode was the use of animals. This led to the development of trackways as the loaded animals required more horizontal and vertical clearances.
- The invention of wheel in Mesopotanian civilization led to the development of animal drawn vehicles. Then it became necessary that the road surface should be capable of carrying greater loads. Thus, roads with harder surfaces emerged.

1. Roman Road

- Romans constructed an extensive system of roads radiating in many directions from Rome.
- Romans recognized that the fundamentals of good road construction were to provide good drainage, good material and good workmanship.

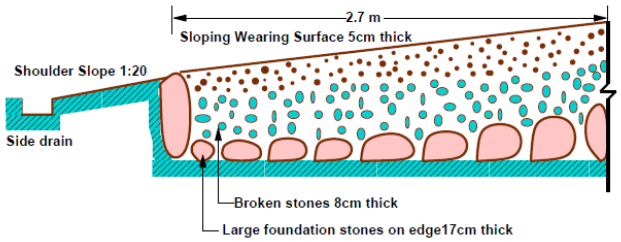


- Roads were constructed on a firm-ground subgrade strengthened where necessary with wooden piles.
- Roads were bordered with longitudinal drain.
- **Construction of Agger:**
  - Raised formation upto 1m high and 15m wide.
  - Constructed with materials excavated during side drain construction.
  - This was then topped with a sand levelling course.
  - Agger contributed greatly to moisture control in the pavement.
  - In case of heavy traffic, a surface of large 250mm thick hexagonal flag stones were provided.
- **Main Features:**
  - Built regardless of gradient.
  - Used heavy foundation at bottom.
  - Mortar made from lime and volcanic pozzolana and gravel added to make concrete.
  - Concrete was a major Roman Road making innovation.

The roman road network built during seven centuries extended over a total length of 90000 km. of which about 14000 km still exist in present day.

2. Tresaguet Roads (French Roads)

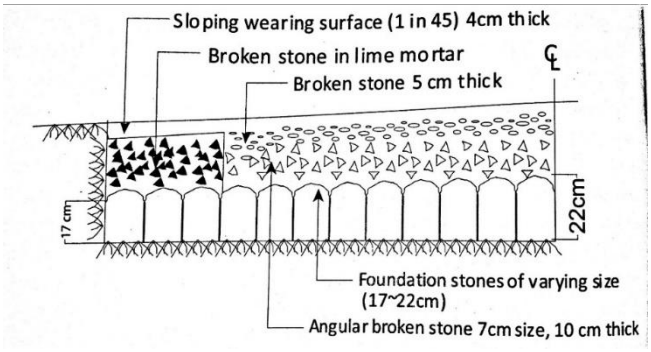
- The next major development in the road construction occurred during the regime of Napolean.
- Contributions were given by Tresaguet in 1764 and was implemented in 1775.
- He developed a cheaper method of construction than the lavish and locally unsuccessful revival of Roman practice.



- Pavement used 200mm pieces of quarried stone of a more compact form and shape such that they had at least one flat side which was placed on a compacted formation.
- Small pieces of broken stones were than compacted into spaces between large foundations to provide a level surface.
- Running layer with 25mm sized broken stone was made.
- All this structure was placed on a trench to make running surface in level with the surrounding country side.
- Drainage problems was counteracted by making the surface as impervious as possible, cambering the surface and providing deep side ditches.

3. Telford Construction

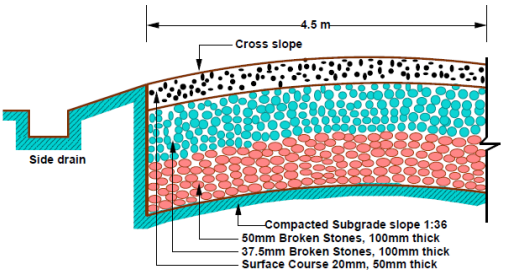
- Telford in England (1757-1834) proposed similar type of construction as Tresaguet in France.
- Slopping surface on the top was achieved by providing varying size of stones in foundation.
- For lateral confinement, Telford used a block made of broken stones in lime water.



4. Macadam Construction (British Roads)

- First scientific road construction method.
- Economical method of road construction.
- Stone size was an important element of macadam road construction.
- John Macadam (1756-1836), a Scottish road builder, is considered as the *pioneer of modern road construction*. Macadam came to realize that 250mm layers of well

compacted broken angular stones would provide the same strength and stiffness and a better running surface than an expensive pavement founded on large stone blocks.



- The mechanical interlock between the individual particles provided strength and stiffness to the course.
- Inter particle friction abraded the sharp interlocking faces and partly destroyed the effectiveness of the course.
- The effect was overcomed by introducing good quality interstitial finer material to produce a well-grained mix.
- Such mix proved to be less permeable and easier to compact.

5. **Modern Roads**
   - Follows Macadam's construction method.
   - Uses bituminous concrete and cement concrete.
   - Various advanced and cost-effective construction technologies are used.
   - Development of new equipment helps in the faster construction of roads.
   - Easily and locally available materials are tested in laboratories.

1.5 Road construction in Nepal:

- 70,000km distance road is constructed in Nepal.
- Local roads contribute to distance more than 52000km.
- Headquarters of Dolpa and Humla are not connected with roads.
- 400 villages are devoid or roads. 15000-20000km roads are to be constructed to overcome this.
- Out of Bhaktapur, Kathmandu and Lalitpur, Bhaktapur is highly fascilated with roads.
- 60% of National Highways are black topped.
- 40-50% of Feeder roads are black topped.
- Total SRN Length: 12898.20km
- Total Population: 26620809
- Total Area: 147181 sq.km.
- Population influenced per km. roads (Nos.) = 2064
- Road Density (km/100 km^2) = 9

1.6 Transportation Planning Including Objective of Road Planning

Transportation system requires a continuous planning to optimally satisfy the mobility requirement of the society. Planning becomes significant when the resources available are limited and requirements are higher. The main objective of planning is to optimally utilize the available resources in the best possible way and in a very systematic manner.

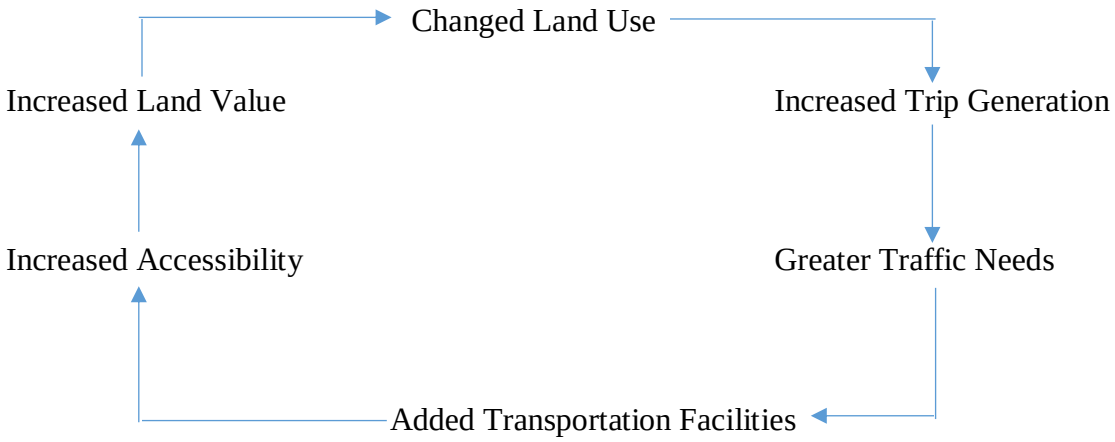


Fig: The land use Transportation Cycle

Types of planning

Transportation planning can be divided into short term, medium term and long-term planning.

Short term (1-3 years) and *medium-term (3-5 years)* planning can be defined relatively in the same way. They are less complex and put no great demand on construction activities and require less capital expenditure. It includes Transportation System Management (TSM).

Long-term (More than 5 years) planning is a complex problem and requires huge financial expenditure and involves large and extensive construction programs which affect the environment in economic, social and natural aspects.

Desired solution is obtained through carefully constructed policy making at the multi-levels of government and administration involved which could be solved best through system approach.

The System Approach

The system approach is a decision-making process for complex problem solving composed of:

- **System analysis:** A clear evaluation of the combinations of all the elements that structure the problem and those forces and strategies needed for the achievement of an objective.
- **System engineering:** Organizing and scheduling complex strategies for problem-solving. It includes:
    - Identifying the problem
    - Tackling the problem considering all facets
    - Use of scientific methods
    - Working as per predetermined sequence
    - Scientific decision

In dealing with long term transportation planning, three basic elements should be considered:

a) Forecasting demand
b) Description of economic, social and environmental changes
c) An evaluation of the system in term of benefits and dis-benefits

The planner should continuously deal with three different groups having their own vested interest namely operators, users and non-users.

- The operator is concerned with capital costs, operating costs, operating revenues and the viability of the plan.
- The user is concerned with monetary cost, journey time, safety and security, reliability and comfort and convenience.
- Large number of people who neither travels nor causes goods or people to move are also affected by the proposals of the transportation planner. Such non-users are affected by land use changes, social disruption and economic effects.

Land Use-Transportation Model

Land use transportation model is an effective way to study and design transportation plans. The land use-transportation model can be studied under two phases: *calibration phase* and *projection phase.* The calibration phase is followed by projection phase. In the calibration, phase models are built and tested using data from a base period and in the projection phase, the developed model is used to determine future transport design based on socio-economic projection for a design year.

Road Plan/Highway Plan

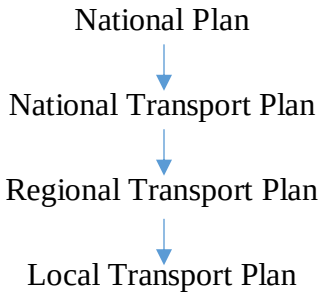


Fig: Hierarchy of Road Transportation Planning

Objectives of Road Planning

1. **To establish an integrated network of road:**

An integrated highway network capable of accommodating all highway travel in an orderly, safe, efficient and economical way is required. Hence highway development plan is an essential part of national transport plan. For this following three processes should be followed:
-Forecast the future requirement of roads needed.
-Set up priorities and schedules of construction and renewal program in accordance with the available resources.
-Financial planning and management.

2. **To fulfill the needs of the society:**

Road planning is basically accepted as an outcome of the needs of the society. The first step in planning is to identify all the present as well as the future need of the society. These needs are to be fulfilled in the second step of planning.

Road planning can be grouped as:

National Road Network Planning

It is the planning of all roads to be developed in the national context and includes:

- National Highways
- Feeder Roads

Nepal's national road network plan is in the form of the linear pattern with the dead ends on hill district headquarters. National highways run east to west and north to south to which feeder roads or district roads are connected to link district headquarters and major cities, towns, villages etc.

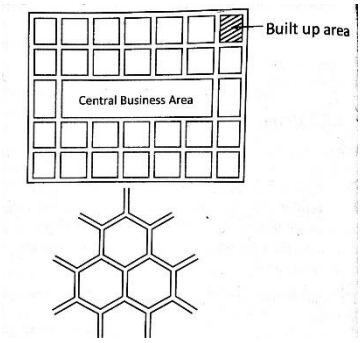
Urban Road Network Planning

Urban areas must be developed in a sustainable way so that the development remains intact for many years. So, planning of road networks in urban areas is an integral part of its development.

The major road patterns developed in modern urban areas are as follows:

1. **Grid Iron Pattern**
- **Rectangular or block**
- **Hexagonal**

2. **Radial Pattern**



Grid Iron Pattern

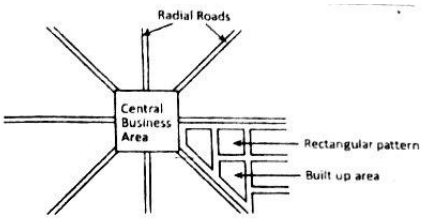
In grid iron pattern the built-up area is obtained in a rectangular or hexagonal shape. It can produce monotonously long streets and dull blocks of the building. However, it encourages even spread of traffic over the grid and as a consequence, the impact at a particular location is reduced.

Advantages

- Low cost
- Simple to plan
- Gives good circulation plan and easy for plots subdivision.
- Efficient in providing drainage and sewerage network

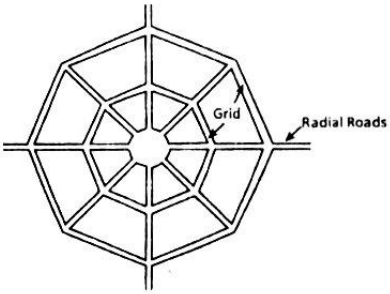
Disadvantages

- Offers limited urban design options
- Produces constrained and rushed psychological effect
- Can be confusing and frustrating.



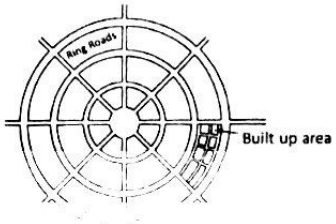
Radial Pattern

This system is widely used in many countries to join one town centre to another town centre. Thus, any given town may have several roads radiating from its centre to other towns and villages around it. As towns grow in size, they turned first to develop along the radial direction and fill in the spaces after that. The main traffic generator is located within the centre area and all radiating roads converge on the main business area of the focal point.



Ring Roads:

- Ring road is a radial pattern of road which runs in circumference to an urban area so as to avoid excess traffic inside the area.
- There may be doubling or tripling of rings depending upon the size of the urban area and requirement of population.



- Due to ring roads there is a direct access to the to the town centre. The town centre may be a core business area and may have banks, shopping complexes, entertainment centers etc.
- In Kathmandu, an inner ring road is already built. Due to the increasing population and increase in no. of vehicles, an outer ring was proposed and now is in construction phase.

Road Transport

Road transport is one of the common, efficient and accessible modes of transport.

Advantages of Road Transport:

- **Wide geographical coverage:** It covers a large area and can penetrate the interior of any region to connect remote places.
- **Large influential area:** Development of other modes of transport is only limited to target areas whereas road network can help in the economic and social development of almost all the areas it passes through.
- **Low capital investment**
- **Flexibility:** Road transport offers most flexible service to the passengers. Other modes like railway and airways have a fixed schedule which cannot be changed according to the demand.
- **Quick and assured deliveries:** Road transport offers quick and assured deliveries. Articles like milk, meat, vegetables and other perishable items can only be transported through roadway. It provides easy and efficient handling of these materials in an uneconomic way.
- **Highest employment opportunities.**
- **Low cost of packaging:** road transport involves very less handling process so the cost of packaging of goods is effectively lessened.
- **Economy:** It is economical for short distance travelling.
- **Safety:** It has less disastrous effect than other modes.

Disadvantages of Road transport

The disadvantages of road transport are:

- Land coverage: Roadways tend to use up more land. It destroys agricultural land and natural terrain. There is a chance of soil erosion, damage of forests lands and other physical structures if not properly constructed.
- Environmental Pollution: Compared to other modes it is one of the main cause for air pollution. Use of bitumen during construction also affects the environment.
- Poor safety records.
- Uneconomical for long distances

Highway engineering and its scope:

The science which deals with the planning, design, construction, operation, and maintenance of roads and roadway facilities for the convenience of road traffic is known as Highway Engineering. The scope of highway engineering can be listed as:

- Highway development, planning and location.
- Highway design: geometrics, structure, hydraulic design of drainage system pavement.
- Highway construction materials, equipment, technology.
- Highway maintenance.
- Traffic operation and its control
- Roadside development and landscaping.
- Highway finance economics and administration.

1.7 Classification of Roads: Strategic Road Network, Rural/Local Road Network, Urban Road

According to Nepal Road Standard (NRS) 2070, roads in Nepal are classified as:

Administrative classification:

According to this classification roads are classifsied as:

- National Highways
- Feeder Roads
- District Roads
- Urban Roads

National Highways: These are main roads connecting east to west and north to south of the country. These roads shall be the main arterial routes passing through the length and breadth of the country as a whole. They provide consistently higher level of service in terms of travel speeds. They are designated by letter 'H' followed by a two-digit number.

Feeder Roads: These roads connect district headquarters, major economic centers, tourism centers to national highways or other feeder roads. They are designated by letter 'F' followed by three-digit number.

District Roads: Important roads within a district, serving areas of production and markets and connecting with each other or with the main highways are district roads.

Urban Roads: Urban Roads are the roads serving within the urban municipalities.

According to the hierarchy of travel movement urban highway can be classified as:

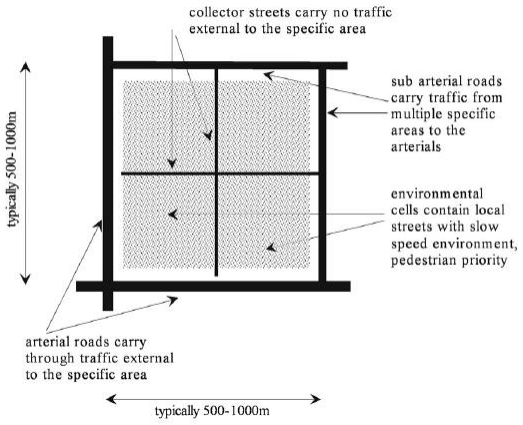
Expressway: They are divided arterial highways for vehicular traffic with full or partial control of access and provides grade separated intersection.

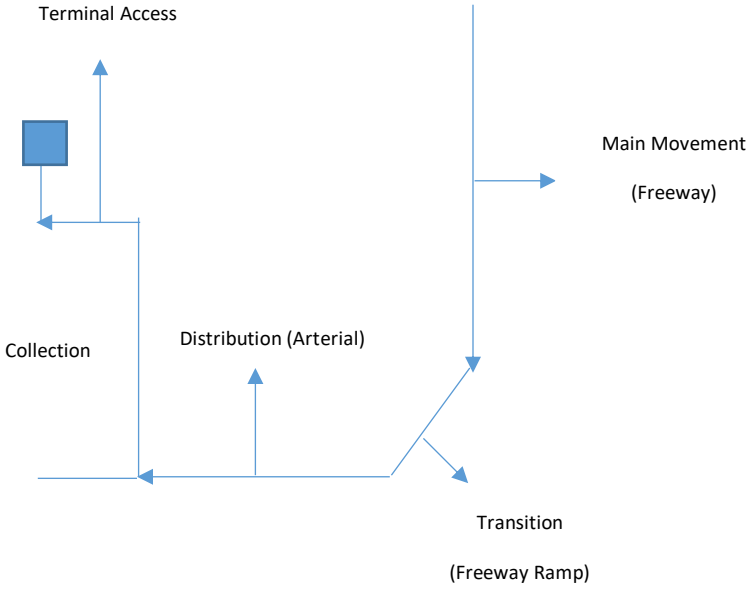
Arterials: They carry through traffic external to the specific area.

Sub-arterials: They carry traffic from multiple specific area to the arterials.

Collector: They provide indirect and direct access for land users within specific area.

Local Streets: They provide direct property access.





In Nepal the overall management of National Highways and Feeder Roads comes within the responsibility of the Department of Roads (DOR). These roads are collectively called *Strategic Roads Network (SRN*) roads. District Roads and Urban Roads are managed by Department of Local Infrastructure Development and Agricultural Roads (DOLIDAR). These roads are collectively called *Local Roads Network (LRN)* roads.

Technical Classification:

	Design Speed(km/hr)	ADT in 20 years prospective period (pcu)
Class - I	120	>20,000
Class - II	100	5000-20,000
Class - III	80	2000-5000
Class - IV	60	<2000

PCU- Passenger Car Unit.

For the design of roads, the class of road is taken as the basic deciding factor which is ascertained based on the traffic volume on the road. But an approximate correlation can be established between the administrative and functional classifications of the roads as follows in the table below:

	Plain and Rolling Terrain	**Mountainous and Steep Terrain**
National Highway	I, II	II, III
Feeder Roads	II, III	III, IV

Rural Road Classification

District Road Core Network (DRCN): An important road joining a VDC HQ's office or nearest economic centre to the district headquarters, via eithera a neighbouring district headquarters or the Strategic Road Network.

Village Road: Smaller roads not falling under District Road Core Network category are Village Roads, including other Agriculture Road.

Reference:

Khanna, S., & Justo, C. *Highway Engineering.* Nem Chand & Bros, Roorkee.

Marsani A. and Shrestha D.K. (2071), Transportation Engineering Volume - I, Divine Print Support, Lagan Tole, Kathmandu

Parajuli P.M. (1999), Course Manual of Transportation Engineering - I, IOE, Pulchowk Campus, Lalitpur, Nepal.

Nepal Road Standard 2070

Nepal Rural Road Standard 2071

IIT Lecture Notes