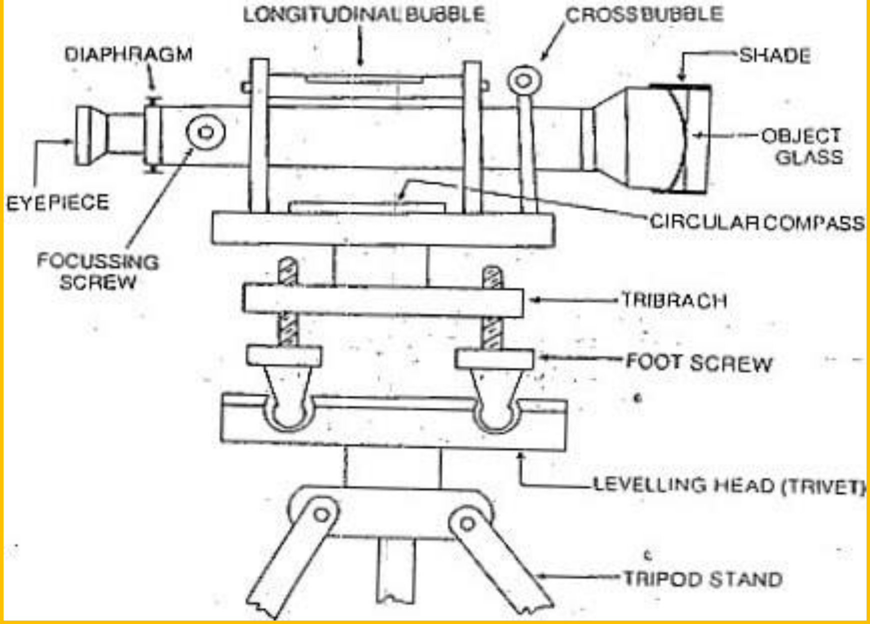
GEOG - 605

PRACTICAL GEOGRAPHY



DEPARTMENT OF GEOGRAPHY AND NATURAL RESOURCE MANAGEMENT

SCHOOL OF EARTH AND ENVIRONMENTAL SCIENCE
UTTARAKHAND OPEN UNIVERSITY

(Teenpani Bypass, Behind Transport Nagar Haldwani (Nainital) Uttarakhand)

M.A / GEOG - 605

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BLOCK -1 MAP PROJECTION

UNIT-1 MAP PROJECTION, MEANING, PRINCIPALS & CLASSIFICATION

1.1 OBJECTIVES

- To know the importance of projections in map making.
- To convey the usefulness of projections in the study of the entire area of the globe to researchers.
- To do a detailed study of the methods, requirements and types of construction of projections.

1.2 INTRODUCTION

Map projection generally means a network of latitude and longitude lines, which play an important role in clarifying the maps and geographical features of different regions of the vast earth. Map projection is the art of displaying the spherical three-dimensional earth on a flat two-dimensional map. Since the earth is spherical, displaying it on a flat surface is a complex task, but with the help of map projections, a cartographer prepares surface maps by creating projections for different parts of the earth. Because every projection has some problem related to area, distance, direction and size, this is the biggest drawback of projections. But with the help of different projections, maps of the earth's surface are easily prepared using mathematical and statistical techniques. While displaying the three-dimensional form of the earth in two dimensions, many distortions have to be faced, the solution of which is only map projections. Because the size of the earth is so huge it can neither be seen at once nor can the whole part be made in three-dimensional form. Thus, to fulfil various purposes and to solve map-related problems, maps are prepared with the help of projections and those projections as per the region.

The selection of map projection depends on the purpose for which the map is being made. Thus, according to the regional diversity of the earth, projections are made by cartographers on a flat surface by light or geometric methods, which are mainly, divided into four parts for the convenience of study, conical, cylindrical, zenithal and conventional projection etc. In conical projection, the earth is projected in the shape of a cone. This projection shows the regions near the poles more easily, which shows continents such as maps of the northern hemisphere's North America, Europe and Asia easily. Cylindrical projection is especially useful for equatorial regions, in which exact direction and exact shape maps of the world are easily made. Mercator projection is considered to be the most useful among cylindrical projections, which is used a lot in navigation. While in zenithal projection, maps are made by considering any one point of the earth as the centre.

This projection is useful for air travel and radio communication because, in this, maps are prepared by considering any centre point of the earth as the base. Zenithal projections are classified as centroidal, stereoscopic, and orthogonal projections. In the same conventional projection, a map is made arbitrarily to fulfil a specific purpose, based on which it is called conventional projection. Apart from this, mathematical projections are also being used at present, which work to remove the distortions of most projections, for example, Robinson projection is its main example. Map projections are mainly used to provide correct information about the local area of the earth, to provide direction-related information, and to make map projections more useful by removing distortions of maps by displaying them in the form of small parts on the vast surface of the earth, so that maps can be made as per the standards of cartography.

1.3 MAP PROJECTION, MEANING, PRINCIPALS& CLASSIFICATION

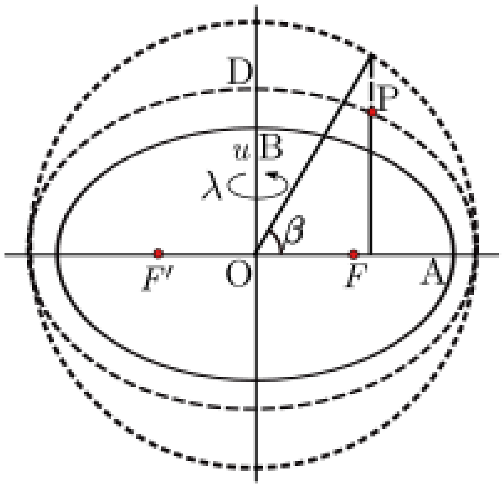
1.3.1 Map projection Meaning and definition-The grid of latitude and longitudelines on the sphere of the earth is called map projection. The land grid of latitude and longitude lines with the help of geometric or light for making a map of any large area of the earth on a flat surface is called map projection. The literal meaning of map projection is to display a figure made on a transparent film or paper on a wall with the help of light. The geometrical method is the most suitable in the making of maps by which the errors in the map are removed because the exact depiction of the shape of the earth is possible only through a globe and no map projection is correct in terms of size, area and direction, but it is possible to make a projection of any particular quality from the properties of pure direction in equal area and orthogonal projections. Therefore, keeping in mind the objective of the map, the appropriate projection is selected. Different scholars have clarified the definition of map projection, but the meaning generally appears the same.

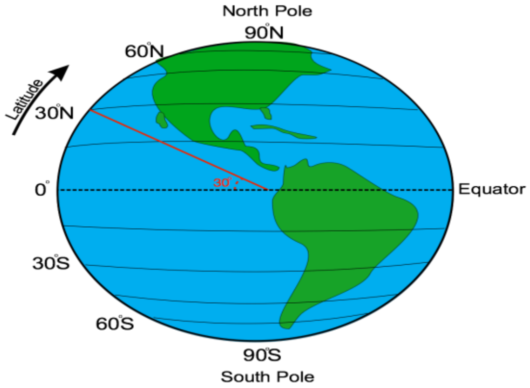
1. **Irwin Rays**“Any systematic sequence of latitude circles and meridians on which a map can be made can be called a projection”.
2. **F.J. Mockhouse**“The display of the earth's latitude circles and meridians in the form of a network or line grid on a flat surface is called map projection”.
3. **J.S. Steers** “Map projection displays the globe's latitude and longitude lines on a flat

Paper".

1.3.2 Elements of Map Projection-Due to the vast area of the earth's surface, it is difficult to display it accurately on a flat surface. As on the globe, the sum of the three angles included in the triangle formed by the equator and any two longitude lines situated at a distanceof 90^0degrees is equal to three dimensional, whereas the sum of the angles included in the three dimensionalon a flat surface is 180 degrees. The reason for this is that on the globe, except the poles, the latitude and longitude lines are divided at right angles at all other places, that is, latitude and longitude are required to make a map of any land area of the earth. These latitude-longitude and latitude circle meridian are the elements of map projection.

1. Latitude -The angular distance measured in parts of the arc of the meridian between any place and the equator on the globe is called the latitude of that place. The number of latitudes in the entire globe is 180 along with the equator, 90 imaginary lines are drawn on the globe to the north and south of 0 latitude. The distance between two latitudes keeps on decreasing from the equator towards the east and west hemispheres. Only on the equator, the distance is equal and in the rest of the latitudes, it is negative.





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2. Latitude Circle-The line joining the points equidistant from the equator of all the meridians on the globe is called the latitude line or latitude circle. The imaginary lines showing the value of any place between 0^0 to 90^0 to the north or south of the equator are called latitude circles which are drawn at intervals of 5^0, 10^0 and 15^0 degrees and tell the position of any point on the globe to the north or south of the equator. Latitude circles have some characteristics.

1.As all latitude circles are drawn parallel to each other at equal distances.

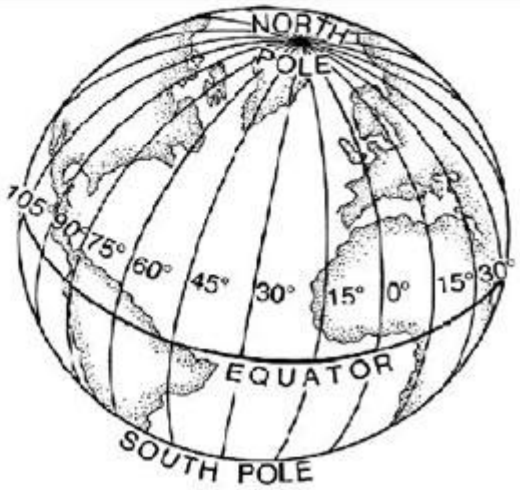
2. These circles cut the meridians at right angles to the poles.

3. The circle of the equator is known as the great circle.

4. The latitude circles of the poles are in the form of points.

5. The upper part of the equator is known as the northern hemisphere and the southern part is known as the southern hemisphere.

3. Longitude - The imaginary 360^0 lines drawn at an equal distance from the main longitude on the sphere of the earth by light or geometrical method are called longitude lines. At the international level, the standard line has been named as Green Witch Line which passes through the Royal Observatory near London. Other longitude lines drawn towards east and west are calculated from the Green Witch Line only. 180^0-180^0 degrees lines are drawn to the east and west of 0^0 longitudes. The distance between two longitude lines is 111.32 km. The time is determined based on longitude lines only in the entire earth, i.e. all the countries have their standard longitude and based on that the time and daily calendar of that place is determined.



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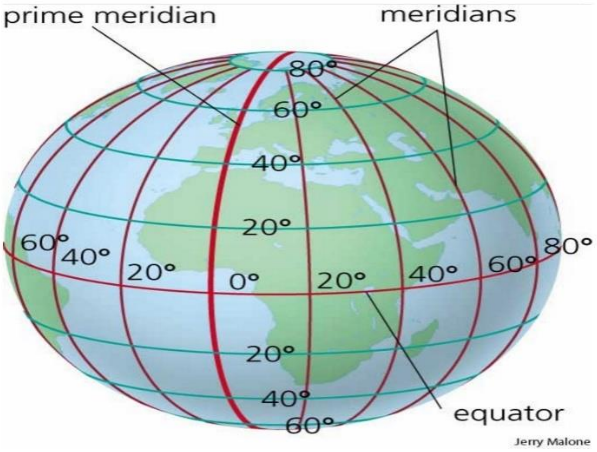
4. Meridian-The imaginary lines joining the places of the same longitude on the globe are called meridians. Each meridian is a big circle through which half part represents the eastern hemisphere and half part represents the western hemisphere which is called eastern and western longitude. The northern and southern ends of the longitude lines meet at the poles. 180^{0}eastern and western longitude lines are the same line. One characteristic of a meridian is that each longitude line is half part of a big circle. The meridian drawn on the globe has some characteristics which are described by the following points.



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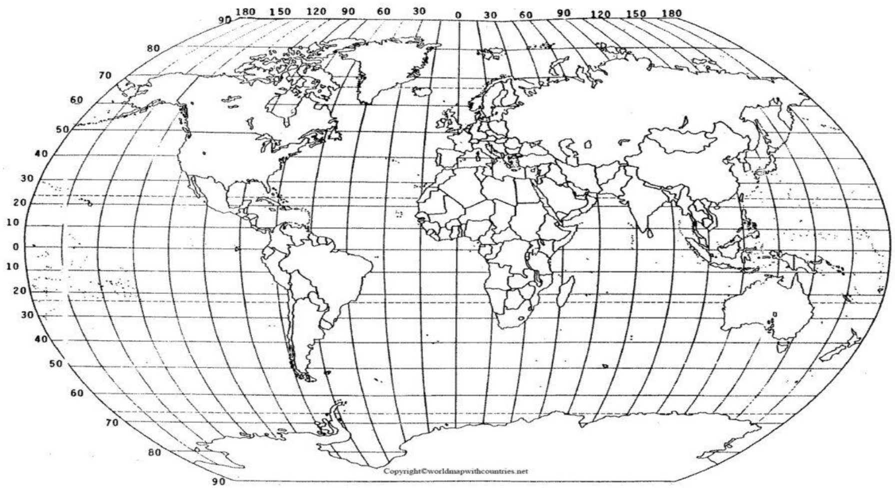
1. The direction of all longitude lines is from north to south.

2. The maximum distance between longitude lines is on the equator and it is zero on the poles.

3. The lines drawn on the globe are drawn at a fixed interval. That interval is 180^0.

4. Longitude lines indicate the east and west parts of a place.

5. Geogrid- The network of latitude and longitude lines is called geogrid. This grid reveals the direction and location of the points situated on the surface. If a grid is situated at 75^0 north and west longitude, then the geometric position of that place will also be 75^{0}north and west longitude. Similarly, the geometric position of all the places on the globe is determined through the grid.



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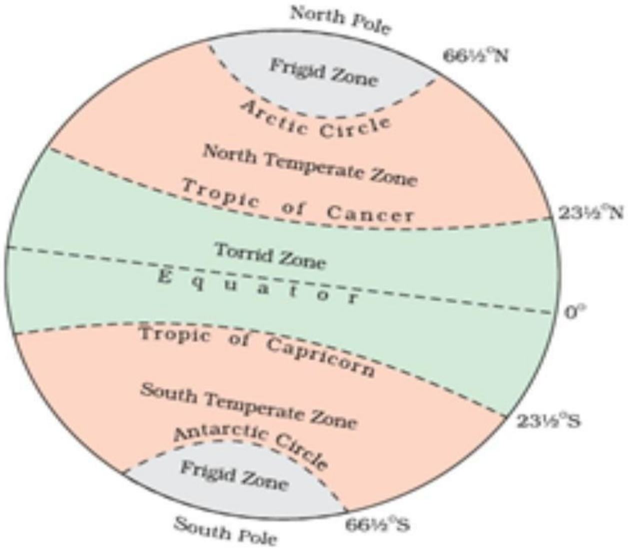
6. Zones and tropics-The part situated between two adjacent longitude lines on the sphere of the earth is called a zone and the part between two latitude lines is called a zone, such as a tropical zone, tropical zone cold zone etc. The area of the tropics on the globe keeps on decreasing towards the poles, this is the main characteristic of the tropics.



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7. Scale -For the construction of maps of any land part of the earth, the scale of the projection is determined first. Because in the absence of scale, projections and maps cannot be constructed and neither do we have any paper available to show the entire earth on a large scale, therefore the real form of the earth is revealed only through a certain scale. Assuming the length of the radius of the earth to be 635000000 cm or 250000000 inches, the reduced sphere is constructed for the projections of all maps by finding the radius in centimetres or inches. Detailed discussion of various scales of maps has been done in the previous chapters.

1.3.3 Need and history of map projections-The need for projections in maps was first felt to show the flat and huge shape of the earth in a realistic form on paper, but this task was not possible by any one projection. As different projections were required according to regional differences, other projections were created, due to which at present, conical, cylindrical, zenithal and conventional projections were created by mathematical and geometric methods. The need for projections was first felt by a Greek scholar named Eratosthenes, who measured the circumference of the earth and made a map of the known world using seven latitude and seven longitude lines.

Hipparchus modified Eratosthenes' irregular grid and drew latitude and longitude lines at equal distances, while Thales used nomadic projection for astronomical maps.The greatest contribution to the development of cartography was made in the Greek period, the proof of which is found in the great book Geographia by Claudius Ptolemy, who mentioned the methods of making globe and map projection in the first section of this book. In the same dark age, the prevalence of religious superstitions of Christianity had obstructed the development of cartography, while the period from the 14th to the end of the 17th century was the Renaissance period when the development of cartography took off again and new projections were created. In 1559, Girardus Mercator created the cylindrical Mercator projection, Nicolanus Sanson created a projection in 1650, John Flamsteed created the sinusoidal projection, and Johann Heinrich created the Lambert projection, thus giving a modern form to the projection development. Modern James Gaul Malvid and G.Titer Schmid did remarkable work.

The need for maps was mainly to bring the large form of the earth on paper, to avoid difficulties in carrying the globe from one place to another, to solve the problem of measuring complex distances between two places on the globe, to show small parts of the earth on a large scale and to reduce the cost of the globe. Map projections were needed by which the above problems of the globe were solved. Especially more accurate maps are prepared by equal area and orthographic projection. However, map projections are not required in preparing maps of small parts of the earth because these maps are not affected by the spherical nature of the globe.

1.3.4 Classification of map projections- Map projections are mainly divided into three types.

1.Based onthe use of light

2.Based onthe method of construction

3.Based on Merrit

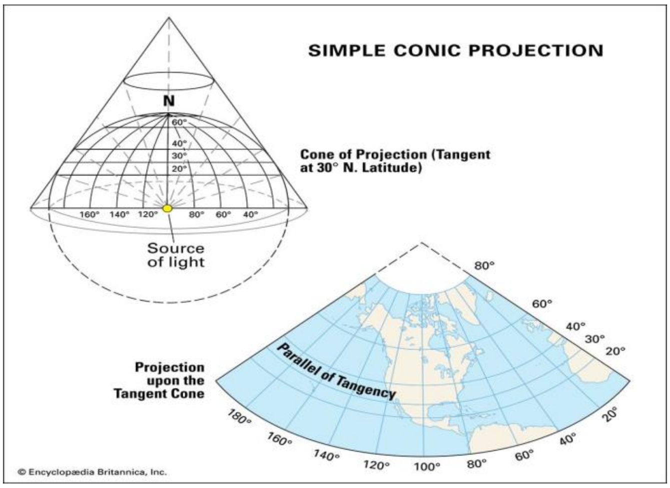
1. Based onthe use of light-Based on light, map projections are divided into two parts.

1. Perspective map projection- Map projections made with the help of light are called perspective projections. In these projections, by throwing light from a fixed point, its shadow is transferred to a flat surface. After this, a picture is prepared with the shadow of latitude circles and meridians with the help of a pencil. Perspective projection is also called geometrical projection.

2. Non-perspective map projection- The map projection prepared by perspective map projection with the mathematical method is called non-perspective projection. These projections are those which show geometrical, equal area or pure direction.

2. Based on construction method- Based on construction method, map projections can be divided into four categories.

1. Conic projection - Conic projection works on the principle of transferring the geo-grid marked on the globe to a paper cone and after the transfer, spreading the paper of the cone on a flat surface. In these projections, it is assumed that the paper cone touches the globe at a selected latitude circle and the apex of the cone is situated at a point on the extended polar axis of the earth, just above the pole. That is the centre of the earth, the pole and the apex of the cone all three are in a straight line. The latitude circle at which the paper cone touches the globe is called the standard latitude. Conic projections are of two types such as simple conic projection (one standard latitude), and modified conic projection (projection with more than one standard latitude), Bonn, multiconic, and international projections are examples of conic projections.



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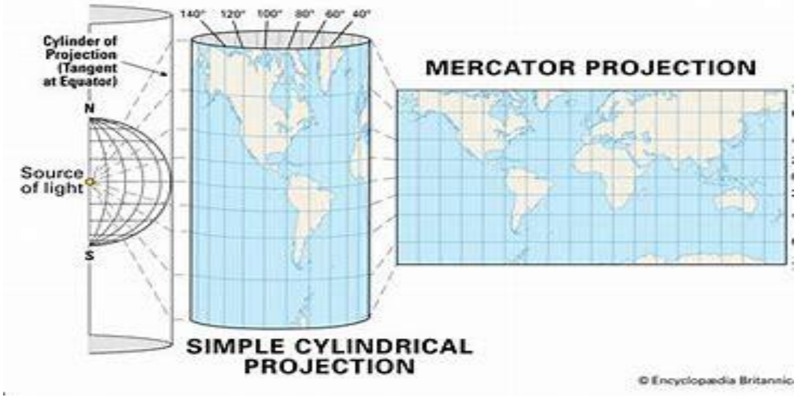
2. Cylindrical projection - Cylindrical projection generally touches the cylindrical globe at the equator. These are projections made from the latitude-longitude network after projecting the geo-grid on the outer surface of the hollow cylinder paper and then spreading the paper of the cylinder flat. Under these projections, exact or perspective cylindrical, normal or equidistant cylindrical, cylindrical equal area, Mercator or cylindrical orthographic and Galle projections are mainly included. Cylindrical projections have some common features which are as follows.

1. Except forthe equator, the scale is inaccurate at other latitudes and all latitude circles are in the form of straight and parallel lines of equal length.

2. All longitude lines are straight and parallel lines of equal length.

3. Every longitude line intersects each other at right angles.

4. The distance of latitude circles is determined based on the objectives of the projection.



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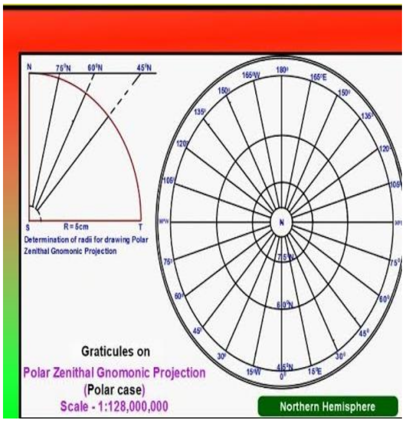
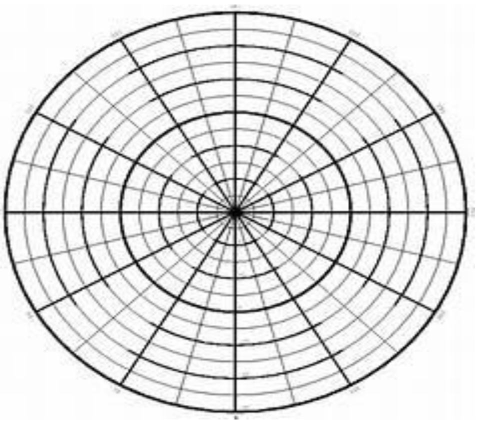
3. Zenithal projection- The latitude-longitude network projected on a flat surface touching the sphere of the earth at any point is called Zenithal projection. The plane of the projection touches the globe at the equator, pole or any point situated between the two. Normic, stereoscopic, orthogonal, polar Zenithal, oblique Zenithal and equatorial Zenithal projections are included under Zenithal projection. Like cylindrical projections, Zenithal projections also have their distinct features which are described as follows.

1. All the large circles passing through the centre of the Zenithal projection are shown by straight lines on the map.
2. All the points situated at the same distance from the centre oftheprojection are also equidistant on the map.
3. There is also equality in the amount of change and distortion of scale at places situated at equal distancesfrom the centre of the map.
4. The zenithal projection represents one hemisphere.





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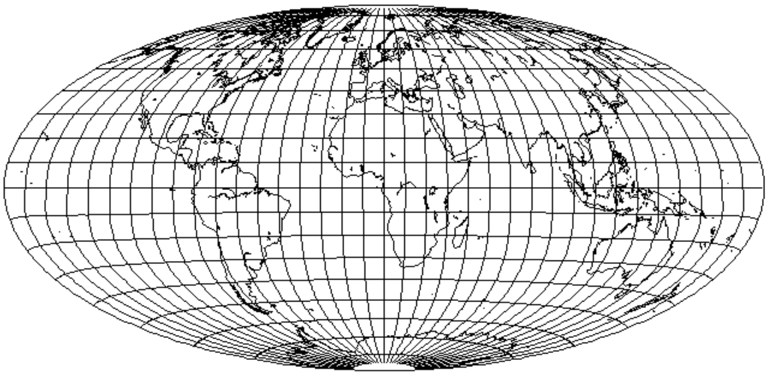
4. **Conventional projection-** The projection made on the principle chosen arbitrarily to fulfil a specific purpose is called conventional projection. In conventional projections, maps of the entire world can be prepared.

3. Projection based on Merrit

No projection has all the properties such as pure shape, pure area, pure direction, pure scale and composition-related properties of a projection, in which pure shape, area and direction are the most important. Based on these three properties, map projections are divided into three parts.



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1. **Orthogonal projection-** This projection displays the same shape of any smallest part of the earth on the map as is on the globe. On this basis, it is named orthogonal projection.

2. **Equal Area Projection-**The area remains pure everywhere in the projection made with the help of equal area projection, hence it is named equal area projection. In these projections, the scale is increased in one direction and decreased in the other direction, as a result of which the area of a region in the map remains pure but its actual shape changes. Malvid and Sanson Flamsteed's Sinusoidal Projection are the main examples of equal area projection.

3. **Pure direction projection-** Maps made on Mercator and zenithal projection have pure direction. Pure direction means the direction of the straight line joining two points on the map.

1.4 SUMMARY

Map projection is a network of latitude and longitude lines, which clarify the maps and geographical features of the vast land area of the earth. Map projection is the art of displaying the spherical three-dimensional earth in a flat two-dimensional map. Maps of different parts of the earth are prepared with the help of map projections because in every projection there is some problem related to area, distance, direction and size. In the construction of map projections, the three-dimensional form of the earth is displayed in two dimensions with the help of mathematical and statistical techniques, in which many types of distortions occur which are removed with the help of map projection. Because the size of the earth is so huge it can neither be seen at once nor can the entire part be made in three-dimensional form. In this way, to fulfil different objectives and solve map-related problems, maps are prepared by projection according to the region, which depends on the purpose for which the maps are being made.

In this way, according to the regional diversity of the earth, projections are made by cartographers with the help of light or geometric methods on a flat surface, which are mainly divided into four parts for the convenience of study, conical, cylindrical, zenithal and conventional projection etc. In conical projection, the earth is projected in the shape of a cone, while in cylindrical projection, exact direction and exact shape maps of equatorial regions are made, polar maps are made by zenithal projection and maps of the entire earth are made by conventional projection, i.e., latitude-longitude are required to make a map of any land area of the earth. Elements of map projection include latitude-longitude, latitude circles and meridians.

1.5 GLOSSARY

Map projection	The network of latitude and longitude lines is called map projection.
Conical projection	The process of making the land grid marked on the globe on a cone and spreading it on a flat surface.
Cylindrical projection	Making a map projection by making a network of latitude and longitude on a flat surface and wrapping it in a hollow cylinder is called cylindrical projection.
Zenital projection	The network of latitude and longitude lines projected on a flat surface **is** considered to be touching any point of the globe.
Conventional projection	The projection made on the principle selected arbitrarily to fulfill certain objectives is called conventional projection.
Northern Hemisphere	The northern part from $0^0$to 90^0latitude of the equator is called the Northern Hemisphere.
Southern Hemisphere	The southern part from $0^0$to 90^0 latitude of the equator is called the Southern Hemisphere.

Latitude	The 180^0 imaginary lines drawn from east to west parallel to the equator are called latitude.
Longitude	The 360^0 imaginary lines drawn from north to south parallel to the 0^0 line are called longitude.
Scale	The proportion of paper used for making maps of any landmass on the earth is called scale.
Meridian	The imaginary lines joining the places of same longitude on the globe are called meridians.
Latitude Circle	The line joining the points equidistant from the equator of all meridians on the globe is called a latitude circle.

1.6 ANSWER TO CHECK YOUR PROGRESS

- Map projection generally means a network of latitude and longitude lines.
- Map projection is the art of displaying the spherical three-dimensional earth on a map in two dimensions on a plane.
- In conical projection, the earth is projected in the shape of a cone.
- Mercator projection is considered to be the most useful among cylindrical projections.
- Zenith projection is useful for air travel and radio communication.
- Robinson projection is an example of mathematical projection.
- Every meridian is a large circle through which half part represents the eastern hemisphere and half part represents the western hemisphere.
- The literal meaning of map projection is to display a figure made on a transparent film or paper on a wall with the help of light.
- Latitude The angular distance measured in inches of arc of meridian between a place and the equator on the globe is called the latitude of that place.
- Latitude Circle The line joining the points equidistant from the equator of all meridians on the globe is called a latitude line or latitude circle.
- The imaginary lines joining the places of equal longitude on the globe are called meridians.
- Girardus Mercator projection was created in 1559.

- Johann Heinrich gave a modern form to projection development by creating Lambert projection.
- Map projections are mainly divided into three parts based on light, composition and quality.
- Map projections made with the help of light are called perspective projections.
- The map projection prepared from perspective map projection by mathematical method is called non-perspective projection.

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1.8 TERMINAL QUESTIONS

1. Long Answer Questions

Q.1-Explain the meaning, definition and elements of map projection and describe in detail the types of map projections.

2. Short Answer Questions

Q.1- Explain what is map projection?

Q.2- Write the meaning and definition of map projection?

Q.3- Describe the main elements of map projection.

Q.4-What do you mean by latitude circle?

Q.5- What is a meridian?

Q.6- Explain the need and history of map projections?

Q.7- Classify map projections?

Q.8- Explain map projections based on light?

Q.9- Classify map projections based on quality?

Q.10- What is the role of scale in a map?

3. Multiple Choice Questions

Q.1. What is displayed in a map projection?

A) Latitude

B) Longitude

C) Latitude and longitude network

D) None of the above

Answer C

Q.2- The shape of the globe is?

A) One-dimensional

B) Two dimensional

C) Three dimensional

D) All of the above

Answer C

Q.3- Mercator projection is used for?

A) For maps of equatorial regions

B) For navigation

C) For Polar Regions

D) A and B above

Answer D

Q.4-Mathematical projections are used for?

A) To remove distortions in projections

B) To make projections attractive

C) For use of mathematics in projections

D) All of the above

Answer A

Q.5- Each meridian of the earth represents?

A) A small circle

B) A large circle

C) Conic circle

D) All of the above

Answer B

Q.6- What is the literal meaning of map projection?

A) A figure drawn on a cloth

B) A network of figures drawn on a transparent film or paper

C) A film drawn on a wall

D) All of the above

Answer B

Q.7- "The representation of the earth's latitude circles and meridians in the form of a network or a line network on a flat surface is called map projection." Who said this?

A) Monkhouse

B) Hartshorne

C) Ptolemy

D) Steers

Answer A

Q.8- What is meant by geogrid?

A) A network of latitude and longitude lines

B) A group of latitude lines

C) A group of longitude lines

D) All of the above

Answer A

Q.9- Who created the Lambert projection?

A) Girardus Mercator

B) Johann Heinrich

C) Flamsteed Sinusoidal

D) None of the above

Answer B

Q.10- Map projections are mainly divided into how many parts?

A) 5

B) 8

C) 3

D) 4

Answer C

Q.11- Map projections are divided based on light into?

A) Perspective map projection

B) Non-perspective map projection

C) Mathematical projection

D) A & B of the above

Answer D

UNIT-2 CONSTRUCTION OF PROJECTION ON GRAPHICAL TRIGONOMETRICAL METHOD

2.1 OBJECTIVES

After studying this chapter you will be able to:

- Comprehend the basics of projection and trigonometry.
- Understand different types of projections.
- Identify the various map projections by using latitude and longitude patterns.
- Creating different types of Projections.

2.2 INTRODUCTION

The representation of the Earth's curved surface on a flat map has always been a challenge in cartography. Different projection techniques are applied to resolve this, projecting the three-dimensional Earth onto two-dimensional planes. Among these, the Graphical Trigonometrical Method is one of the classical techniques that employ trigonometric principles to construct map projections. This chapter delves into the construction of projections using this method, explaining its significance, principles, and step-by-step procedures. The Graphical Trigonometrical Method is a geometric approach that uses the principles of trigonometry to create projections. This technique, which is especially helpful for producing azimuthal and conical projections, usually entails the graphical generation of latitude and longitude lines using trigonometric computations.

2.3 CONSTRUCTION OF PROJECTION

2.3.1 CONICAL PROJECTION

There are numerous ways to depict the earth's shape on its surface. In this projection, the globe hits the cone at a certain point after folding a flat piece of paper into the shape of a cone and covering it on the globe. This idea has guided the construction of the conical projection. The prime latitude line of the projection is the latitude line of the globe that contacts the cone. In this manner, the pole will appear as the top of the cone if a light is placed in the center of the globe. The equator cannot become the prime latitude line since the cone never touches it.

SIMPLE CONICAL PROJECTION WITH ONE STANDARD PARALLEL

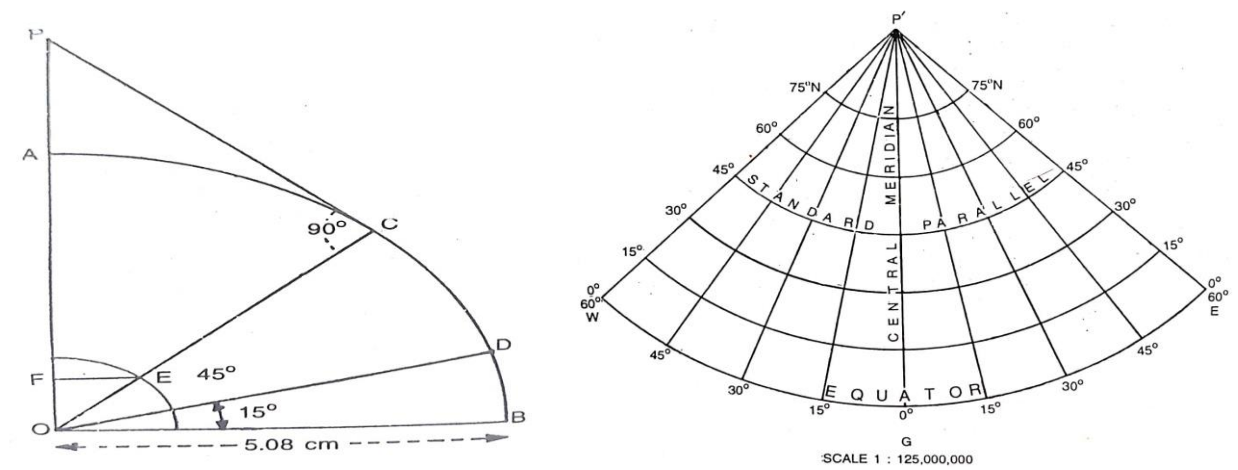
Example- Scale 1:125,000,000; Standard latitude, 45° North; Area Extension from 0 to 75° North latitude and 60° West to 60° East longitude; Interval 15°,

Radius of the reduced sphere of the earth according to the given scale, that is

$$= \frac{635,000,000}{125,000,000} + 5.08\ cm \ldots$$

According to Figure 2.1 A, draw the quadrant ABO of the circle with radius 5.08 cm. At point O of line OB, make angle DOB equal to 15° interval and angle COB equal to standard latitude. Draw a perpendicular at point C which intersects the extended line OA at point P. Now considering O as centre, draw a circle with BD semi diameter which cuts the OC line at point E. Draw EF perpendicular to line OA from point E.

Fig: 2.1Simple conical projection with one standard parallel



A **B**

Source: practical geography by J. P. Sharma

To make the projection, draw a perpendicular straight line P'G, which will be the central meridian in this projection and its value will be 0° longitude as per the question (Fig. 2.1 B).

Now draw a circle from point P' taking a distance equal to PC, which will show the standard latitude line of 45° North in the projection. To make other latitude circles, put two marks towards P' and three marks towards G from the standard latitude line at a distance of BD on the central meridian. Draw arcs of circles through these marks taking point P' as the centre and write the values of latitude lines in degrees on these arcs as per the figure.

Now mark four marks on either side of the central meridian at a distance of EF in standard latitude. Draw the straight lines joining these marks to point P'. These straight lines will show the longitude lines in the projection. Complete the projection by writing their values on the longitude lines.

Uses - This projection is often used to make maps of small countries located in the middle latitudes. Apart from this, maps of such regions are also made on this projection which has less latitudinal extension.

SIMPLE CONICAL PROJECTION WITH TWO STANDARD PARALLEL

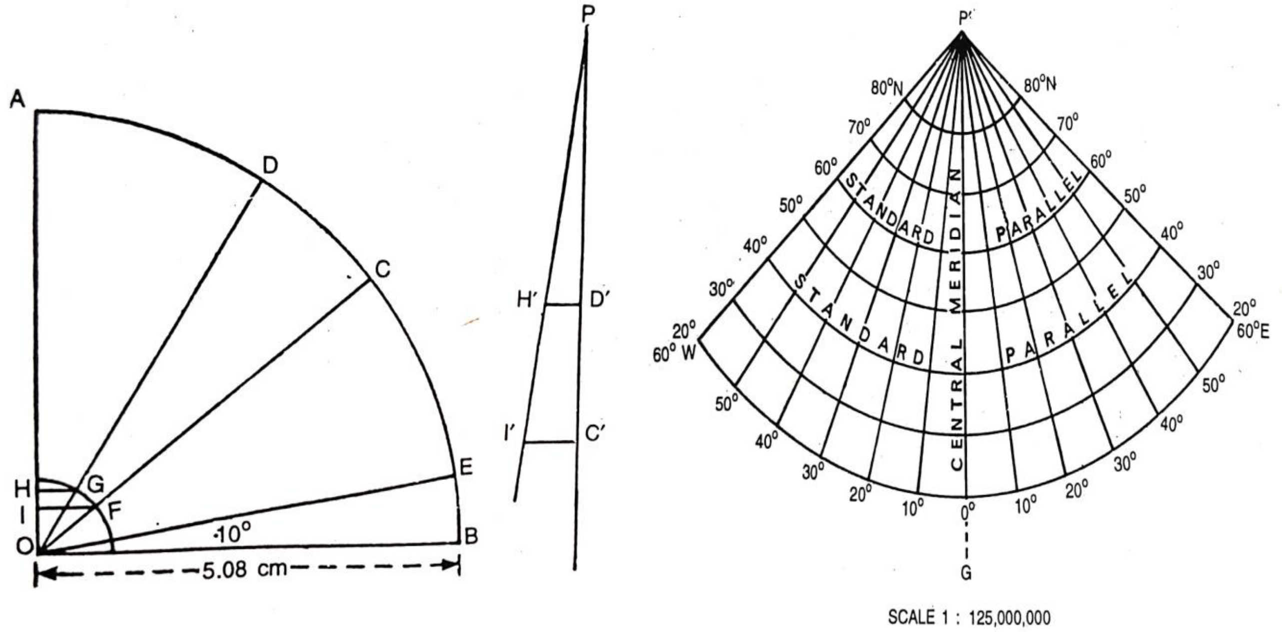
Example- Scale 1:125,000,000; Area Extension from 20° to 80° North latitude and 60° West to 60° East longitude; Interval 10°, consider the 40° and 60° N latitude circles as standard latitudes.

Radius of the reduced sphere of the earth according to the given scale, that is

$$R= \frac{635,000,000}{125,000,000} + 5.08\ cm \ldots$$

As per Figure 2.2A, draw a quadrant ABO of a circle with a radius of 5.08 cm. At point O of line OB, draw an angle EOB equal to 10° interval and angle COB and angle DOB equal to standard latitudes of 40° and 60°N respectively. Draw a quadrant of the circle at point O with arc distance EB which cuts OC and OD lines at points F and G respectively. Drop perpendiculars FI and GH from points F and G on line OA respectively. Draw a perpendicular straight line as per Figure 2.2B and cut a distance C'D' equal to CD in this line. Draw perpendiculars C'I' and D'H' equal to FI and GH respectively at points C' and D'. Draw a straight line joining points I' and H' which cuts the extended C'D' line at point P. In the projection, the arcs of the circle drawn with radii PC' and PD' with P' as the centre will represent 40 degree and 60 degree north standard latitudes respectively.

Fig: 2.2 Simple conical projection with two standard parallel



A **B**

Source: practical geography by J. P. Sharma

To make the projection, draw a perpendicular straight line P'G (Fig. 2.2 B). Taking P' as the centre, draw standard latitudes of 40° and 60° north respectively through radii PC' and PD'. Find the midpoint of both the standard latitudes on the central meridian. The distance of this point from any standard latitude will be equal to EB and the arc of the concentric circle passing through it will represent the 50 degrees north latitude circle. To make other latitude circles, mark the required number of marks on the central meridian at the distance of EB as in Example 1 and draw arcs of circles through these marks taking P' as the centre. At the standard latitude of 60°, mark six marks on both sides of the central meridian at the distance of perpendicular distance GH and draw straight lines joining these marks to P' which will represent the longitude lines in the projection. Remember, if you have to mark 40° north standard latitude for drawing longitude lines, then FI distance will be taken instead of GH. Complete the projection by writing their values on latitude circles and longitude lines.

Uses - In maps made on this projection, as the distance from the standard latitudes increases, the distortion in the shape and area of the regions starts increasing, hence maps of countries with large latitudinal extensions are not made on this projection. This projection has been used a lot in the cartographies of Europe and Australia for making maps of different countries or states.

BONNE’S PROJECTION

Example- Scale, 1 : 125,000,000; longitude, 15°; standard latitude, 45°N; extent of zone, 15°N to 75°N latitude and 15°E to 165°E longitude.

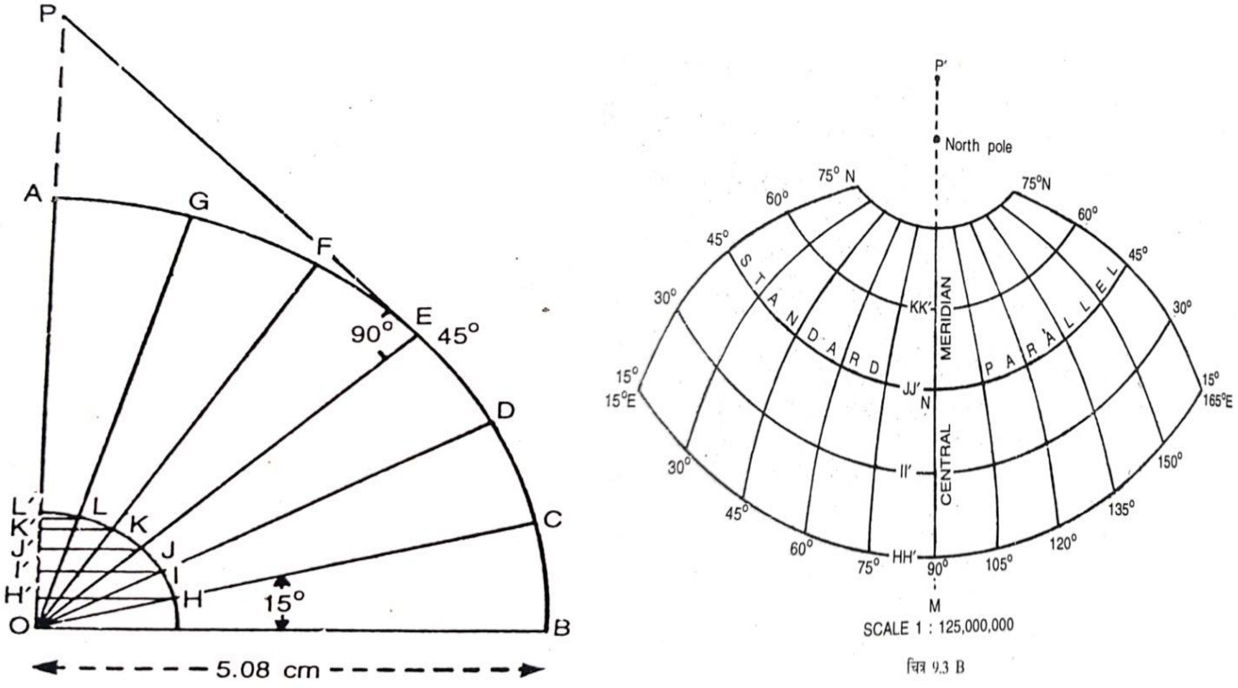
The radius of the sphere of the reduced earth according to the given scale, i.e.

$$= \frac{635{,}000{,}000}{125{,}000{,}000} + 5.08\ cm \ldots$$

As per Figure 2.3 A, draw a quadrant ABO of a circle with radius 5.08 cm. Draw lines OC, OD, OE, OF and OG at an angle of 15 degrees at point O of OB line. Draw a tangent at point E which cuts the extended OA line at point P. Now draw an arc with radius CB taking point O as the centre which cuts OC, OD, OE, OF and OG lines at points H, I, J, K and L respectively. From these points of intersection, drop perpendiculars HH', II', JJ', KK' and LL' on OA line respectively.

Now draw a perpendicular straight line P' M as shown in Fig. 2.3B, which will be the central meridian in the projection. Taking P' as the centre, draw an arc with the radius PE which cuts the central meridian at point N. This arc will represent the standard latitude of 45°N. After filling the BC distance in the compass, mark two marks on the central meridian from point N towards the pole and two marks from point N towards the equator. Draw arcs of concentric circles from the centre P' through these marks and write 15°, 30°, 45°, 60° and 75° north on them. Remember, point P' will not be the pole. In fact, if we mark another mark on the central meridian at a distance equal to BC beyond the 75° north latitude circle, then this mark will become the North Pole Will reveal.

Fig: 2.3 Bonne's projection



A **B**

Source: practical geography by J. P. Sharma

To draw longitude lines, mark at intervals of HH' on 15° latitude circle, at intervals of II' on 30° latitude circle, at intervals of JJ' on 45° standard latitude circle, at intervals of KK' on 60° latitude circle and at intervals of LL' on 75° latitude circle. Five marks will be made on each latitude circle on both sides of the central meridian. Complete the longitude lines by joining the marks of the same serial number of latitude circles and write its value in degrees on each longitude line.

Uses - Maps of Europe, Asia, and North America Bonne projection is widely used for making maps of America, South America, Australia and other large areas. But this projection is especially useful for showing areas with less longitudinal extension. For example, if the central meridian is chosen as 70° west, then an ideal map of Chile can be made on Bonne projection. The reason for this is that in Bonne projection, the shape along with the area near the central meridian remains correct to a great extent. Despite the increased distortion in the shape of the parts situated away from the central meridian, this projection is widely used for distribution and statistical maps of mid-latitudes. Apart from this, topographical maps are also made on this projection in countries like France, Switzerland and Belgium.

2.3.2 CYLINDRICAL PROJECTION

CYLINDRICAL EQUAL AREA PROJECTIONS

This projection is also known as **Lambert's cylindrical projection** in which the distance between latitude decreases towards the higher latitudes. In this projection, the pole is shown with the parallel equal to the equator; hence the shape of the area gets highly distorted at the higher latitudes. Therefore, the projection is non-orthomorphic. The parallels of latitude and the meridians of longitude intersect each other at the right angle. Area lying between 45º N and S latitudes can be suitably shown on this projection. The projection is also suitable to show the distribution of tropical crops such as coffee, rice and rubber etc.

Example- Draw a Cylindrical Equal-Area Projection for the world map on the scale of 1:320,000,000 with the interval of 15º. In drawing the projection, the following steps are followed.

Radius (R) of the reduced earth

$$= \frac{640{,}000{,}000}{320{,}000{,}000} = 2 \text{ cm (Radius of the actual earth is } 640{,}000{,}000 \text{ cm)}$$

Length of Equator 2πR or

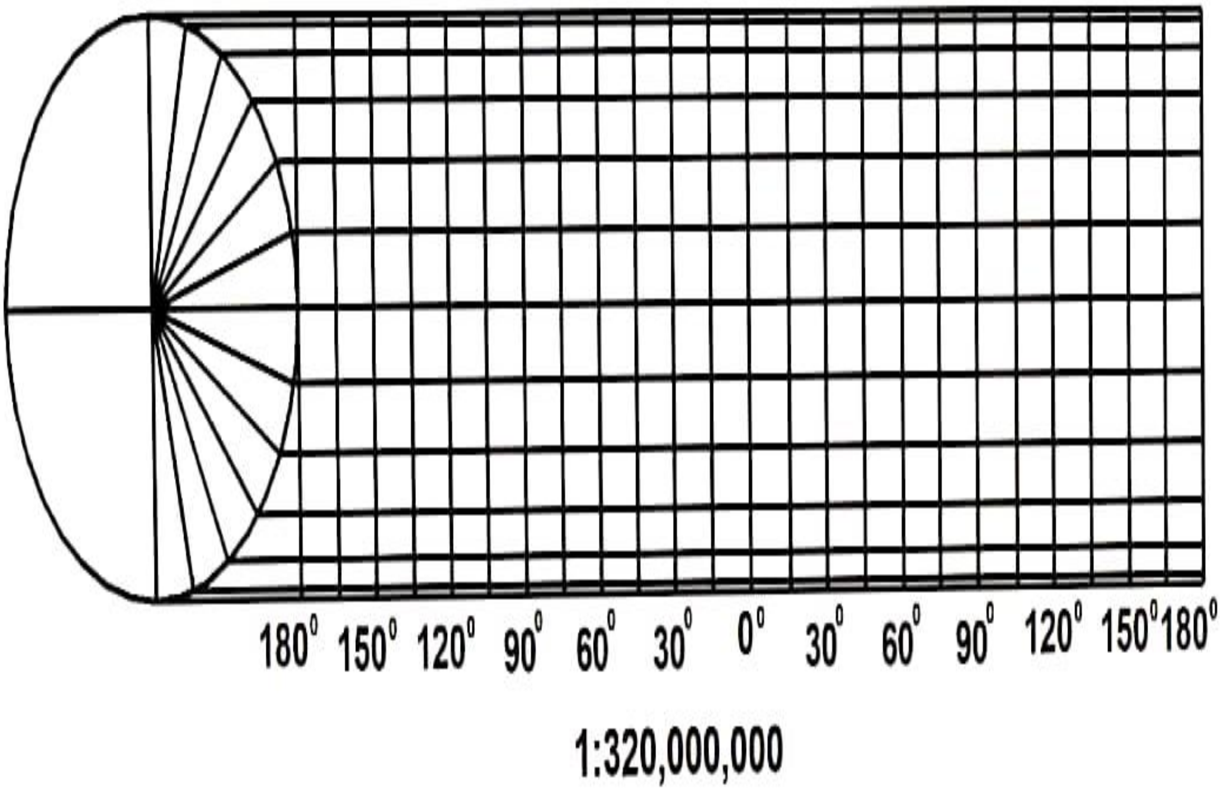
$$\frac{2\text{x}22\text{x}2}{7} = 12.57\ cm$$

Interval along the Equator

$\frac{12.57 \text{ x } 15°}{360°}$ = 0.52 cm

1. **1.** Draw a circle of 2.0 cm radius.
2. **2.** Mark the angles of 15º, 30º, 45º, 60º, 75º and 90º for both, northern and southern hemispheres.
3. **3.** Draw a horizontal straight line of 12.57 cm long to represent the equator on this projection.
4. **4.** Divide this line into 12 equal parts with the help of compass so that each part is 0.52 cm long. Draw a perpendicular North-South (NS), on West East (WE), at the central part. This will represent the central meridian.

Fig: 2.4 Cylindrical Equal-Area Projections



Source: Practical Geography by by J. P. Sharma

5. Divide the central meridian NS into six equal parts, with the help of a pair of compasses, each part being 0.52" long; in such a way that three parts are in the north of equator and the remaining three are to the south of equator. Draw lines parallel to the equator through these points. These lines will represent parallels of 30°, 60°and 90° north and south of the equator.
6. Similarly, draw lines parallel to NS and perpendicular to WE through the points already marked on WE. These lines will represent meridians of 30°, 60°, 90°,120°, 150° and 180° east and west longitudes.

This will complete the network of the projection (Fig. 2.4).

Uses and limitations of Cylindrical equal area projections

- This projection is most suitable for the area lying between 45º N and S latitudes.
- It is most appropriate to show the distribution of tropical crops like rice, tea, coffee, rubber and sugarcane etc.
- Distortion increases as we move towards the pole.
- The projection is non-orthomorphic.
- Equality of area is maintained at the cost of distortion in shape.

MERCATOR OR CYLINDRICAL ORTHOMORPHIC PROJECTION

A Dutch cartographer Mercator Gerardus Karmer developed this projection in 1569. The projection is based on mathematical formulae. So, it is an orthomorphic projection in which the correct shape is maintained. The distance between parallels increases towards the pole. Like cylindrical projection, the parallels and meridians intersect each other at right angle. It has the characteristics of showing correct directions. A straight line joining any two points on this projection gives a constant bearing, which is called a Laxodrome or Rhumb line.

- Very useful for navigation purposes showing sea routes and air routes: Since all the parallels and meridians intersect each other at right angles and both the parallel and meridian scales have the same ratio of exaggeration, any straight line drawn on this projection makes equal angles with all the parallels and meridians and represents a line of constant bearing on the projection. A line of constant bearing that intersects all the meridians at the same angle, such a line keeps constant bearing is known as Rhumb Line or Loxodrome.

- More suitable for a world map and widely used in preparing atlas maps.
- Drainage pattern, ocean currents, temperature, winds and their directions, distribution of worldwide rainfall and other weather elements are appropriately shown on this map.

Major limitations of the projection are as follows:

- Although, this is an orthomorphic projection in which shape as well as direction is preserved, its use is limited to small areas only.
- The exaggeration of scale is different at different latitudes and true orthomorphism is not applicable to large areas such as continents.
- Poles in this projection cannot be shown as 90º parallel and meridian touching them are infinite.

Example- Draw a Mercator's projection for the world map on the scale of 1:250,000,000 at 15º interval.

Radius of the reduced earth (R) is

$$= \frac{250{,}000{,}000}{250{,}000{,}000} = 1 \text{ inch (Radius of the actual earth is } 250{,}000{,}000 \text{ inch)}$$

Length of Equator 2πR or

$$\frac{2\text{x}22\text{x}1}{7} = 6.28 \text{ inches}$$

Interval along the Equator

$$\frac{6.28 \text{ x } 15°}{360°} = 0.26 \text{ inches}$$

Construction of Mercator's Projection

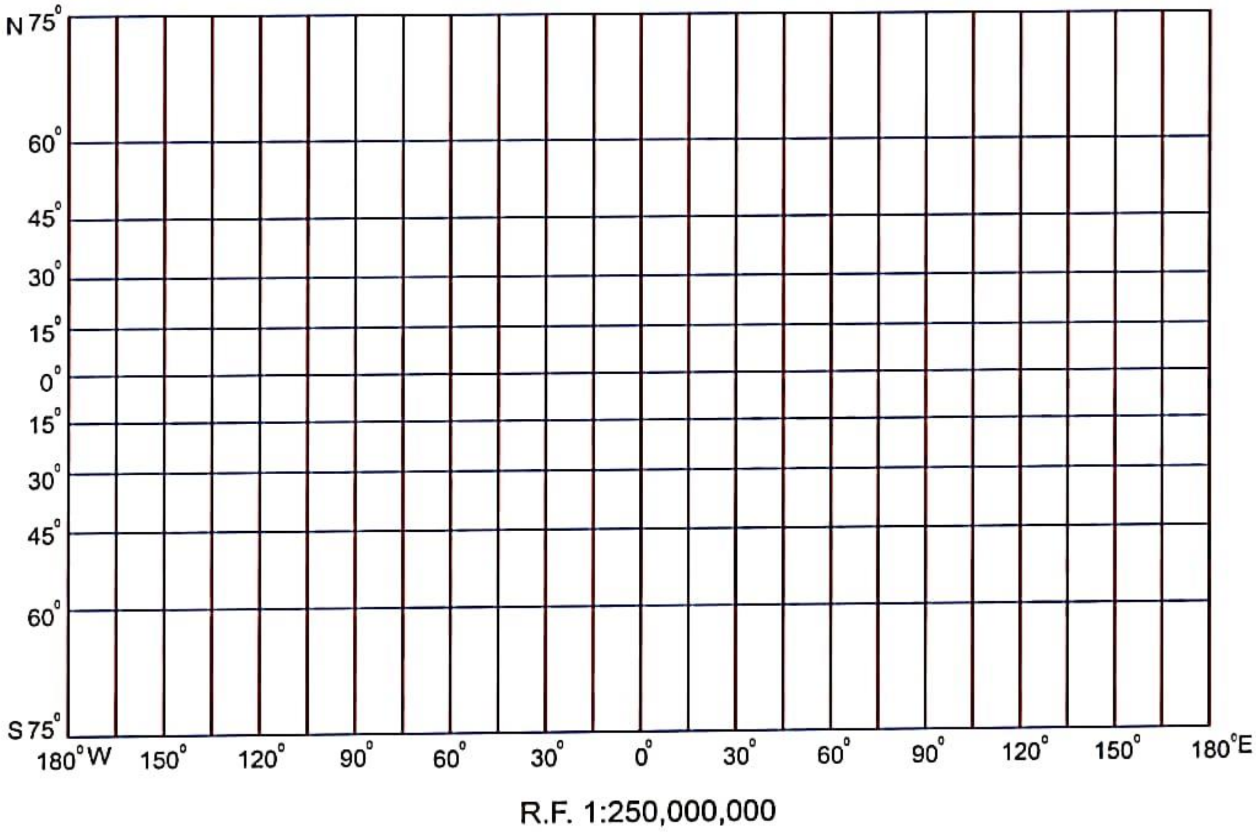
(i) Draw a line of 6.28" inches representing the equator as EQ:

(ii) Divide it into 24 equal parts. Determine the length of each division using the following formula:

(iii) Calculate the distance for latitude with the help of the table given below:

Latitude	Distance
15º	0.265 x 1 = 0.265" inch
30º	0.549 x 1 = 0.549" inch
45º	0.881 x 1 = 0.881" inch
60º	1.317 x 1 = 1.317" inch
75º	2.027 x 1 = 2.027" inch

Fig: 2.5 Mercator's Projections



Source: Practical Geography by by J. P. Sharma

GALL'S STEROGRAPHIC PROJECTION

The Gall's Projection is a cylindrical projection. The meridians are equally spaced, but the parallels are spaced at increasing intervals away from the Equator. This projection is neither conformal nor equal-area, but has a blend of various features.

Example- Construct a Gall projection for the world on a Scale of 1:250,000,000; keep the Interval in the projection at 15°.

(1) Radius of the reduced sphere of the earth, that is

$$R = \frac{635{,}000{,}000}{250{,}000{,}000} + 2.54\, cm \ldots$$

(2) Length of 45° latitude

$$= 2\pi \mathrm{R} \cos 45°$$

$$= \frac{2\times22\times2.54\times0.7071}{7} \text{ cm}$$

$$= 11.3 \text{ cm}$$

(3) Distance between longitudes and 15° interval

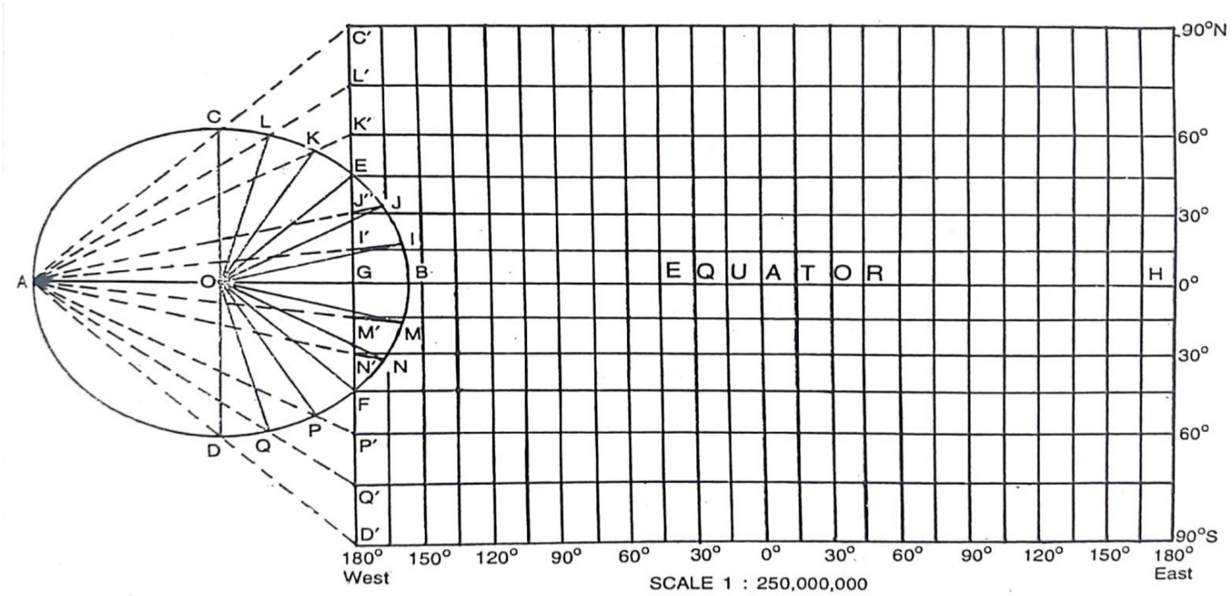
$$= \frac{2\pi R \cos 45° \times interval}{360}$$

$$= \frac{11.3\times15}{360} = 0.47$$

To make the projection, first draw a circle with a radius of 2.54 cm, in which AB and CD lines are the equatorial and polar diameters respectively (Fig. 2.6). Draw lines making angles at an interval of 15° on both sides of the OB line. These angle lines cut the circumference of the circle at points I, J, E, K, L and C on the upper side of the OB line and at points M N, F, P, Q and D on the lower side of the OB line. Now draw a straight line C'D' passing through the points E and F, the intersection points of the circumference of the circle and the 45° angle lines, which cuts the OB line at point G. This straight line will be 180° west longitude in the projection. Extend the OB line further and cut a GH line equal to 11.3 cm in it. The GH line will show the equator in the projection. Draw lines parallel to GH from points E and F, which in the projection will be the latitude circles of 45° N and 45° S respectively.

To draw the remaining latitude circles, draw straight lines joining point A to points I, J, K, L, C, M, N, P, Q and D situated on the circumference of the circle. These straight lines, when extended within the circle or further, cut the C'D' line at points I', J', K', L', C', M', N', P', Q' and D' respectively. Complete the northern latitude circles of 15°, 30°, 60°, 75° and 90° respectively by drawing lines parallel to GH from I', J', K', L' and C'. Similarly, draw southern latitude circles by drawing lines parallel to GH from M', N', P', Q' and D'. To draw longitude lines, divide the GH line into 24 equal parts at an interval of 0.47 cm and draw perpendiculars on both sides of the GH line at the dividing points.

Fig: 2.6 Cylindrical Equal-Area Projections



Source: Practical Geography by by J. P. Sharma

Uses - The Gall projection is especially useful for general maps of the world.

2.3.3 ZENITHAL PROJECTION

GNOMONIC OBLIQUE ZENITHAL PROJECTION

In the construction of this projection, like other gnomonic meridional projections, the light source is imagined at the center of the globe, but the position of the projection point can be imagined anywhere on the globe except the poles and the equator. Since the projection plane is located at a point between the equator and the pole, it is called the oblique case of gnomonic zenith projection.

Example-

Construct a gnomonic oblique zenith projection with 1:200,000,000 scales and 15° intervals. The center of projection is the point of intersection of the circle of 0° longitude and 60° N latitude.

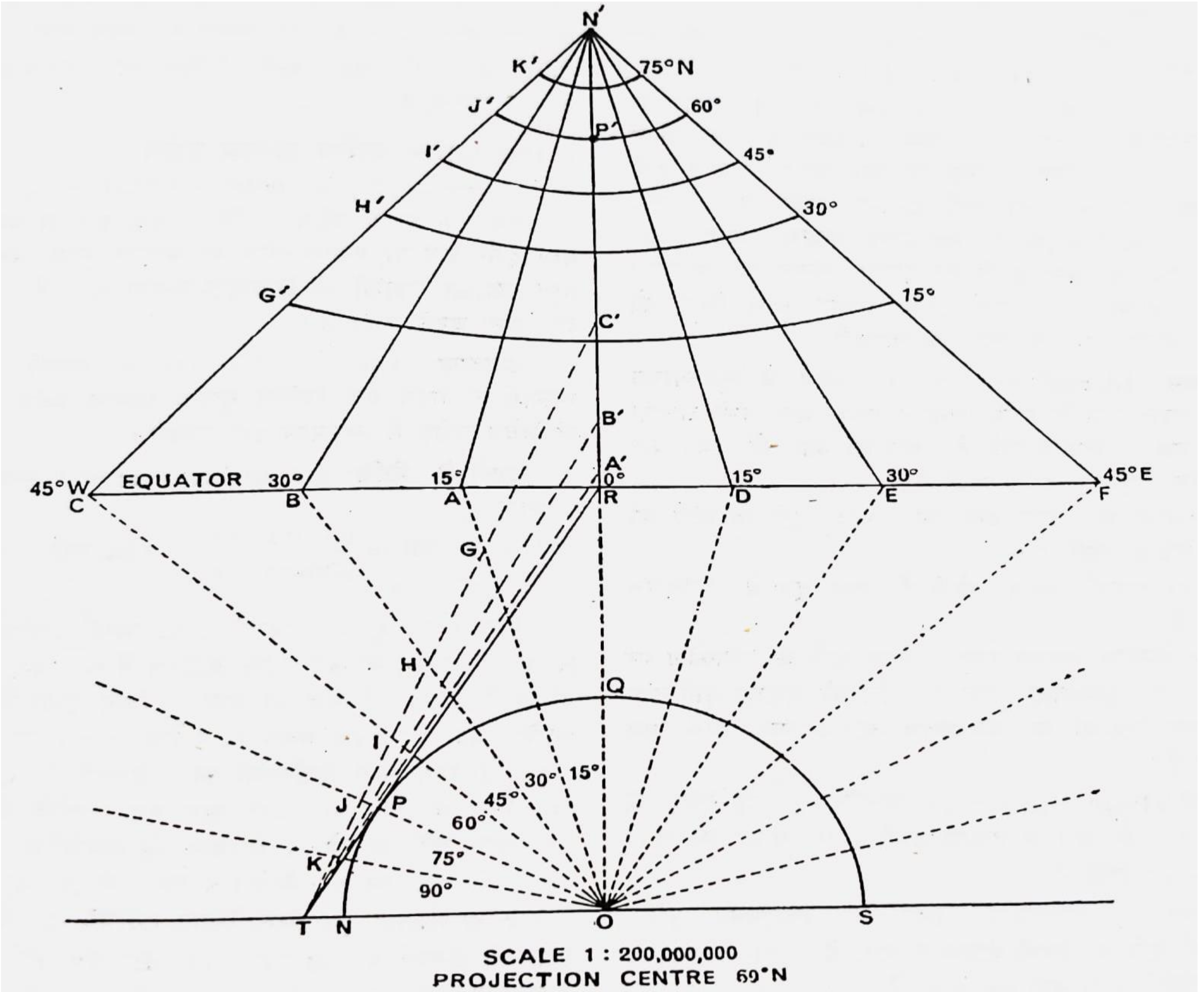
Radius of the reduced sphere of the earth, that is

$$R = \frac{635{,}000{,}000}{200{,}000{,}000} + 3.17\ cm \ldots$$

Draw a semicircle NQS with radius 3.17 cm as shown in Figure 2.7. In this semicircle, point N represents the North Pole, point S represents the South Pole and line OQ represents half of the equator. Draw angles of 15°, 30°, 45° and 60° on both sides of line OQ. The angle line of 60° north latitude cuts the semicircle at point P; hence this point represents the position of the centre of projection on the reduced earth's sphere. Draw a tangent TR at point P which cuts the extended ON and OQ lines at points T and R respectively. Draw a line CF parallel to NS at point R. Extend the angle lines of 15°, 30° and 45° and mark the points A, B, C and D, E, F on CF line. Now cut a distance RN' equal to the TR tangent in the extended line OQ. In the projection, the point N' will represent the North Pole and the CF line will represent the Equator. Join the points A, B and C with N' by drawing straight lines. These straight lines in the projection will be 15°, 30° and 45° western longitude lines (5) respectively from the centre of projection. Join N' with the points D, E and F and draw 15°, 30° and 45° eastern longitude lines respectively.

To draw latitude circles, draw TC', TB' and TA' lines is equal to N'C, N'B and N'A respectively. Now mark the distances of intercepts cut by angle lines drawn on TC', TB' and TA' lines on N'C, N'B and N'A respectively. For example, the distances CG', G'H', H'T', I'J', J'K' and K'N' marked on N'C longitude are equal to the distances of C'G, GH, HI, IJ, JK and KT intercepts of TC' line respectively. Mark the east longitude of a degree at the same interval at which marks are marked on the western longitude of a degree. The distances of intercepts of TR line will be marked on N'R line (central meridian of 0° longitude). Complete the curves of latitude circles by joining the same numbered marks marked on the longitude lines.

Fig: 2.7 Cylindrical Equal-Area Projections



Source: Practical Geography by by J. P. Sharma

Uses- This is a useful projection for general and navigational maps of small areas as the shape and area near the projection centre remain almost accurate. In navigation, this projection is often used along with the Mercator projection. The biggest utility of this projection is that it can be created by considering any point as the projection centre.

2.3.4 CONVENTIONAL PROJECTION

MOLLWEIDE'S HOMOLOGRAPHIC PROJECTION

This is an equal area projection which was first created by a German cartographer named Karl Branden Mollweide in 1805. Hence, it is called Mollweide projection or 'Mollweide's equal area projection'.

Example- Construct a Mollweide projection for the world on a Scale of 1:250,000,000; keep the Interval in the projection at 15°.

Radius of the reduced sphere of the earth according to the given scale, that is

$$R = \frac{635{,}000{,}000}{250{,}000{,}000} + 2.54\ cm \ldots$$

Radius of the intermediate circle formed by the projection drawn at 90° east and west longitude lines,

$r=\sqrt{2}\ R$

$=1.414\times2.54 = 3.59$ cm

To make the projection, first make a circle NBSA with radius equal to 3.59 cm (Fig. 2.8). In this circle, draw AB horizontal diameter and NS polar diameter (central meridian), which intersect each other at a point. Now with the help of Table 2.1, find the distances of different latitude circles from the equator at an interval of 15° in the following manner -

Table 2.1

Distance of 15° latitude circle from the equator,

$=0.205\times r=0.205\times 3.59=0.74$ cm

Distance of 30° latitude circle from the equator,

$=0.404\times r=0.404\times 3.59=1.45$ cm

Distance of 45° latitude circle from the equator,

$=0.592\times r=0.592\times 3.59=2.12$ cm

Distance of 60° latitude circle from the equator,0

$=0.762\times r=0.762\times 3.59=2.73$ cm

Distance of 75° latitude circle from the equator,

$=0.906\times r=0.906\times 3.59=3.25$ cm

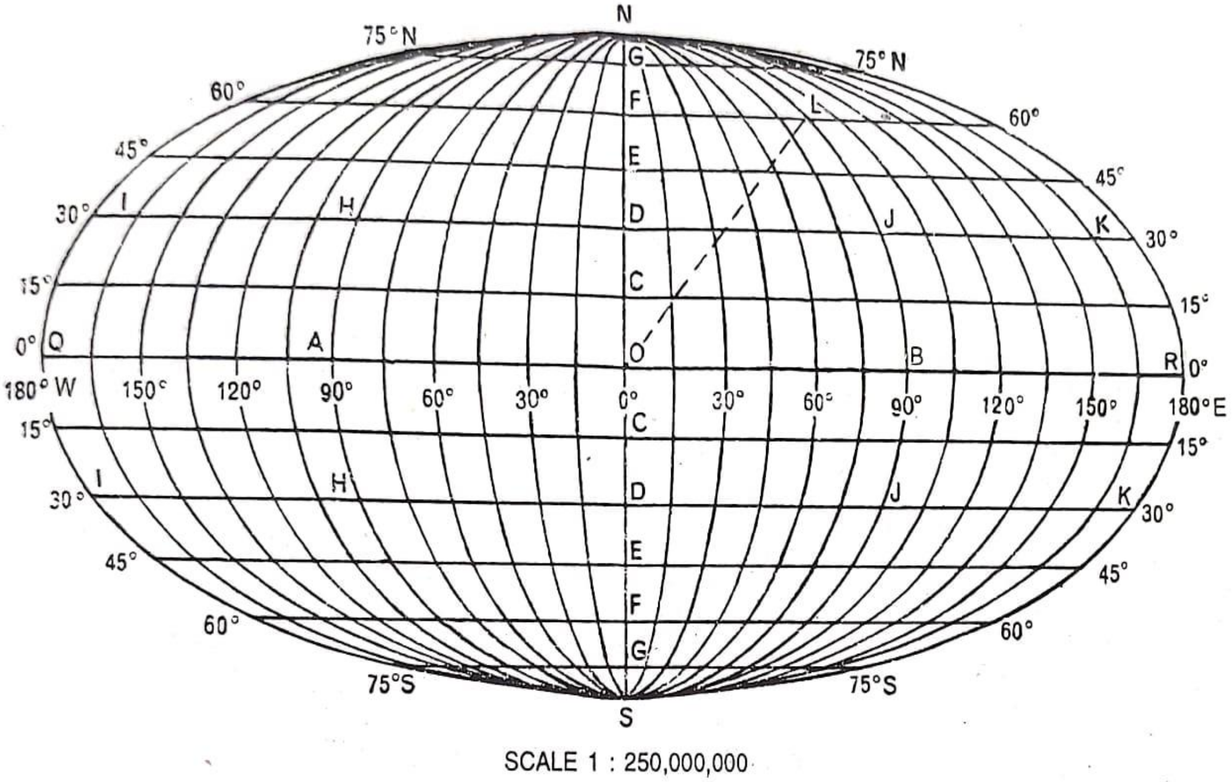
Distance of 90° latitude circle from the equator,

$=1.000\times r=1.000\times 3.59=3.59$ cm

Mark points C, D, E, F and G respectively at distances of 0.74, 1.45, 2.12, 2.73 and 3.25 cm on both sides from point O on the NS line. Lines drawn parallel to AB from these points will reveal north or south latitude circles of 15°, 30°, 45°, 60° and 75° respectively in the projection.

Now extend the AB line on both sides so much that OA becomes equal to AQ and OB becomes equal to BR. Similarly, make the other latitude circles situated within the circle twice as big. For example, in the figure, HI has been made equal to DH and JK has been made equal to DJ. Divide each latitude circle including the equator (QR line) into 360/15 = 24 equal parts and make ellipses by joining the marks of equal longitude value marked on the latitude circles with the poles (N and S points), which will reveal the longitude lines in the projection.

Fig: 2.8 Cylindrical Equal-Area Projections



Source: Practical Geography by by J. P. Sharma

It is clear from the above description that in the projection the QR meridian has been made twice as long as the NS central meridian or $4\times\sqrt{2}$ R= 14.36 cm longer.

Uses- Mollweide projection has been used a lot in atlases to make world distribution maps. Since the shape of the regions gets very distorted towards the edges in the world map made on this projection, nowadays the interrupted Mollweide projection is used more in atlases instead of the normal Mollweide projection. For example, the interrupted Mollweide projection has been chosen for the world distribution maps in the Phillips University Atlas.

SANSON FLAMSTEED'S SINUSOIDAL PROJECTION

This projection was first created in 1650 by a French cartographer and geographer named Nicolas Sanson. About 50 years later, the famous British astronomer John Flamsteed used this projection. Hence, it is called Sanson- Flamsteed projection after the names of these two scholars. Due to the use of sine curves in the construction of the projection, it is called sinusoidal or sinusoidal projection. This is an equal area projection which is considered to be a special form of Bonne projection on the basis of construction method.

Example- Construct a sinusoidal projection for the world on a Scale of 1:250,000,000; keep the Interval in the projection at 15°.

1) Radius of the reduced sphere of the earth according to the given scale, that is

$$R = \frac{635,000,000}{250,000,000} + 2.54\ cm \ldots$$

2) Net length of the equator

$$= 2\pi R = \frac{2\times22\times2.54}{7}\ \text{cm}$$

$$= 15.96\ \text{cm}$$

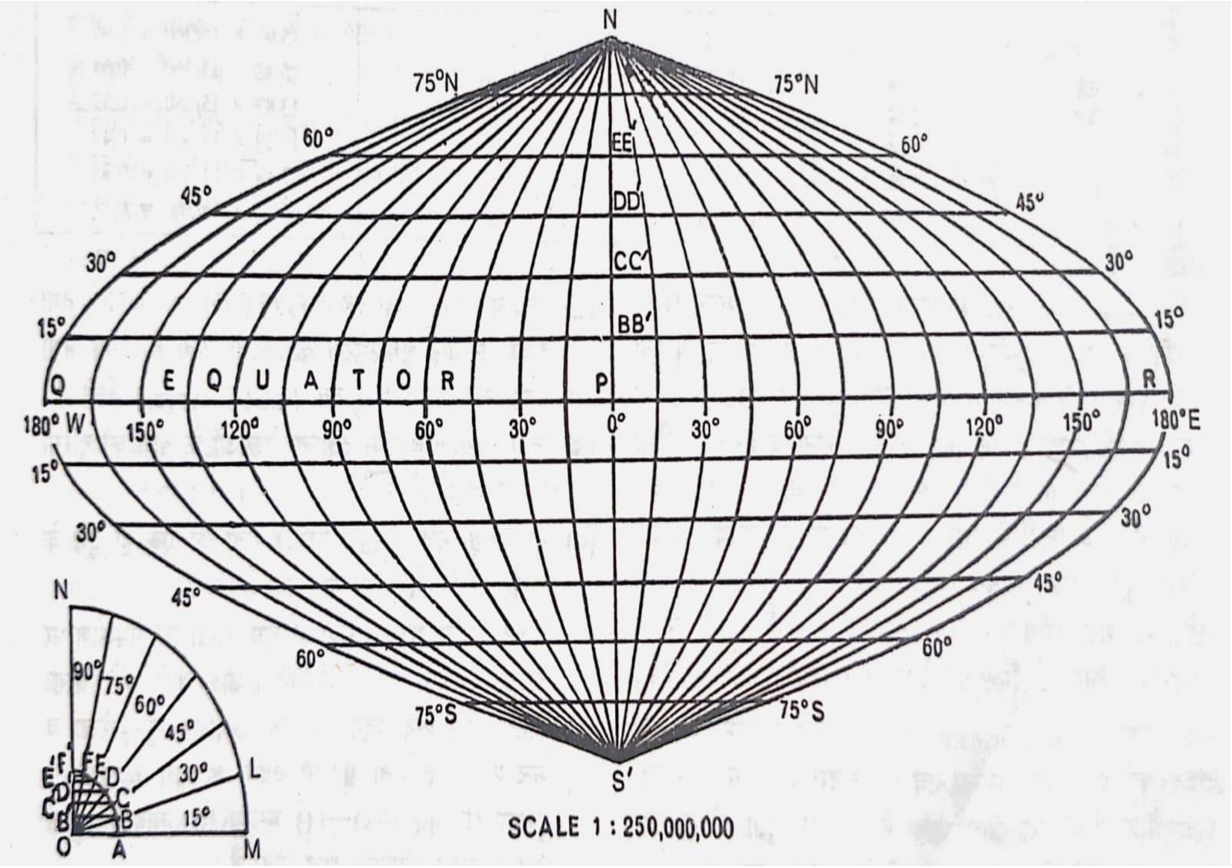
3) Length of central meridian

$$= \frac{2\pi R}{2} = \frac{15.96}{2} = 7.98\ \text{cm}$$

First of all, draw a quadrant NMO of a circle with a radius of 2.54 cm (Fig. 2.9). Draw lines at O point making an angle at an interval of 15° with the OM line. The angle line of 15° cuts the circumference of the quadrant of the circle at point L. Draw a quadrant at point O taking a radius equal to the arc distance ML, which cuts the angle lines of 0°, 15°, 30°, 45°, 60° and 75° at points A, B, C, D, E and F respectively. BB', CC', DD', EE' and FF' dropped from these points on the ON line show the distance between any two adjacent longitude lines on the respective latitude circles in perpendicular projection.

Now, as per Figure 2.9, draw a horizontal line QR 15.96 cm long and divide it into 360/15 = 24 equal parts. At the midpoint P of this line, draw a perpendicular line N'S' on both sides.

Fig: 2.9 Sinusoidal Projection



Source: Practical Geography by by J. P. Sharma

Mark six marks on both sides from point P on the N'S' perpendicular line (central meridian) at the same distance at which the QR line (equator) has been divided and draw parallel lines to QR from these marks. These parallel lines will reveal the northern and southern latitude circles at an interval of 15° in the projection.

To draw longitude lines, mark twelve marks each on both sides of the central meridian at equal distances of BB', CC', DD', EE' and FF' respectively in latitude circles of 15°N and 80, 30°N and 60, 45°N and 50, 60°N and 50, 75°N and S (see picture). Complete the longitude lines by joining the marks of equal longitude value marked on the latitude circles with the poles (N' and S' points) through curves. Considering the central meridian as the longitude of 0°, write the values in degrees on the remaining longitude lines.

Uses - Although the world map can be made on this projection, but due to the shape of the regions in the border areas being highly distorted, sinusoidal projection is usually not used for this purpose. The shape is less distorted in the Mollweide projection as compared to the sinusoidal projection. Therefore, the world map on the Mollweide projection is better than the sinusoidal projection. Sinusoidal projection is very useful for making equal area maps of continents with relatively less east-west extension, i.e. Africa and South America, situated on both sides of the equator.

2.4 SUMMARRY

The technique of projecting the Earth's curved surface onto a flat surface, like a map, is known as a map projection. The development of a map projection involves putting the Earth's curving surface onto a flat plane, which requires specific mathematical approaches to manage distortions. Scale, projection points, and light source placement are important aspects of the procedure. To create various projections, such as gnomonic or Mollweide, the center meridian must be found, latitude and longitude lines must be plotted, and equal area or shape accuracy must be adjusted. Geometric shapes like cones, cylinders, and planes are frequently used in projections. Each method offers a balance between accuracy and distortion based on the map's purpose.

But there will always be some distortion in terms of area, direction, shape, or distance as a result of this process. Every kind of projection has advantages and disadvantages of its own, and no projection is ideal for every situation.

2.5 GLOSSARY

- **Conical Projection**: A map projection where the surface of the globe is projected onto a cone, usually touching the globe along a line of latitude.
- **Standard Latitude**: The latitude line where the cone or projection surface touches the globe, minimizing distortion.
- **Central Meridian**: The vertical line on a map that represents 0° longitude, often used as a reference point in conical projections.

- **Latitude Circles**: Circular lines on the projection representing different latitudes on Earth, drawn as arcs in conical projections.
- **Longitude Lines**: Vertical or angular lines that represent different longitudes on a map, radiating from the center in conical projections.
- **Distortion**: The inaccuracy in shape, distance, or area that occurs when projecting a three-dimensional Earth onto a two-dimensional surface.
- **Rhumb Line**: A line on the Earth that crosses all meridians at the same angle, representing a constant bearing on a Mercator projection.
- **Exaggeration of Scale**: In cartography, the stretching of distances in certain areas of a map, which happens in projections like Mercator near the poles.
- **Sine Curve**: A mathematical curve used in the construction of sinusoidal projections, giving the projection its distinctive shape.
- **Equal-Area Projection**: A type of map projection that preserves the relative sizes of regions, ensuring areas is proportional.

2.6 ANSWER TO CHECK YOUR PROGRESS

1. A map projection where the surface of the globe is projected onto a cone, usually touching the globe along a line of latitude called Conic projection.
2. A cylindrical map projection preserving shapes and directions, often used in navigation but with increased distortion near the poles called Mercator’s Projection. .
3. Orthomorphic Projection is a projection that preserves shape and direction, ensuring that angles between lines remain correct.
4. Gall’s Stereographic Projection is a cylindrical projection that blends elements of conformal and equal-area projections, commonly used for world maps.
5. Gnomonic Projection is a type of projection where great circles on Earth, like meridians and equators, are shown as straight lines. It is useful for navigation.

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2.8 TERMINAL QUESTIONS

Long Questions

1. Compare and contrast Simple Conical Projection with One Standard Parallel and Two Standard Parallels. What are the key differences in their construction methods? Explain with the examples.
2. Draw the Gall’s projection for world map on a scale of 1:250,000,000 and explain the construction method.
3. To make a world map on a scale of 1:250,000,000, Prepare a Mollweide or sinusoidal projection. Keep the interval 30° in the projection.

4. Why cylindrical projections are frequently used for general world maps. Construct a Mercator's Projection. Explain the Uses and limitations of Mercator projection.

Short Questions

1. Describe the basic principle behind creating a conical projection.
2. What is Mollweide's Homolographic Projection?
3. Who created the Sanson-Flamsteed's sinusoidal projection, and why is it named as such?
4. What is the major difference between Mollweide and sinusoidal projections?
5. What is Rhumb Line?
6. Write two uses and limitations of cylindrical equal area projection.
7. What are the typical uses of Bonne's projection according to the text?
8. What is the utility of the gnomonic oblique zenithal projection?
9. What are the major limitations of the Mercator projection?

Multiple Choice Questions

1. What shape is used in a conical projection?

(A) Sphere

(B) Cone

(C) Cylinder

(D) Rectangle

2. Which latitude line touches the cone in a conical projection?

(A) Equator

(B) Prime latitude line

(C) Tropic of Cancer

(D) Arctic Circle

3. What happens to the distortion in the shape and area of regions as the distance from the standard latitudes increases in a simple conical projection?

(A) It decreases

(B) It remains the same

(C) It increases

(D) It becomes negligible

4. What is another name for the Cylindrical Equal-Area Projection?

(A) Mercator Projection

(B) Lambert's Projection

(C) Gall's Projection

(D) Orthomorphic Projection

5. In a gnomonic oblique zenithal projection, where is the light source imagined?

(A) At the poles

(B) At the equator

(C) At the center of the globe

(D) At the projection plane

6. What is the position of the projection point in a gnomonic oblique zenithal projection?

(A) At the poles

(B) Anywhere on the globe except the poles and equator

(C) Only at the equator

(D) Only at the poles

7. What term describes a straight line on the Mercator Projection that represents a constant bearing?

(A) Rhumb Line

(B) Prime latitude line

(C) Equator

(D) Meridian

8. Which projection is often used along with the gnomonic oblique zenithal projection in navigation?

(A) Conic Projection

(B) Cylindrical Projection

(C) Mercator Projection

(D) Polyconic Projection

9. Who first created Mollweide's Homolographic Projection?

(A) John Flamsteed

(B) Karl Branden Mollweide

(C)Nicolas Sanson

(D) Ptolemy

10. Which projection is better for making equal area maps of continents with less east-west extension, like Africa and South America?

(A) Mollweide projection

(B) Conic projection

(C) Mercator projection

(D) Sinusoidal projection

Answer. 1. B, 2.B, 3.C, 4.B, 5.C, 6.B, 7.A, 8.C, 9.B, 10.D

BLOCK-2 BLOCK DIAGRAMS AND GEOLOGICAL MAP

UNIT-3 ONE OR TWO POINT PERSPECTIVE BLOCK DIAGRAMS BD

3.1 OBJECTIVES

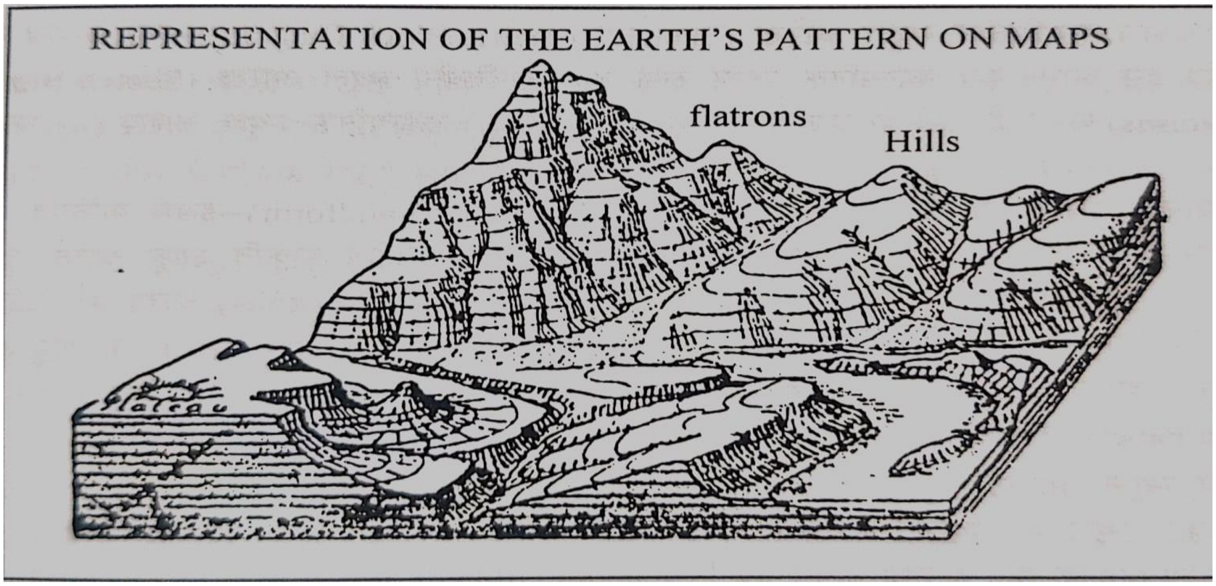
After studying this chapter you will be able to:

- To know about types of block diagrams.
- Understand and explain the principles of one-point and two-point perspective in block diagrams.
- Accurately construct one-point and two-point perspective block diagrams, demonstrating the ability to apply the concepts of vanishing points, horizon lines, and depth.
- Analyze the differences between one-point and two-point perspectives block diagrams.
- Develop the ability to visualize and represent three-dimensional objects.

3.2 INTRODUCTION

In the study of geography, understanding the Earth's physical features and the spatial relationships between them is fundamental. One of the most effective tools for visualizing and interpreting these three-dimensional features on a two-dimensional surface is the block diagram.

Fig: 3.1 Landform



Source: Practical Geography by P. L. Mishra

Block diagrams are simplified, three-dimensional representations that help geographers, students, and researchers to grasp the complex structures of landscapes, landforms, and geological features in a clear and accessible manner.

Three-dimensional = Length + Width + Height

A block diagram is a perspective three-dimensional representation of relief features and their underlying geological section. It provides an excellent method of representation of relief. It was enunciated by G.K. Gilbert and perfected by W.M. Davis in the late 19th century. A block diagram has two important elements:

(i) Block or base upon which representation is made.
(ii) The diagram is the drawing of the relief feature.

A geological block diagram shows both structure and relief. A block relief diagram provides a perspective view of the landscape and enjoys much visual appeal. But it should be borne in mind that it does not picture the actual terrain with its manifold complexities: sometimes it is used as a handy tool for illustrating a geographical principle. A block diagram is a generalized representation. It is not drawn true to scale but gives only a lateral view. The perspective form of a block diagram certainly appeals to the memory and its message is lasting.

A rectangular or cubic "block" that symbolizes a section of the Earth's surface and its underlying strata is the standard format for block diagrams. In addition to the geological strata that lie beneath the surface, the diagram can show a variety of elements of the terrain, such as mountains, valleys, plateaus, and other features. Block diagrams provide a realistic representation that can be rotated or viewed from many angles by using perspective. This allows for the visualization of information that is not as easily given by flat maps or cross-sectional diagrams.

As compared to a map, a block diagram has a better visual appeal. It provides a vivid correlation of the structure and the relief of the terrain. These advantages of a block diagram certainly relate to its perspective scale and three-dimensional effect. But a map gives a more correct representation in size and shape and provides a vivid picture of terrain.

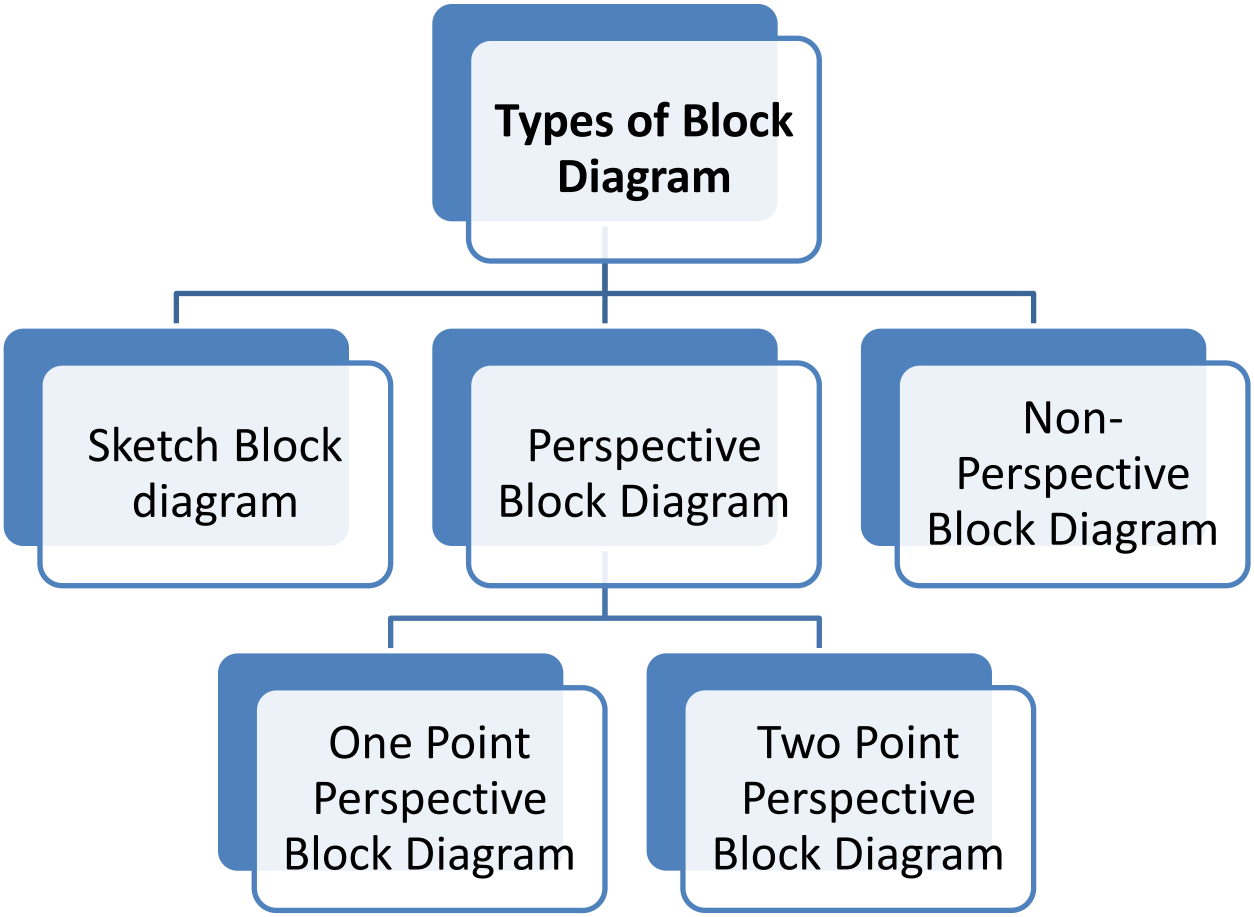


Fig. - 3.2

3.3 PERSPECTIVE BLOCK DIAGRAM

Perspective Block Diagram is visual, so these diagrams where the horizontal and vertical scales do not remain the same continuously like in non-visible block diagrams. In other words, the thickness and width of the block decrease as the distance from the observer increases. There are two types of perspective Block Diagram – (i) One point perspective Block Diagram, (ii) Two point perspective Block Diagram.

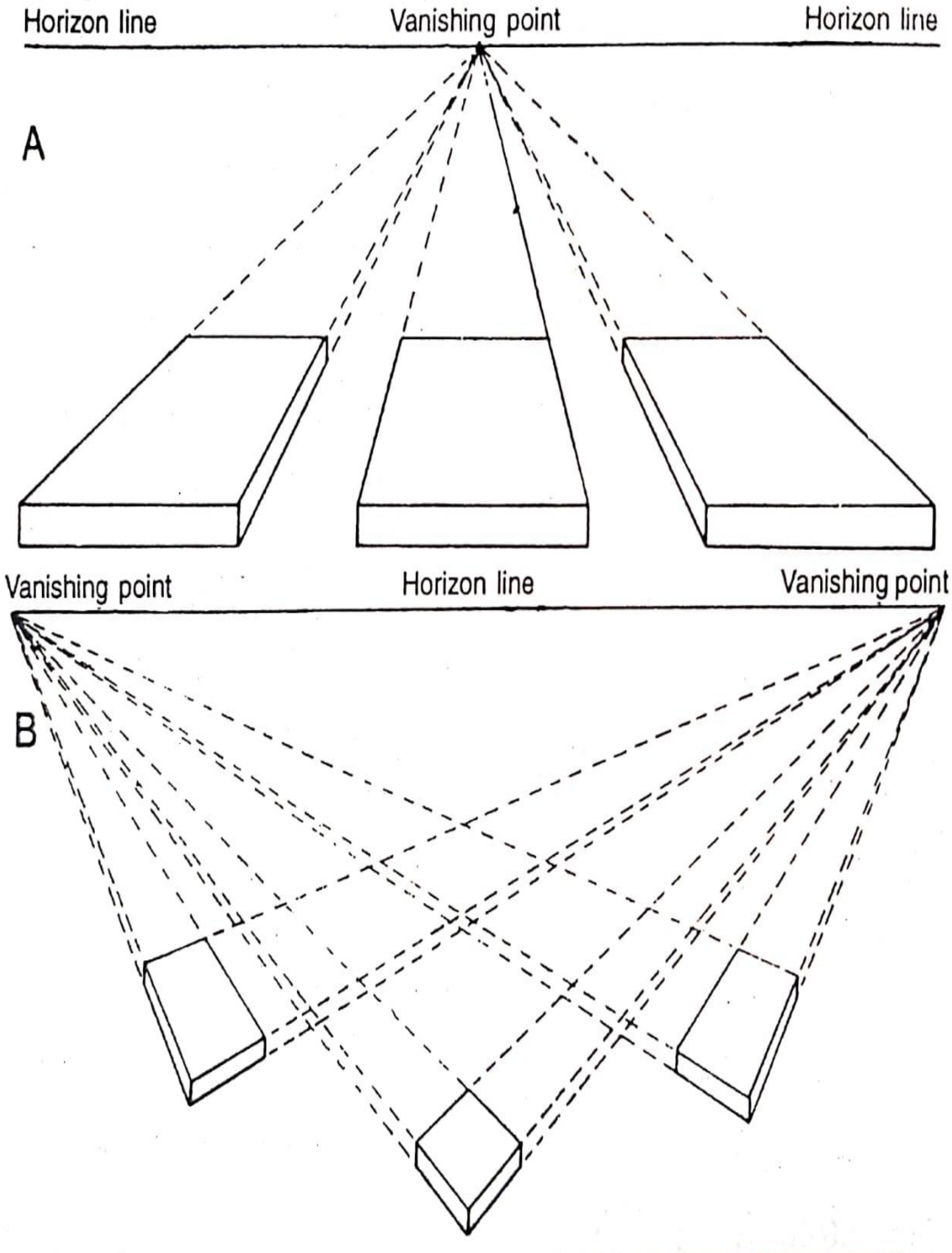


Fig.- 3.3

A-One point perspective Block Diagram B- Two point perspective Block Diagram

(Source: Practical Geography by J. P. Sharma)

3.4 ONE POINT PERSPECTIVE BLOCK DIAGRAM

One point perspective Block Diagram has two main Characteristics:-

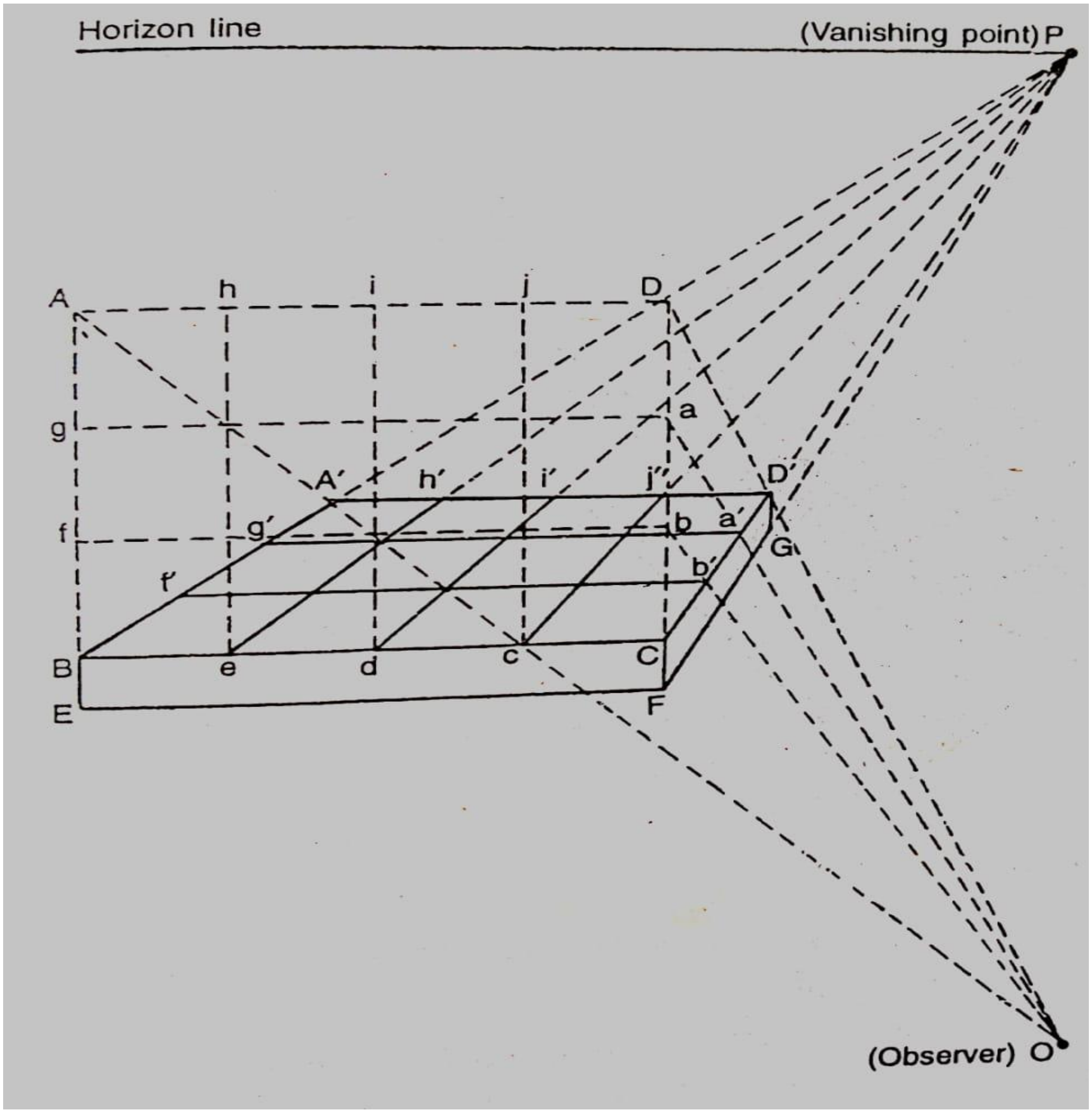
(i) The side of the block situated exactly in front of the observer is in the form of a rectangle and the back edge of this block is shorter than the front edge but parallel to it for example, in figure 3.4, the BEFC side is a rectangle and the BC side of this rectangle is larger and parallel to the A 'D' side of the block.

(ii) The thickness of the other side of the block visible to the observer decreases with increasing distance from the observer. For example, in the figure 3.4, the CF side is longer than the D'G' side. In other words, if the CD' and FG arms of the block are extended to the horizon of the observer, then these lines will meet each other at a point on the horizon, which is called the vanishing point.

The construction method of one point perspective Block Diagrams is as follows:

- ABCD be a rectangular area drawn on a map (figure 3.4), which is to be converted into a one-point perspective block diagram. Draw a square grid on this area using horizontal lines g a and f b and vertical lines h e, i d and j c.
- Draw rectangle BEFC on side BC, which will be the front side of the block. In this rectangle, the length of BE line is fixed as per requirement (usually one centimeter).
- Mark a vanishing point P on the horizon line drawn upwards and a point O indicating the position of the observer in line with the Ac line.
- Join points B, e, d, c, C and F with point P by straight lines.
- Joining points O and A, draw line OA which intersects line PB at point A'. The BA' side will reveal the left edge of the block. Now draw line OD from point O which intersects PC line at point D'. Match A' and D'. A'D' line will reveal the back edge of the block and this line will be parallel to the BC line. The D'C line will represent the right edge of the block.
- From point O, draw lines O a and O b which intersect the PC line at points a' and b' respectively. From points a' and b' respectively. From points a' and b' draw lines a' g' and b' f' parallel to line A'D' respectively.

Fig.- 3.4 One point perspective Block Diagram



Source: Practical Geography by J. P. Sharma

- Complete the second side of the block by drawing line D’G parallel to CF from point D’. As is clear from figure 3.3, A One point perspective Block Diagram can be oriented in many ways but its construction method is the same. In this picture, in the block diagrams on the right and left, two sides are visible to the observer, whereas in the middle block, only one side is visible to the observer.
- Complete the second side of the block by drawing line D’G parallel to CF from point D’.

As is clear from figure 3.3, A One point perspective Block Diagram can be oriented in many ways but its construction method is the same. In this picture, in the block diagrams on the right and left, two sides are visible to the observer, whereas in the middle block, only one side is visible to the observer.

3.5 TWO POINT PERSPECTIVE BLOCK DIAGRAM

Two vanishing points are used in constructing the diagram from two point perspective block diagram. The two opposite sides of the block diagram are shown meeting at one vanishing point and the remaining two opposite sides are shown meeting at the other vanishing point. Unlike a one point perspective Block Diagram, none of the sides of a two point perspective Block Diagram are rectangular. In these block diagrams, there is no side of the block in front of the observer but there is a corner of the nudge block in front of them. In contrast, a two-point perspective block diagram employs two vanishing points, allowing for a more realistic three-dimensional view by showing the object from multiple angles, with lines converging at both points.

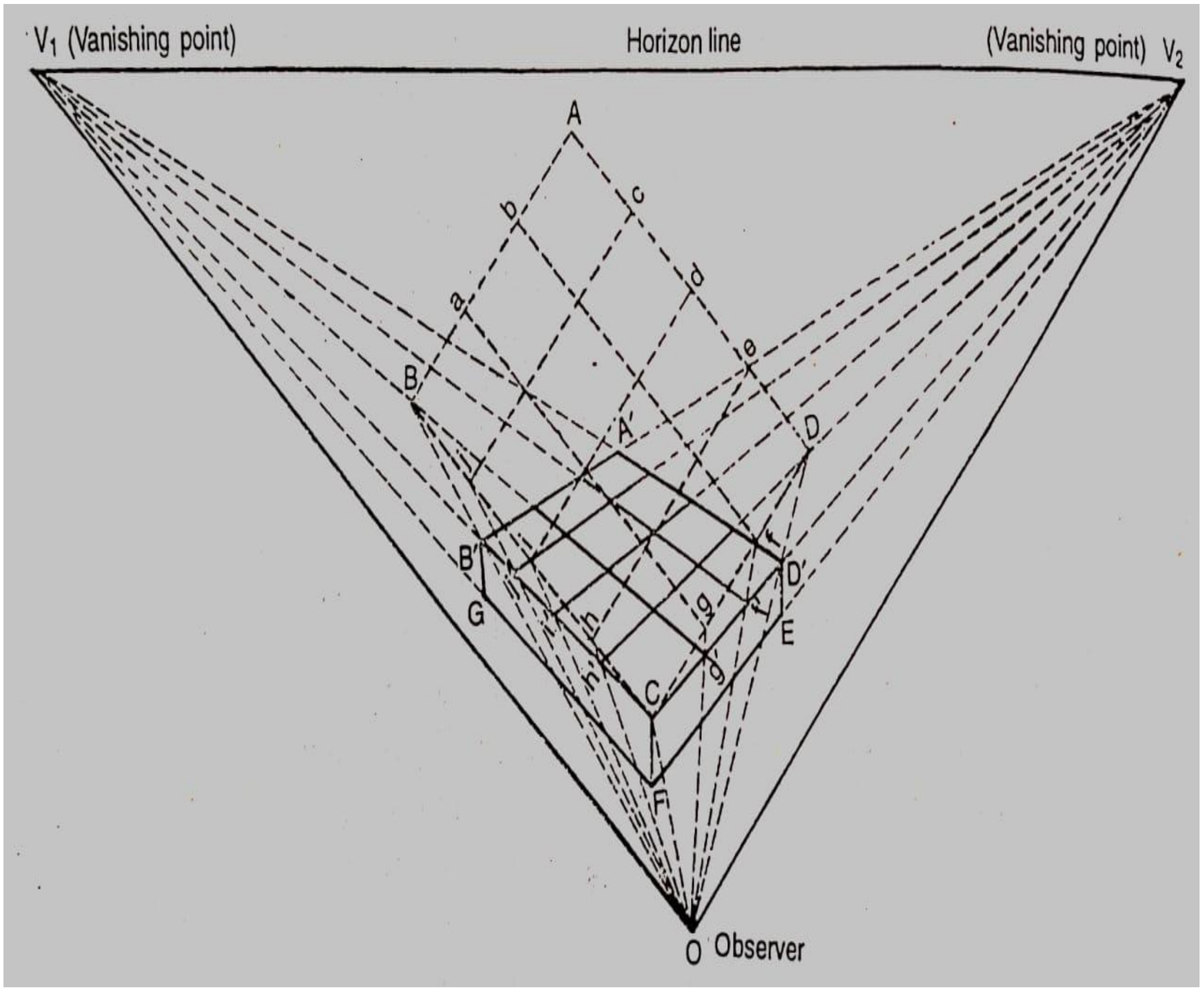
Two point perspective Block Diagrams are constructed according to the following method:

- Suppose ABCD is a rectangular map, which is to be displayed as a two point perspective Block Diagram (figure 3.5). Draw a network of squares on the map with the help of j c, i d, h e, a g and b f grid lines.
- Mark a point O that reveals the position of the observer and place the given map in such a way that one corner of the map (here point C is such a corner) is situated in front of the observer.
- Draw a horizon line at any convenient distance on the top of the map. The closer this line is made to the map, the more flat the surface of the block will appear.
- From point O, draw line OV_1 parallel to line BC which intersects the horizon line at point V1. Similarly, draw OV_2 line parallel to CD line which cuts the horizon line at point V2. V_1 and V_2 will be the two required vanishing points.
- Join point C with V_1 and V_2. Now draw line OD which intersects CV_2 line at D'. Line CD' will be one side of the surface of the block. Draw lines $B'V_2$ and $D'V_1$ which

intersect each other at A'. Lines A'B' and A'D' will be the remaining two sides of the surface of the block.

- Drop the perpendicular CF to make the sides of the block. The length of this perpendicular line is determined as per convenience. Draw lines parallel to CF from points B' and D' which intersects lines FV_1 and FV_2 at points G and E respectively. B'GFC and CFED' will be the two sides of the block visible to the observer.

Fig.- 3.5 Two point perspective Block Diagram



Source: Practical Geography by J. P. Sharma

- Now draw lines O j, O i and Oh which cut the side B'C at points j', I', h' respectively. Similarly, by making lines O g and O f, the points g' and f' on the side CD' will be found. Complete the grid lines on the block by joining j, i' and h' to V_2 and g' and f' to

V_1. Like one point perspective Block Diagrams, two point perspective Block Diagrams can be oriented in different ways (figure 3.3 B), but their construction is the same.

3.6 SUMMARRY

A block diagram is a perspective three-dimensional representation of relief features and their underlying geological section. It provides an excellent method of representation of relief. When incorporating perspective, block diagrams can be drawn using one-point or two-point perspective techniques. A one-point perspective block diagram uses a single vanishing point on the horizon line, creating the illusion of depth as all parallel lines converge at this point. In contrast, a two-point perspective block diagram employs two vanishing points, allowing for a more realistic three-dimensional view by showing the object from multiple angles, with lines converging at both points. These techniques enhance the visual realism of block diagrams, making them more effective for conveying spatial relationships and depth.

3.7 GLOSSARY

- **Perspective**: A technique used to represent three-dimensional objects on a two-dimensional plane.
- **Vanishing Point**: The point at which parallel lines appear to converge in a perspective drawing.
- **Horizon Line**: The level at which the sky meets the ground in a perspective drawing.
- **One-Point Perspective**: A perspective technique where all lines converge to a single vanishing point.
- **Two-Point Perspective**: A perspective technique where lines converge to two separate vanishing points.

3.8 ANSWER TO CHECK YOUR PROGRESS

1. Do you know that the Perspective Block Diagram is visual?

2. A block diagram is a perspective three-dimensional representation of relief features.
3. A one-point perspective block diagram uses a single vanishing point.
4. A two-point perspective block diagram employs two vanishing points.

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3.10 TERMINAL QUESTIONS

Long Questions

1. Explain the characteristics of one point perspective Block Diagram and explain its construction by drawing a diagram.
2. What are the characteristics of two point perspectives Block Diagram? Explain the construction with the help of a diagram.

Short Questions

1. Write the types of block diagram.
2. What is perspective Block Diagram?
3. What are two important elements in block diagram?
4. What is the main advantage of using two point perspectives block diagram?
5. How does a two-point perspective block diagram differ from a one-point perspective block diagram?

Multiple Choice Questions

1. How do parallel lines look in a block diagram in one point perspective?

(A) They converge at two points on the horizon line

(B) They remain parallel and never meet

(C) They converge at a single point on the horizon line

(D) They diverge from each other

2. What does a one-point perspective block diagram's vanishing point represent?

(A) The point where all vertical lines meet.

(B) The point where all horizontal lines meet.

(C) The point on the horizon where parallel lines appear to converge.

(D) The center of the block.

3. What is the best way to describe the technique of two-point perspective?

(A) It creates a flat, two-dimensional view.

(B) It provides a realistic three-dimensional view by using two vanishing points.

(C) It simplifies complex systems by using only one vanishing point.

(D) It is used to represent only the front view of an object.

4. How many vanishing points are used in a Two Point Perspective Block Diagram?

(A) One

(B) Two

(C) Three

(D) None

Answer. 1. C, 2.C, 3.B, 4.B

UNIT-4 GEOLOGICAL MAPS CROSS SECTIONS AND THEIR INTERPREATION

4.1 OBJECTIVES

4.2 INTRODUCTION

4.3 TYPES OF GEOLOGICAL MAPS

4.4 CONVENTIONAL SIGNS AND SHADING METHOD OF GEOLOGICAL MAPS

4.5 GEOLOGICAL CROSS SECTION

4.6 SUMMARY

4.7 GLOSSORY

4.8 ANSWER TO CHECK YOUR PROGRESS

4.9 REFERENCES

4.10 TERMINAL QUESTIONS

4.1 OBJECTIVES

After studying this chapter you will be able to:

- Usefulness of geological maps.
- Different types of geological maps and their usefulness.
- Recognize the representation of geological features on geological maps.
- Recognize and describe the main elements of geological maps, such as scales, colors, symbols, and legends.
- Understand the purpose and components of geological cross sections in visualizing vertical arrangements of geological features.

4.2 INTRODUCTION

Lines, symbols, and colors are used in a geological map to depict details about the types and locations of rock units in a given region. Typically, a geological map will depict mappable rock or sediment units. A unit of rock or sediment that can be consistently identified, traced over a landscape, and described by a geologist is one that can be mapped so that other geologists can confirm its existence and identify it. A mappable unit is typically a geologic formation. On a base map (often a topographic map), these mappable units are represented by various colors or patterns, over which geologic contacts, strikes, and dips are depicted. In order to create these maps, geologists carefully observe multiple outcrops—exposed rocks at the surface of the earth—during the mapping region. Geologists note details about the type of rock, the strike and dip of the rock layers, and the relative age of each outcrop. geologists record information such as rock type, strike and dip of the rock layers, and relative age data. Geologic maps take practice to understand, since they display three- dimensional features, such as folds, on a two-dimensional surface.

Geological maps are important for two reasons. First, as geologists make geologic maps and related expiations and cross-sections, they develop a theoretical understanding of the geology and geologic history of a given area. Second, geologic maps are essential tools for practical applications such as zonic, engineering, and hazard assessment. Geologic maps are also vital in finding and developing geological resources, such as sediments, groundwater, fossil fuels, and minerals.

In the fields of geography and geology, geological maps and cross sections are vital resources. They offer important details regarding the composition of the Earth, including as the age, kind, and distribution of rock formations. Comprehending these instruments facilitates the interpretation of Earth's past events and the forecasting of geological occurrences by geologists and geographers. The principles of geological maps and cross sections, as well as their creation and interpretation, will be covered in this chapter.

4.3 TYPES OF GEOLOGCAL MAPS

Generally there are four types of geological maps.

1. Surficial maps

2. Outcrop maps

3. Areal maps

4. Structural maps

Surficial maps

Rocks of many kinds make up the surface of the earth. Surface maps are those that provide details about the location and characteristics of these rocks. When building reservoirs, dams, transit projects, and drainage systems, these maps are a huge help.

Outcrop maps

The rocks found below the surface rocks or rocks are called bed rocks. But when the surface rocks are removed through erosional activity, the bedrock found below them becomes solid and becomes visible on the surface.

- In a landscape map, those places of that area or region are shown where bedrock is visible on the surface.
- Landscape maps are very helpful in discovering minerals as well as in obtaining information about building materials.

Areal maps

A map showing information about the plan view of the geological formulation of any place, region or region is called areal geological maps. In this type of map, geological units, both visible and inferred, are shown as a continuous sequence. Each geological unit is represented by different accepted conventional symbols or through shadows. Regional geological maps are used in geomorphology, physical geography and physical geology.

Structural maps

As it becomes clear from the above name itself, in a structural geological map the geological structure is shown through conventional structural symbols. The structure sometimes keeps changing at short distances. The structures built there are displayed with ritual symbols. Thus, where the geological structure is complex and difficult, the usefulness of the structural map increases. It is absolutely necessary to write the conventional symbols used in the map in a legend or index.

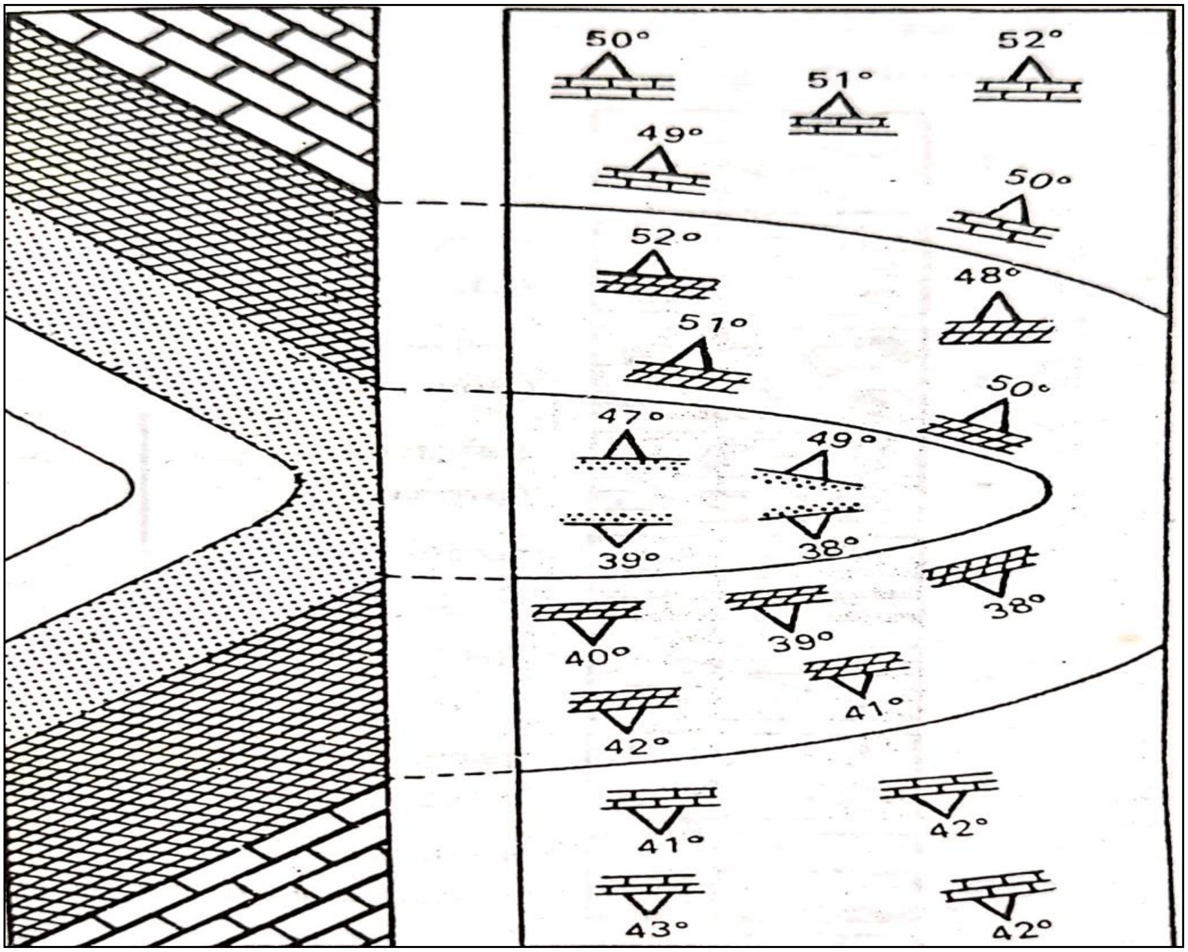
Many geographers and geologists have divided geological maps into only two parts.

(i) Geological drift map

(ii) Solid geological map

In the above classification, surface and side maps are kept in the category of apogee maps and regional and structural maps are kept in the category of solid maps. It is worth keeping in mind that here we will study only including regional geological maps under solid maps.

Fig-4.1 Structural Geological maps



Source: Google

4.4 CONVENTIONAL SIGNS AND SHADING METHOD OF GEOLOGICAL MAPS

Complete information about the rock layers shown in any geological map, such as their Geological age, folding, fracture, lineation, foliation, dip and Natilamba (dip and strike) etc. are expressed through various ritual symbols and shadows. There is mutual difference between ritual symbols and shadows in different countries, hence In the legend or index of conventional symbols and shadows used in the map It is necessary to write.

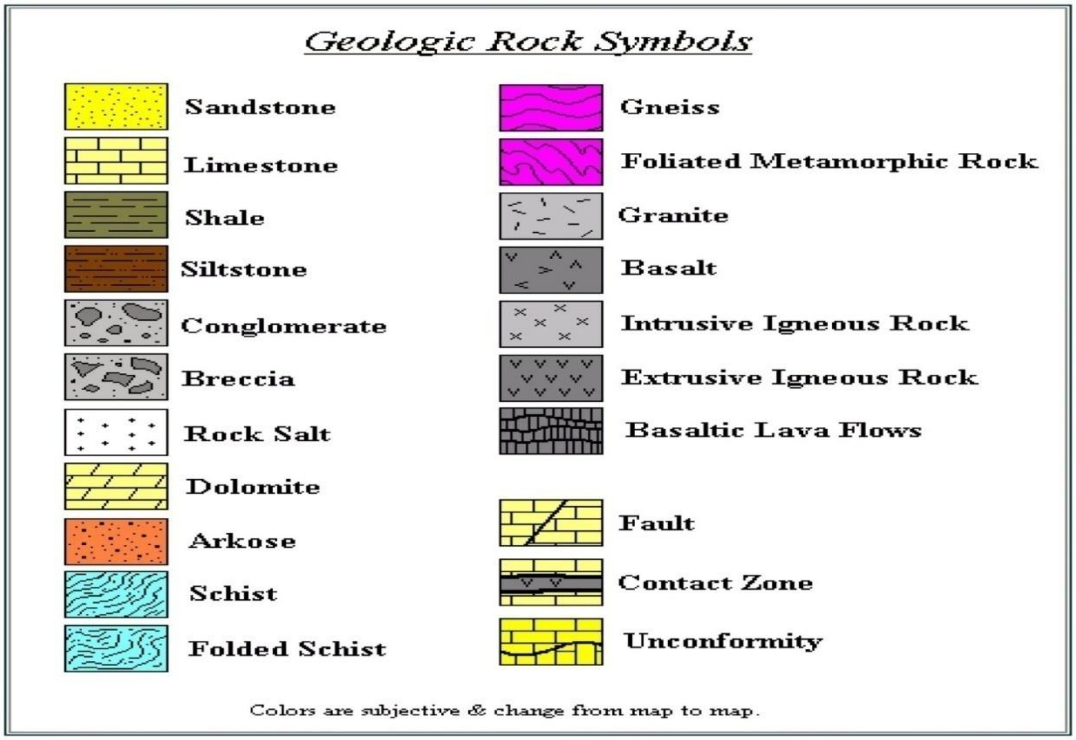
The age of rock layers in a geological map can be expressed in two ways:-

(i) By color method

(ii) By letter method

In the color method, different types of rock layers are shown with different colors, whereas in the letter method, the age is shown by using conventional letters or by writing the first letter of the name of the geological era in that rock layer.

Fig-4.2 Geological Rock Symbols



Source: Google

4.5 GEOLOGICAL CROSS SECTION

The construction of a geological section, also known as a cross-section, is an essential task in geology that provides a two-dimensional view of subsurface geological features. A geological section represents a vertical slice through the Earth’s crust, revealing the arrangement and relationships of rock layers, faults, folds, and other geological structures. These sections are vital for understanding the geological history of an area, assessing natural resources, and predicting the occurrence of natural hazards. A key goal of structural geologists is to understand the three dimensional geometry of the rock layers. A geological map is a two dimensional representation of geological features on the Earth’s surface. In order to provide a third dimension, one or more slices through the Earth are needed. Although cross sections are usually vertical, there are instances where it is desirable to project geologic structures on to a dipping plane such as the profile plane of a plunging fold. Cross sections show thicknesses, dip directions, folds, faults, unconformities, sediment thickness changes, igneous intrusions etc

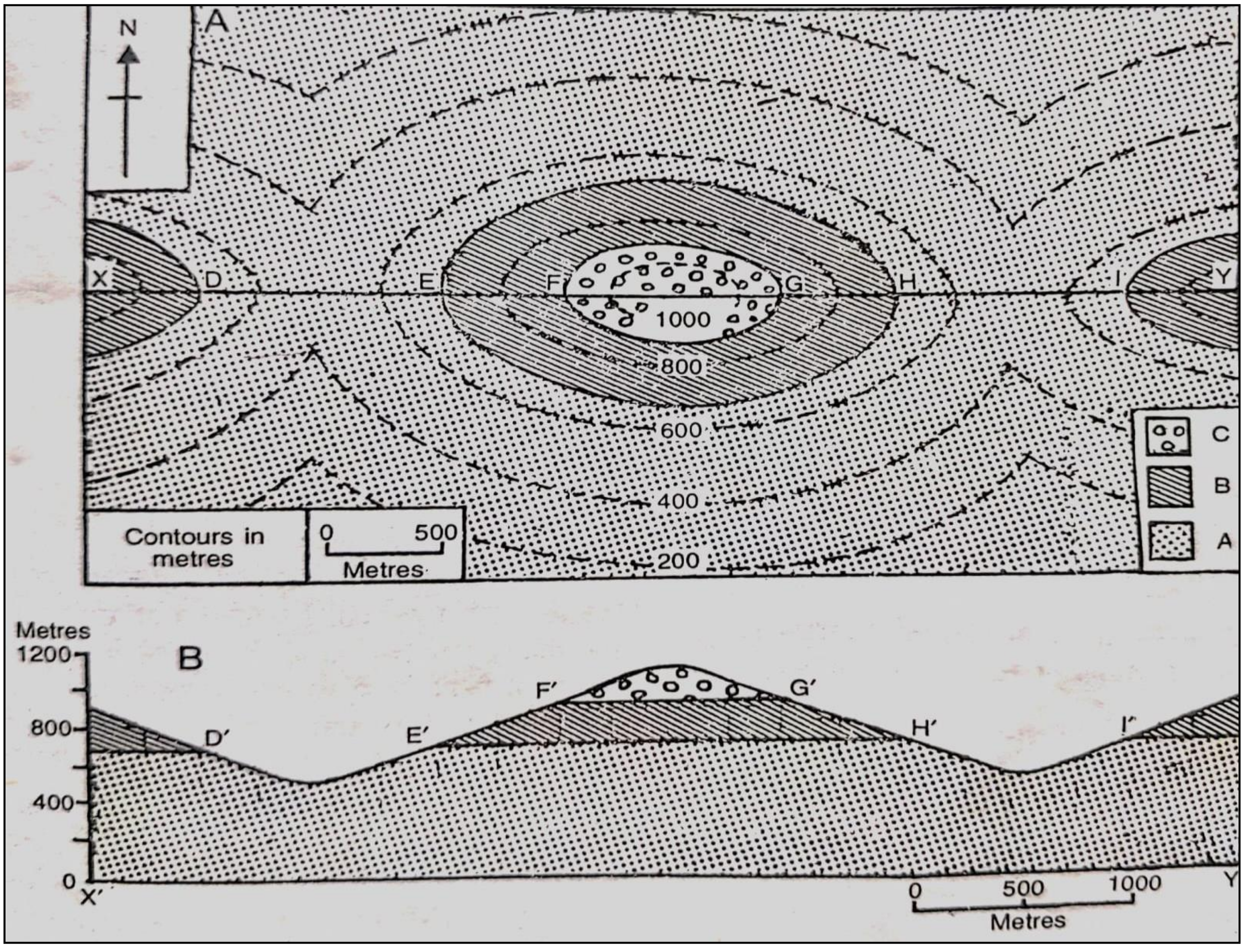
GEOLOGICAL MAPS OF HORIZONTAL ROCK-BEDS

The main characteristic of Geological Maps of Horizontal Rock-Beds is that contour lines do not intersect boundaries of rock layers in a geological map. The contour lines and the boundaries of the layers in the map are almost parallel to each other (fig- 4.3).

Construction of section

Draw a line XY on the map. Make the base line X'Y' of the section equal to this cut line. Raise perpendiculars at both ends of the base line and mark heights on these perpendiculars according to the scale given in the map. Now according to the method mentioned above, construct the surface profile by transferring the intersection points of the cut line and contour lines to the base line of the section. Express the intersection points D, E, F, G, H and I of the section and strata by the points D', E', F', G', H' and I' respectively on the secant. Now as per the picture Draw lines parallel to X'Y' from these points marked on the secant. These lines will reveal the bedding planes of different beds in the section. Complete the section by filling the shadows shown in the map in the respective layers.

Fig-4.3 Horizontal Rock-Beds



Source: Practical Geography by J. P. Sharma

Geological Analysis

In this example, a geological map made at 1/40,000 resolution is shown. The contour line interval in this map is 200 meters. From the viewpoint of the surface structure, three saddle-shaped hills are visible in the map. The height of the central hill is a little more than 1,000 meters above sea level. The other two hills are slightly lower than the central hill.

Three horizontal rock layers A, B and C are shown in the map. Layer C is at the top and layer B is below it. Layer A is situated at the bottom. Thus, layer C is the newest and layer A is the oldest. Layer B was deposited before layer C and after layer A. The actual thickness of layer C is 240 meters and the actual thickness of layer B is about 200 meters. From the viewpoint of geological history, these strata were deposited in some sea etc. which later rose above the sea level as a result of uplift. This uplift did not cause any dip in the strata and these strata remained in their original horizontal form. Thereafter, these strata were eroded by the rivers situated on both sides of the central hill. The maximum effect of erosion is seen on strata C. This strata has been cut to a great extent by the rivers and only a small part of it remains on the top of the central hill. As a result of erosion, strata A and B have been exposed on the banks of the river valleys.

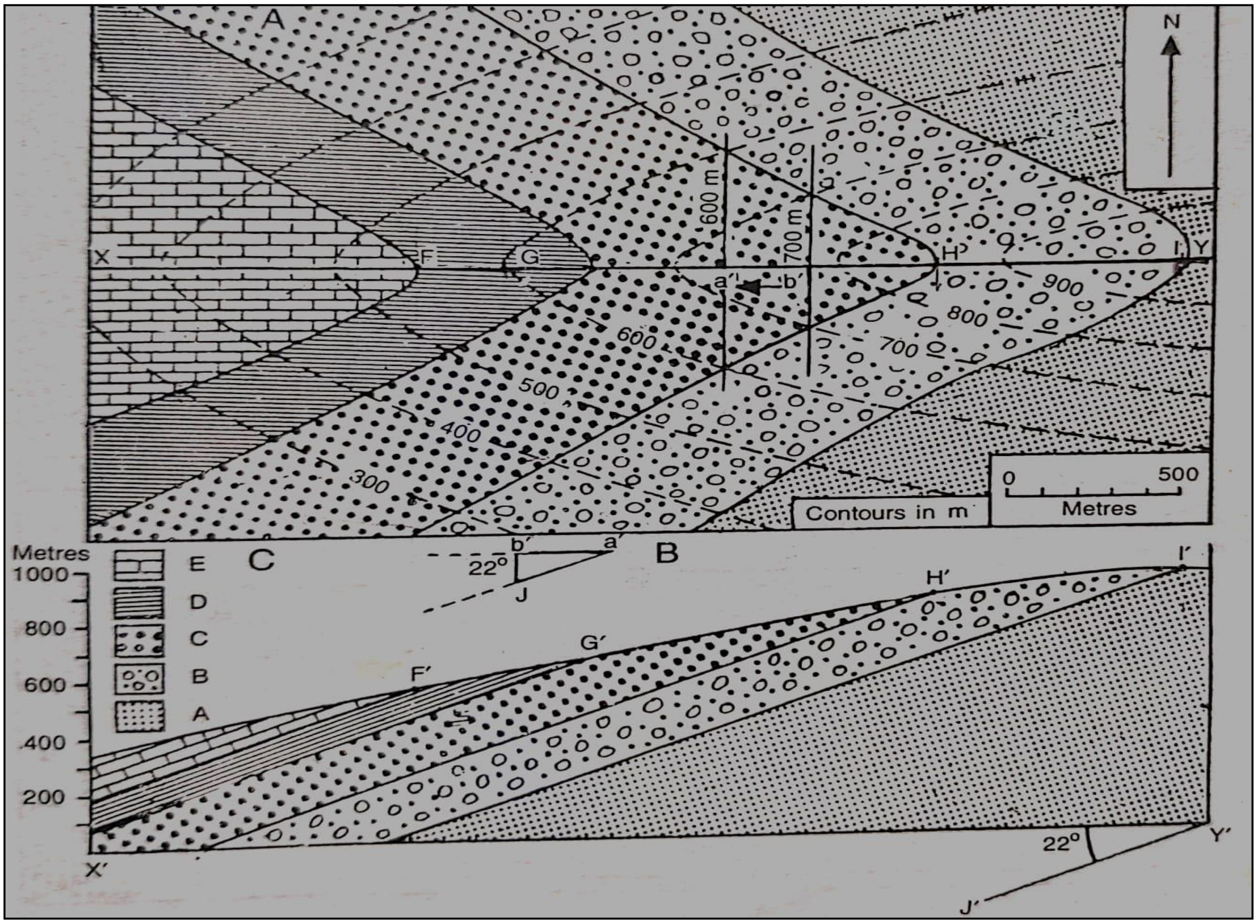
GEOLOGICAL MAPS OF INCLINED ROCK-BEDS

The geological maps in which the boundaries of the layers intersect the contour lines in the form of curved lines are definitely having inclined layers. In a map with inclined strata, both the boundaries and bedding planes of a stratum are somewhat parallel to each other. In this map, the boundaries of A, B, C, D and E layers are almost parallel to each other and intersect the contour lines in the form of curved lines, which shows that all these layers are inclined.(fig- 4.4 A)

Construction of section

To show inclined beds in section, the amount of dip of the beds is first determined by drawing two perpendicular lines on any bedding plane shown in the map. In the presented example, perpendicular lines of 600 and 700 meters have been drawn on the upper bedding plane of C layer and the perpendicular distance a b between these perpendicular lines has been expressed by a' b' in the right angle ∆ J a' b' (Figure 4.4 B). In this triangle, the b' J line reveals the distance according to the scale of the interval of perpendicular lines (i.e. 700-600 = 100 meters) and ∠Ja'b', whose value is 22°, shows the amount of dip of the beds. . Now draw XY cut line on the map and according to the previously instructed method, make a surface section by taking X'Y' base line of equal section of the cut line (Figure 4.4 C). In the map, show the points of intersection of the section line and bedding planes by the points F', G', H' and I' on the secant. It is clear from the tip of the arrow drawn between the perpendicular lines that the dips of the beds.

Fig-4.4 Inclined Rock-Beds



Source: Practical Geography by J. P. Sharma

Geological Analysis

The representation fraction of the geological map given in the example is 1/25,000. The contour interval in the map is 100 meters. From the study of contour lines, it is known that the slope of a hill shown in the map is uniformly inclined. This hill is about 950 meters high from the sea level. On this slope, the visible parts of five rock beds are shown. All the beds are inclined and their dip is the same. The slope of the ground and the direction of dip of the beds are also the same. The amount of dip of the left beds is 22° and the direction of dip is 90° north-west. According to the order of superimposition, the A bed is the oldest and the beds B, C, D and E situated above it are progressively younger in age, i.e. the A bed was deposited first and then the B, C, D and E beds were deposited respectively. The actual thickness of each of the B and C beds is 150 m and the vertical thickness is 200 m. The actual thickness of the D bed is 75 m and the vertical thickness is 100 m. From the viewpoint of geological history, these strata are conformable, because the same amount of dip indicates that the deposition of all the above strata took place continuously in the same geological era. While rising above the sea level, these strata, which were originally in a horizontal position, got tilted.

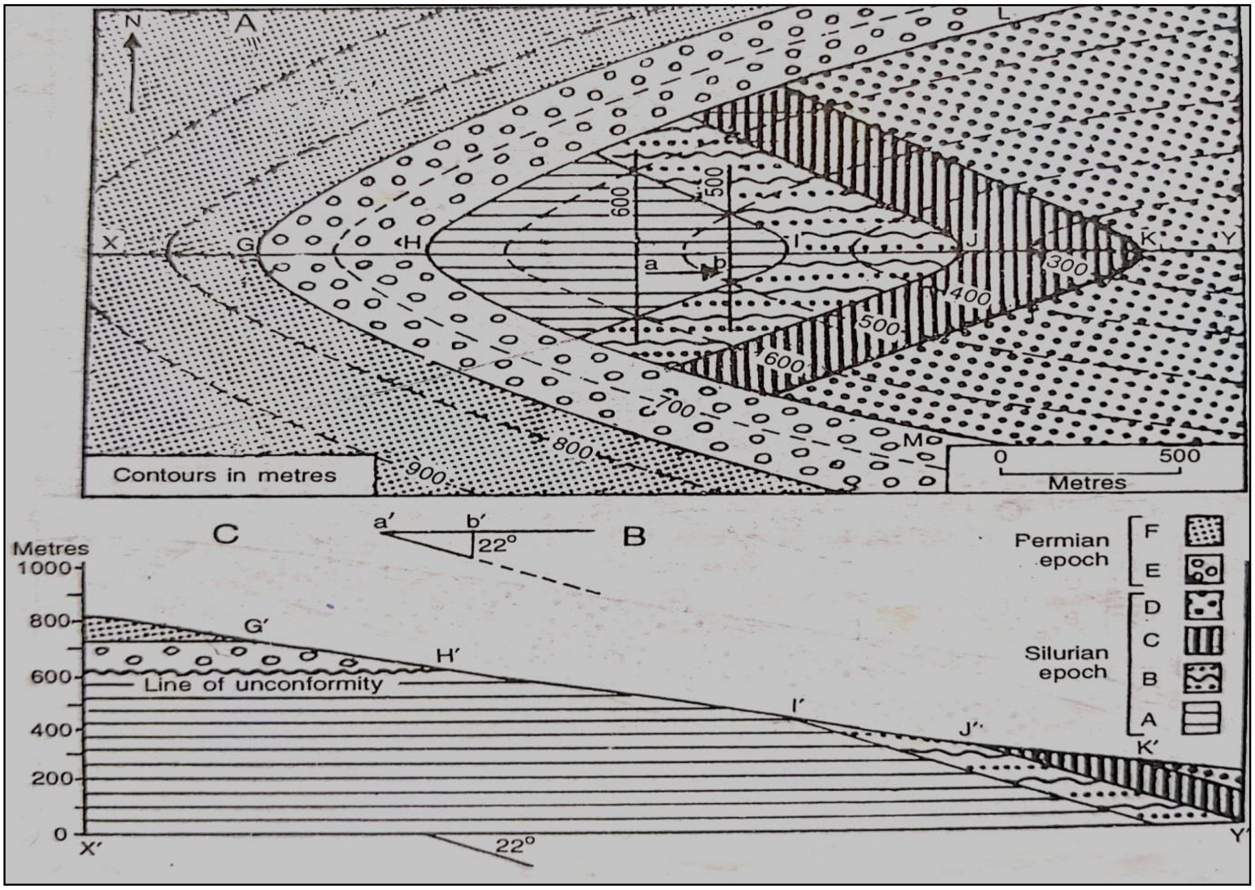
GEOLOGICAL MAPS OF UNCONFORMABLE BEDS

Unconformity refers to that geological structure in which rock formations of different geological periods are related to each other in a discordant manner. In simple words, if in the geological structure of an area, rock groups of two or more geological ages are arranged in an unconformable form, that is, the bedding planes of one rock group are not located parallel to the bedding planes of the other rock group, then that structure Will be called odd configuration. The plane that separates two different rock groups from each other is called the plane of unconformity and the line along which this plane intersects the surface is called the line of unconformity. In other words, if two rock groups meet in any area, then the lower bedding plane of the new rock group will be anomalous plane. This layer is expressed through a conventional symbol in the geological section. In Fig- 4.5 A, the LHM line (lower bedding plane of E layer) is the anomalous line.

Identification of Unconformable Beds

1) In these maps, the layers of one rock group appear to cover the layers of another rock group. In Map 4.5, the E layer of the Permian age rock group is seen covering the layers of the Silurian age rock group.
2) The boundaries of the layers of the rock group to be covered end abruptly at the boundary of the covering layer. In the above map, the boundaries of A, B, C and D layers end abruptly at the MHL boundary of E layer
3) In the map, the amount and direction of bending of the beds of one rock group is different from the amount and direction of bending of the beds of another rock group. In the above map, the beds of the Permian era are horizontal while the beds of the Silurian era are inclined.
4) Unconformity can also be detected by looking at the legend of the map because different rock groups are shown separately in it.

Fig-4.5 Unconformable beds



Source: Practical Geography by J. P. Sharma

Construction of section

Draw the XY cut line. Make the X'Y' base line of section equal to this line and construct the surface section as per the previously instructed method. Express the intersection points G, H, I, J and K of the section line and bedding planes by the points G', H', I', J' and K' respectively on the secant. In the map, the boundaries of E and F layers are parallel to the contour lines, hence these layers are horizontal. To show these layers in section, draw lines parallel to the X'Y' line from points G' and H'. The strata of the Silurian era are inclined, hence to show these strata in section, the amount of dip will be determined with the help of perpendicular lines. In the map, the angle of dip has been determined by drawing perpendicular lines of 500 and 600 meters on the upper bedding plane of the A layer, which is 22° (Figure 4.5 B). The direction of dip is 90°E, hence according to the method explained earlier, make an angle of dip towards the east below the base line and draw parallel lines from points I', J' and K'. These lines will reveal the layers of the Silurian rock group in the section. In the section, display the anomalous plane with a regular symbol and make a guide to the order of superposition of the layers.

Geological Analysis

This map is made on 1/25,000 representational scale and the contour interval is 100 meters. This map shows a hill slope which has a constant slope and its height is about 850 meters above sea level.

Two rock groups are shown in this map. The rock group of Silurian age has four layers namely A, B, C and D whereas the rock group of Permian age has two layers namely E and F. The amount of dip of the beds of Silurian age is 22° and the direction of dip is 90° N.E. In contrast, the beds of Permian age are horizontal i.e. their dip is zero. From the point of view of superposition, bed A is the oldest and after this bed, beds B, C, D, E and F were deposited respectively. The actual thickness of each bed of Permian age is 100 meters. Since these beds are horizontal, hence their vertical thickness is equal to the actual thickness. The actual thickness of each of the beds B and C of Silurian age is a little less than 100 meters. In the map, if the 500 meter perpendicular line of the upper bedding plane of the A bed is extended further, then it becomes a 600 meter perpendicular line on the upper bedding plane of the B bed. Hence, the vertical thickness of the B bed is 600-500 = 100 meters. Similarly, the vertical thickness of the C bed is also 100 meters.

The superposition order of the beds in the map and the position of the anomaly plane, the geological history of this area can be easily estimated on the basis of general geological knowledge. In the Silurian era, first the A beds and then the B, C and D beds were deposited in the sea etc. Even before the Silurian era ended, these beds rose above the sea level and a dip developed in them. From the time of uplift to the Permian era, these beds were eroded and in the same era these beds were submerged again. In the submerged state, the deposition work started again on the eroded surface (anomaly plane) of these beds. Thus, in the second order of deposition, first the E bed and then the F bed was deposited on the anomaly plane. Subsequently, there was regeneration and erosion removed some parts of the Permian age strata, exposing the Silurian age strata.

GEOLOGICAL MAPS OF FOLDED ROCK-BEDS

Identification of folded rock-beds

Folded rock layers shown in a geological map can be identified according to the following points:

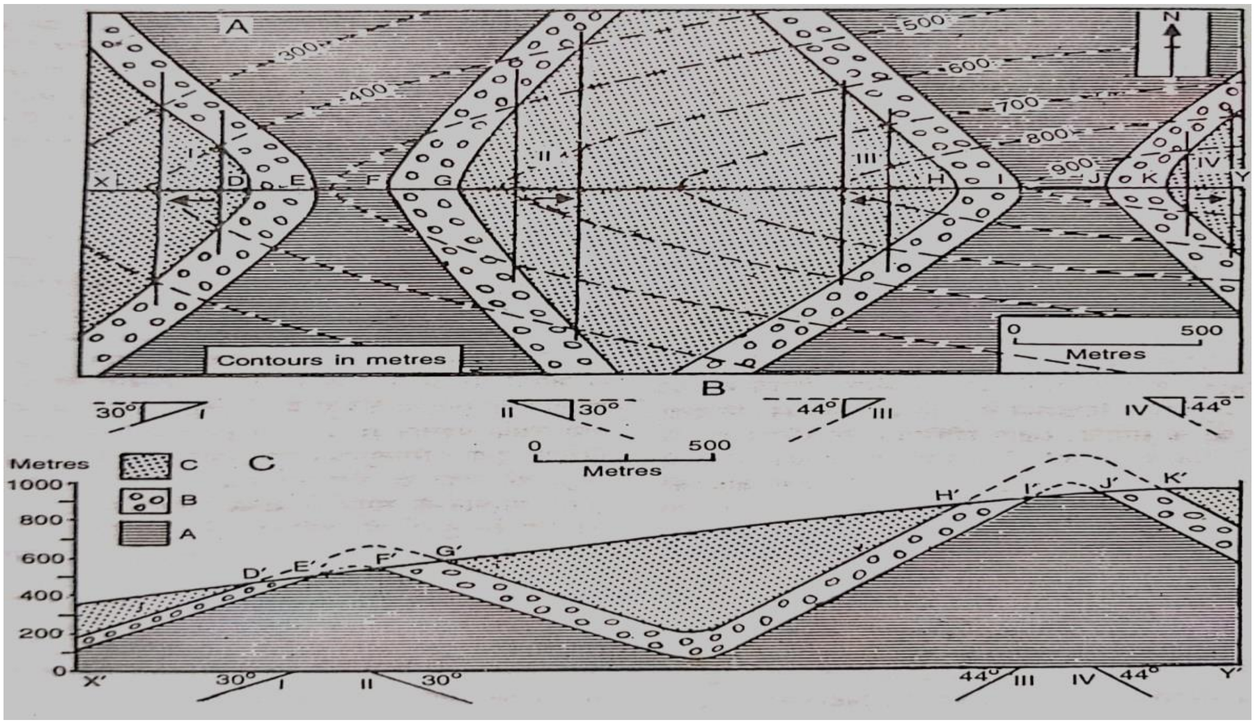
1) In the geological map of folded beds, visible parts of a bed appear at many places. In Map 4.6, sections of A bed are visible at two places, sections of B bed are visible at four places and sections of C bed are visible at three places, which shows that the beds shown in it are folded.

2) If the direction of dip of a bed is opposite to each other in any two of its successive outcrops, then that bed is definitely folded. In this example, the direction of dip in I and II, II and III and III and IV views of B bed is opposite to each other, hence B is a folded bed.
3) The presence of anticline or syncline or both in a fold depends on the pattern of bending direction. Similarly, by comparing the amounts of bending of a bed in two successive views, the type of folding, such as symmetrical, asymmetrical, etc., can be identified.

Construction of section

Looking at the map, it is known that the direction of subsidence has been shown at four places through arrows, therefore; first of all, find out the amounts of subsidence by making separate perpendicular lines at four places according to the method suggested earlier. In Figure 4.6 B, the values of dip have been determined at places I, II, III, and IV which are 30°, 30°, 44° and 44° respectively. Now draw the XY cut line in the map and make the X'Y' base line of the section equal to the length of this line. Make a surface profile by marking heights according to the scale of the map on both sides of the base line. In the map, the cut line intersects the layers at points D, E, F, G, H, I, J and K.

Fig-4.6 folded rock-beds



Source: Practical Geography by J. P. Sharma

By transferring these points on the secant, they become D', E', F', G', H', I' respectively. Find points J', and K'. Now make dip angles of 30°, 30°, 44° and 44° with the base line just below the points E', F', I', and J' of the secant. Remember, E' and'. Angles of dip will be made towards the west under F' and J' towards the east because in the map E and. At F and J the direction of dip is shown as N 90° W and at F and J the direction of dip angle is N 90° E. Now, from the points D' and E' of the secant Parallel to II, parallel to II from points F' and G', H' and'. From points parallel to ∠III. And by drawing lines parallel to 8 IV from the K' points, show the bedding planes of different layers in the section. Complete the gradients of folding with dotted lines as shown in Figure 4.6 C.

Geological Analysis

The representative fraction of the given geological map is 1/25,000 and the contour interval is 100 meters. The uniform slope of a hill about 950 meters above sea level has been shown by drawing contour lines at equal distances on the map.

Three folded beds A, B and C are shown in the map. As a result of folding, there is a difference in the amount and direction of dip. Among these beds, bed A is the oldest, hence the deposit of this bed was the first. After bed A, bed B and finally bed C were deposited. The actual thickness of bed B is about 125 meters. Two anticlines and three synclines are visible in the map. The entire part of the central syncline is visible, whereas the remaining two synclines on the right and left are visible only partially. Due to these anticlines and synclines, two folds have been formed in the bed. Since the sides of the folds in each fold are inclined in the same manner, these folds are of symmetrical type. From the viewpoint of geological history, these strata were deposited in the sea as horizontal layers. After this, these strata rose above the sea level in the form of folded strata due to the effect of compressional forces. These strata were eroded on the surface and due to the anticlines of the folds being cut down, the sides of the folds got separated from each other on one side and on the other side the A stratum got exposed at two places. The eroded part of the anticlines has been shown by dotted lines in the section.

<u>GEOLOGICAL MAPS OF FAULTED ROCK-BEDS</u>

Identification of fauled rock-beds

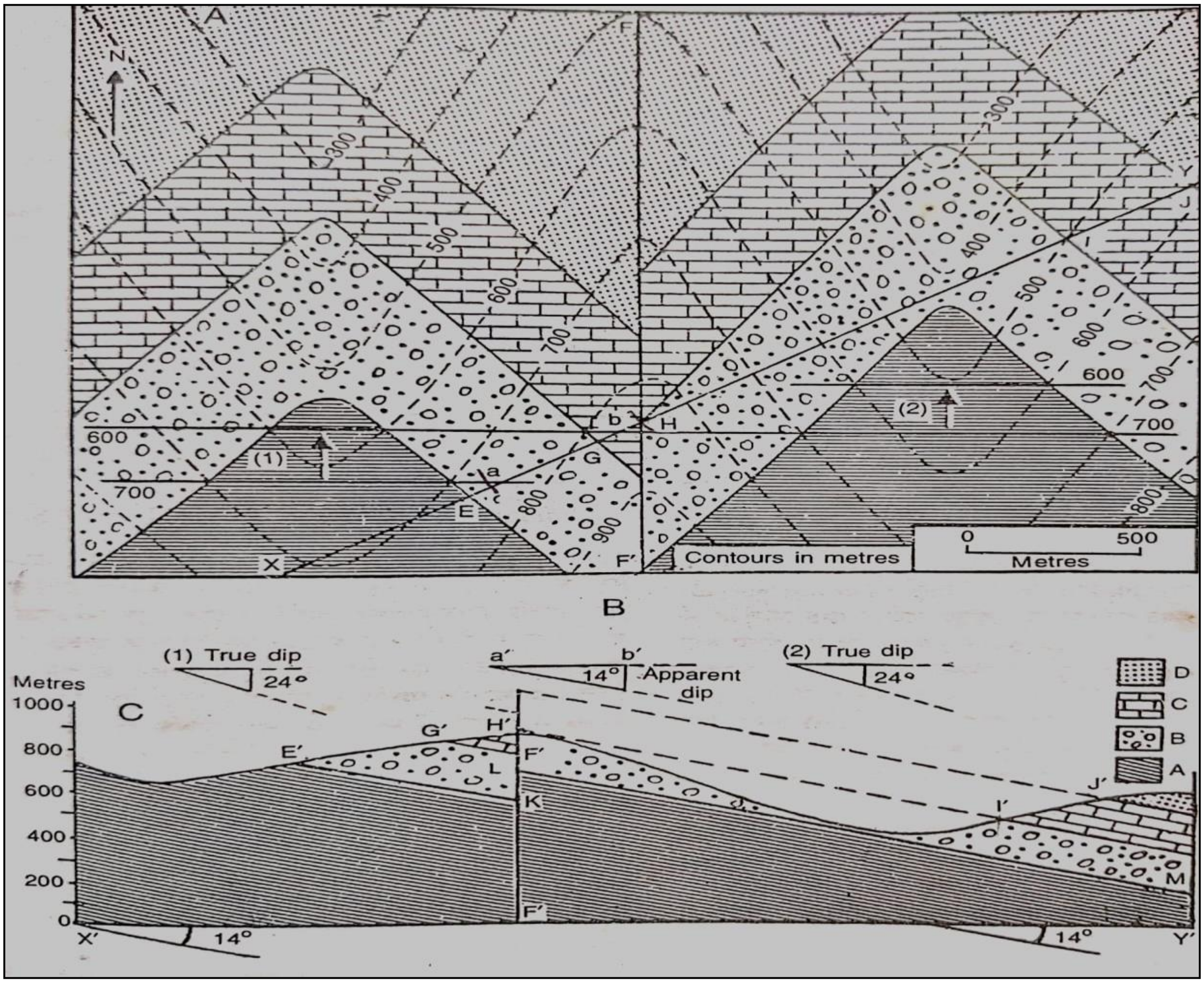
In order to make sections of geological maps of faulted strata and interpret them, it is very important for the students to have proper knowledge of the types and characteristics of faults. The topography resulting from the breaking of rock layers under the influence of internal forces and the migration of broken fragments is called a fault. The plane along which these rock fragments move is called fault plane. The fault plane can be in any form like horizontal, inclined, vertical or curved etc. The angle between a fault plane and an imaginary horizontal plane is called fault dip and the angle between a fault plane and an imaginary vertical plane is called elevation. The rock block raised higher as a result of a fault is called the up throw side and the relatively lower rock block is called the down throw side. A normal fault is formed by the movement of two rock fragments in opposite directions and a reverse fault is formed by their movement towards each other. In a normal fault with an inclined fault plane, the vertical distance between the uplift and dip segments is called throw and the horizontal distance is called heave (Figure 4.7).

Construction of section

To make a section, draw an XY cut line on the map and make the X'Y base line of the section equal to this line. Create a surface profile by transferring the intersection points of contour lines and section lines to this base line. The cutting line in the map is inclined; hence the rest of the section will be constructed according to the apparent dip of the beds. To find the apparent dip, the length of the intersecting line between two perpendicular lines is considered to be the distance of horizontal equivalent and the rest of the construction is similar to the method of finding the actual dip. In this example, by making perpendicular lines of 600 and 700 meters on the left side of the fault line, considering the distance a b of the cut line between them as the horizontal equivalent and the distance of 700-600 = 100 meters as the vertical interval, the apparent dip (i.e. 14°) was determined. is (Figure 4.7 B)-. Since this apparent dip has been determined with the help of the cut line, the direction of the cut line (i.e. North 55° East) will be the direction of the apparent dip. Apart from this, since the amount (i.e. 24°) and direction of the actual bending of the beds on both sides of the fault line is the same and the cut line is in the form of a straight line, hence the amount and direction of the apparent bending of the beds to the east of the fault line will be the same. Which is towards the west of the fault line?

When making an angle of 14° (i.e. virtual dip) towards the east with the base line. In the map, the cut line bedding planes are E, G, H. And. intersect at points. Display these points on the secant by transposition as points E', G', H', I' and ' respectively. Now mark the distance X'F' on the base line equal to XH. Draw perpendicular F'F' at point F'. This will show the fault plane in perpendicular section. Complete the bedding plane on the left side of the fault line by drawing lines parallel to the apparent dip angle from points E' and G'. Since there is a vertical section on the right side of the fault line and the value of throw is 100 meters, hence the bedding planes of the right part will be 100 meters higher than that of the left part. Therefore, according to the scale in the section, draw a line LM parallel to E'K at a distance of 100 meters which will reveal the upper bedding plane of the A layer in the right part.' And draw parallel lines from ' to LM to show the remaining bedding planes.

Fig-4.7 faulted rock-beds



Source: Practical Geography by J. P. Sharma

Geological Analysis

In this geological map made on 1/25,000 resolution, a hill about 950 meters above sea level is shown by drawing contour lines at an interval of 100 meters, on both sides of which river valleys are situated. Four rock layers A, B, C, D are shown in the map. Layer A is the oldest and the remaining layers B, C and D are of comparatively younger age respectively. The amount and direction of dip in the map is the same everywhere. The maximum actual thickness of layers B and C is 175 meters. These layers were faulted along the line FF' shown in the map, due to which the bedding planes on the right side of this line have become 100 meters higher than the left part. From the point of view of geological history, these layers were deposited horizontally. Later, due to the effect of tensional forces, these layers got faulted and were uplifted. Thereafter these layers were eroded on the surface and they came into their present form.

4.6 SUMMARRY

Geological maps and cross sections are fundamental tools for understanding the Earth's structure and history. By learning how to read and interpret these tools, students and professionals can gain valuable insights into geological processes, resource distribution, and environmental conditions. Mastery of these techniques is crucial for effective geological and geographical analysis, aiding in everything from academic research to practical applications in various fields. The chapter explores various types of geological maps—Surficial, outcrop, areal, and structural—and explains their practical applications. It also covers conventional symbols and shading methods used to convey rock layers, age, and structural features.

This chapter provides a comprehensive overview of geological maps and cross sections, offering geography students the knowledge and skills needed to interpret these important geological tools effectively.

4.7 GLOSSARY

- **Line of section**: Any straight line drawn on the map along which the section is made is called a Line of section.
- **Strike:** The direction of the line along which an imaginary horizontal plane cuts a bedding plane is called the strike and strike line.
- **Geological Map**: A representation of the Earth's geology showing rock types, structures, and ages using symbols and colors.
- **Surficial Map**: A type of map that shows the distribution of surface rocks and sediments.
- **Outcrop**: Exposed rock visible on the Earth's surface, often depicted on geological maps.
- **Areal Map**: A map showing geological formations in a plan view, typically for larger regions.
- **Structural Map**: A map that represents the geological structures like folds and faults using symbols.
- **Cross-Section**: A vertical slice through the Earth's subsurface, revealing the arrangement of geological features.
- **Unconformity**: A geological boundary where rock layers of different ages meet in a discordant manner.
- **Fault**: A fracture in rock formations caused by earth movements, where rock blocks move relative to each other.
- **Dip**: The angle at which a rock layer or geological feature slopes relative to a horizontal plane.

4.8 ANSWER TO CHECK YOUR PROGRESS

1. Geological maps help illustrate the nature and distribution of rock units within an area.
2. There are different types of geological maps, each with specific uses like surficial, outcrop, areal, and structural maps.
3. Geological maps visually represent features such as rock formations, faults, and folds.
4. Legends, symbols, colors, and scales are key components in reading geological maps.
5. Geological cross-sections offer a vertical view of subsurface geological structures.

4.9 REFERENCE

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4.10 TERMINAL QUESTIONS

Long Questions

1. Write the types of geological maps and explain their features.
2. What are Geological maps? Explain conventional signs and shading method of geological maps with diagram.
3. Define Geological Maps of Unconformable Beds and How to Identify of Unconformable Beds?
4. Explain folded rock-bed and faulted rock-bed.
5. Explain Geological analysis of Unconformable beds with diagram.

Short Questions

1. What is a geological map?
2. What is the purpose of a geological cross-section?
3. What are surficial maps used for?
4. What is an outcrop map?
5. How do areal maps differ from structural maps?
6. What is the line of unconformity?

7. What is a geological fault?
8. How can folded rock layers be identified on a geological map?

Multiple Choice Questions

1. What is the main purpose of a geological map?

A) To display political boundaries

B) To illustrate information about rock units

C) To represent climate patterns

D) To show population distribution

2. What kind of rocks is depicted in a sacrificial map?

(A) Bedrock

(B) Surface rocks

(C) Folded rocks

(D) Faulted rocks

3. What is the purpose of conventional symbols on geological maps?

(A) To represent surface features

(B) To indicate elevation

(C) To display geological features like folds and faults

(D) To mark cities and towns

4. Which type of map shows bedrock visible on the Earth's surface?

(A) Sacrificial map

(B) Areal map

(C) Outcrop map

(D) Structural map

5. What does a geological cross-section represent?

(A) A two-dimensional view of land features

(B) A vertical slice through the Earth

(C) A representation of surface vegetation

(D) A map of water bodies

6. In which type of map are geological units shown as a continuous sequence?

(A) Areal map

(B) Sacrificial map

(C) Outcrop map

(D) Structural map

7. What term describes a two-dimensional view of geological structures on a map?

(A) Cross-section

(B) Contour map

(C) Structural map

(D) Outcrop map

8. Which type of geological map is most useful for constructing dams and reservoirs?

A) Structural map

B) Sacrificial map

C) Outcrop map

D) Areal map

9. Which map type shows the structure of geological formations with conventional symbols?

(A) Sacrificial map

(B) Structural map

(C) Areal map

(D) Outcrop map

10. What does the term "unconformity" refer to in geology?

(A) A geological fault

(B) A break in rock formation between different geological periods

(C) A fold in the rock

(D) A large sediment deposit

11. Which map shows the plan view of geological formations in a region?

(A) Outcrop map

(B) Sacrificial map

(C) Areal map

(D) Structural map

12. What does a folded rock-bed in a geological map indicate?

(A) Faulting

(B) Folding of rock layers

(C) Mineral deposition

(D) Unconformity

Answer. 1. B, 2.B, 3.C, 4.C, 5.B, 6.A, 7.A, 8.B, 9.B, 10.B, 11.C, 12.B

BLOCK-3 SPECIAL NETWORK ANALYSIS:

UNIT-5 MEASUREMENT OF SPATIAL PATTERN OF DISTRIBUTION, NEAREST- NEIGHBOUR ANALYSIS

5.1 OBJECTIVES

After studying this unit you will be able to undertand:

- The essential elements of spatial analysis**.**
- The various types of spatial patterns**.**
- The factors influencing spatial distribution**.**
- How spatial relationships impact the analysis of geographic phenomena**.**
- The application of Nearest Neighbor Analysis (NNA)**.**
- To understand the use of spatial analysis methods in various disciplines.

5.2 INTRODUCTION

Spatial analysis serves as a vital methodology within the field of geography, facilitating the exploration and interpretation of spatial dimensions associated with various phenomena on the Earth's surface. By investigating the location, distribution, and interrelationships among features such as urban centres, waterways, natural resources, and demographic groups, the spatial analysis generates valuable insights into the patterns, trends, and processes that influence physical and human environments. This methodology synthesizes elements from geography, statistics, and computer science, employing tools such as Geographic Information Systems (GIS), remote sensing technologies, and spatial statistical techniques. Through spatial analysis, geographers are equipped to address inquiries regarding the occurrence of specific conditions, the rationale behind particular patterns, and the interconnectivity of different regions. This understanding is crucial for comprehending complex systems, including urban development, environmental degradation, resource distribution, and social interactions, all of which require a spatial perspective for effective decision-making in urban planning, environmental stewardship, public health, transportation logistics, and disaster management. Ultimately, spatial analysis constitutes a foundational element of contemporary geography, enhancing our ability to visualize and scrutinize the spatial organization of our world, thereby improving our capacity to manage and engage with our environment. Additionally, spatial distribution pertains to the geographic arrangement of individuals or groups within a specified area, a concept utilized across disciplines such as geography, demographics, and biology to analyze the spatial distribution of various entities. Likewise, spatial patterns function as analytical instruments for assessing distances between physical locations or objects often represented through colour-coded maps, where distinct colours signify specific, quantifiable variables to depict variations in relative positioning.

Nearest Neighbour Analysis evaluates the dispersion or arrangement of phenomena within geographical contexts, yielding a numerical metric that reflects whether a collection of points exhibits clustering or is evenly distributed. This analytical approach is employed by researchers to determine if the frequency of a phenomenon in a specific area aligns with its prevalence in other regions. By measuring the extent of clustering, this technique facilitates more accurate comparisons of spatial patterns across various locations.

5.3 DEFINITION

Spatial analysis refers to a geographical method employed to investigate the positioning, characteristics, and interconnections of both natural and anthropogenic elements on the Earth's surface, to uncover patterns, trends, and spatial dynamics.

The practice of spatial analysis encompasses the application of statistical, mathematical, and computational methods to evaluate spatial data, enabling geographers to explore phenomena about their geographic distribution and contextual spatial factors.

Within the field of geography, spatial analysis constitutes the examination of spatial data to comprehend the configuration, interactions, and processes that influence both physical environments and human behaviours, frequently utilizing tools such as Geographic Information Systems (GIS) and spatial statistical techniques.

In the context of spatial analysis, the term nearest neighbourhood pertains to the relative closeness of various points or locations within a defined geographical area. This concept is typically quantified by determining the distance from a specific point to its nearest neighbouring points, thereby enabling researchers to examine the distribution, clustering, or dispersion patterns of various phenomena throughout the region.

5.4 MEASURMENT OF SPATIAL PATTERN OF DISTRIBUTION

A spatial pattern is an essential analytical framework for geographers and analysts, enabling the assessment of distances and relationships among two or more physical locations or entities. Typically represented through colour-coded maps, spatial patterns illustrate specific quantifiable variables that facilitate the identification of changes and trends in relative positioning within a given area. This analytical approach, often referred to as spatial distribution, is pivotal in the field of geography, where the exploration of the characteristics, locations, and interactions of Earth's features provides valuable insights into spatial patterns and processes. By recognizing and analyzing these spatial patterns, geographers can enhance their understanding of intricate geographical phenomena and make well-informed decisions regarding environmental, urban, and social planning.

5.4.1 Essential Elements of Spatial Analysis

1. Geographic Location: The precise location of a spatial feature, which can be articulated through absolute coordinates (latitude and longitude) or in relative terms (such as nearness to significant landmarks).

2. Attributes: The attributes or data linked to a spatial feature, encompassing aspects like population density, types of land use, or levels of economic activity.

3. Spatial relationships: The relationships that exist among various spatial features, including proximity, distance, and patterns of clustering. Grasping these interconnections is vital for recognizing underlying patterns.

A spatial pattern denotes the arrangement or distribution of objects, phenomena, or features within a specific area or spatial context. In fields such as geography, ecology, urban planning, and data science, the analysis of spatial patterns is instrumental in uncovering the relationships and frameworks present in both tangible and conceptual spaces. Such patterns can provide valuable insights into the fundamental processes that influence the formation of environments or systems.

5.4.2 Types of Spatial Patterns:

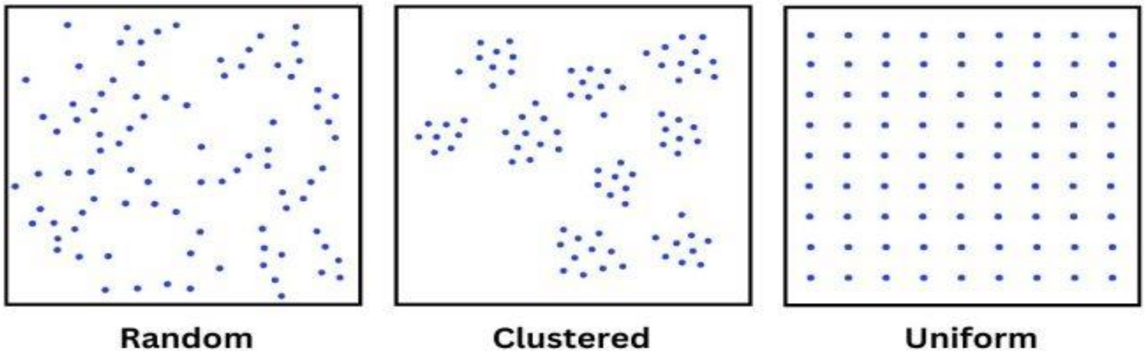
1. **Random Pattern**: Objects are distributed unpredictably and irregularly across space, with no discernible structure or organization.
2. **Clustered Pattern**: Objects are grouped together in specific areas, creating clusters or dense pockets, while other areas remain relatively empty.
3. **Uniform/Regular Pattern**: Objects are spaced evenly or regularly across the space, often following a systematic arrangement.
4. **Linear Pattern**: Objects are distributed along a line, such as along a road, river, or coast.
5. **Radial Pattern**: Objects radiate outward from a central point, often seen in city layouts or environmental phenomena like the spread of disease or ripples in water.
6. **Grid Pattern**: A structured pattern resembling a grid, common in urban planning or agricultural fields.

Three main types of spatial patterns may be observed in the analysis of spatial distribution. Uniform patterns are characterized by a consistent distribution of plotted points, suggesting that human intervention likely influenced the arrangement of a particular variable. In contrast, random distribution indicates the absence of correlation between variables, implying that planning was probably not a factor in the placement. Spatial clustering is identified when a majority of the plotted points are concentrated within a specific area, although their distribution may not be uniform.

Point distribution refers to the method by which particular locations are represented as distinct points on a map. These points can signify a variety of entities; for instance, they may indicate the positions of trees within a forest or the addresses of residences in an urban area.

Through the examination of point distribution, it becomes possible to discern spatial patterns. This analysis may involve clustering points or creating heat maps, among other techniques. Before delving into these applications, it is essential to first explore the different types of point distributions.

- **Random Distribution:** A random point distribution is characterized by the dispersion of points throughout a given area in a manner that lacks any discernible pattern. This implies that the points do not exhibit significant clustering or consistent intervals between them. An illustrative example of this phenomenon can be observed in the landing sites of meteorites on Earth, where the impacts occur independently of one another, resulting in a seemingly random arrangement.



- **Clustered Distribution:** A clustered point distribution occurs when points are concentrated in specific regions. This arrangement implies that the points are influenced by common factors that lead to their aggregation. Areas of high concentration may also signify zones of significant activity or interest. For instance, residential developments around a popular lake may illustrate a clustered distribution, reflecting a preference for living in proximity to water bodies. Similarly, the locations of earthquakes often align with tectonic plate boundaries, further exemplifying this distribution pattern.
- **Uniform Distribution:** Uniform point distribution refers to a scenario where points are distributed evenly throughout a given area, resulting in a consistent distribution pattern. This arrangement often signifies a purposeful organization that leads to regular intervals between

points. An illustrative example of this concept can be observed in a woodlot where trees are planted at equal distances from one another, exemplifying uniform point distribution. Another pertinent example is the placement of street lights along a highway, which are installed at regular intervals. Both cases exemplify intentional uniform spacing within geographical contexts.

5.4.3. Factors Influencing Spatial Distribution

Spatial distribution pertains to the arrangement of species or phenomena across a specific geographic area. Various elements can affect this distribution, including:

1. **Environmental Factors:**

   a. The characteristics of the landscape, climate, and soil types can profoundly impact the distribution of organisms or objects.

   b. For instance, in mountainous terrains, human settlements tend to concentrate in valleys while avoiding steep inclines.

2. **Biological and Social Interactions:**

   a. Interactions such as competition, predation, cooperation, and social structures can influence the distribution patterns of both species and human populations.

   b. An example is the relationship between predators and their prey, which may be spatially aligned to ensure ecosystem balance.

3. **Resource Availability:**

   a. The presence of essential resources, including food, water, and minerals, is crucial in determining the distribution of organisms or industries.

   b. For example, agricultural areas are frequently situated near water sources to optimize crop growth.

4. **Human Influence:**

   a. Factors such as urban development, zoning regulations, transportation systems, and industrialization contribute to the creation of artificial distribution patterns.

b. Cities often display organized or clustered layouts that reflect the underlying infrastructure design.

5. **Abiotic Factors:**

    a. Non-living elements, including temperature, precipitation, and soil composition, can restrict the habitats suitable for certain species. For example, some plants thrive in well-drained soils, while others prefer soils that retain moisture.

6. **Biotic Factors:**

    a. Living components, such as predation, resource competition, and disease, also play a significant role in shaping species distribution. For instance, high levels of predation in a specific area may lead prey species to avoid that location to enhance their survival chances.

7. **Human Activities:**

    a. Actions taken by humans, such as deforestation, urban expansion, and pollution, can significantly modify the natural habitats of various species, resulting in shifts in their distribution patterns.

8. **Geological characteristics**, including mountains, oceans, and other natural obstacles, can impede the movement of organisms, leading to varied distributions in different geographical areas.
9. **Historical occurrences**, such as shifts in climate, volcanic activity, and the introduction of non-native species, can exert enduring influences on ecosystems and their resulting spatial distributions.

5.4.4 Measurement of spatial patterns

It involves quantifying the arrangement or distribution of objects, phenomena, or organisms in space. These measurements are used across disciplines like geography, ecology, urban planning, and data science to identify patterns and understand the processes influencing them. Various metrics and techniques help assess whether a pattern is random, clustered, or uniform.

Key Methods for Measuring Spatial Patterns:

1. ***Nearest Neighbor Analysis (NNA)**:*

- **What it measures**: The average distance between each point and its nearest neighbor.
- **How it works**: Compares observed mean distances with expected distances in a random distribution.

Output:

- If the ratio of observed to expected distances is close to 1, the pattern is random.
- Ratios < 1 indicate clustering (points are closer together), while ratios > 1 suggest uniformity (points are spread out).

- **Applications**: Used in ecology (e.g., plant spacing), crime analysis (e.g., clustering of incidents), and urban studies (e.g., distribution of retail stores).

***Moran's I**:*

- **What it measures**: Spatial autocorrelation, which assesses whether similar values (e.g., population density, temperature) cluster together or are randomly distributed across space.
- **How it works**: Compares the similarity of values at nearby locations with those of distant ones.
- **Output**:
- Values range from -1 (indicating perfect dispersion) to +1 (indicating perfect clustering).
- A value of 0 indicates a random spatial distribution.
- **Applications**: Common in environmental sciences, urban studies, and public health to assess clustering of variables like pollution levels or disease incidence.

2. ***Ripley's K-Function**:*

- **What it measures**: Spatial dependence and clustering at different scales (or distances).

- **How it works**: Calculates the expected number of points within varying distances from each other and compares it with observed values.
- **Output**:
- Helps detect patterns of clustering or dispersion over a range of spatial scales, rather than just at one fixed scale.
- **Applications**: Frequently used in ecology to analyze the spatial structure of trees, animal populations, or other ecological data. Also used in epidemiology to detect disease clusters.

3. **Getis-Ord Gi** ***Statistic (Hotspot Analysis)***

- **What it measures**: Identifies areas where high or low values cluster spatially.
- **How it works**: Compares values in a region to neighboring regions to identify statistically significant clusters of high or low values.
- **Output**: Generates "hot spots" (high-value clusters) and "cold spots" (low-value clusters).
- **Applications**: Commonly used in crime analysis (e.g., to identify crime hotspots), health research (e.g., disease outbreaks), and market analysis (e.g., sales hotspots).

4. Fractal Dimension Analysis:

- **What it measures**: The complexity of spatial patterns and structures, particularly in irregular or fragmented patterns.
- **How it works**: Assesses the level of complexity across scales by calculating how the detail of a pattern changes with the scale of observation.
- **Output**: A fractal dimension value between 1 (simplest structure) and 2 (highly complex structure).
- **Applications**: Used in landscape ecology, urban studies (e.g., the spatial arrangement of streets or land use), and geography (e.g., coastline complexity).

5. ***Quadrat Analysis:***

- **What it measures**: The distribution of points or objects in space by dividing the study area into equally sized quadrats (grids).
- **How it works**: Compares the number of objects in each quadrat to the expected number in a random distribution.

Output:

- If variance is greater than the mean, clustering is indicated.
- If variance is less than the mean, the distribution is more uniform.

- **Applications**: Commonly used in ecology (e.g., for species distribution) and urban analysis (e.g., density of buildings or infrastructure).

6. ***Spatial Autocorrelation (Global and Local):***

- **What it measures**: The degree to which a variable (e.g., income, temperature) is similar across nearby areas.
- **How it works**: Global autocorrelation provides an overall measure of spatial pattern, while local autocorrelation identifies clusters or outliers.
- **Output**: Moran's I is a global measure, while local indicators like LISA (Local Indicators of Spatial Association) help identify localized patterns.
- **Applications**: Used in geography, economics, and environmental science to detect clusters of similar or dissimilar values, such as income inequality or temperature variations across regions.

7. ***Kernel Density Estimation (KDE):***

- **What it measures**: The density of points (events, objects) in space to create a continuous surface showing regions of high and low concentrations.
- **How it works**: Each point spreads out into a smooth curve that peaks at the point location, and all curves are summed together to create a density surface.

- **Output**: A smoothed surface or map highlighting areas with high densities or concentrations.

By using these methods, researchers can accurately describe and analyze spatial distribution patterns, providing insight into the processes influencing the arrangement of objects or phenomena across space.

5.4.5 Applications across diverse domains

Spatial distribution pertains to the geographic or temporal arrangement of a specific phenomenon's occurrence. This concept is pivotal in numerous disciplines, including geography, environmental science, and urban planning, as it aids in comprehending the patterns associated with natural resources, human habitation, and environmental risks. For instance, geographers employ spatial distribution to examine the locations of various ecosystems, such as forests, deserts, and oceans, and to analyze their interrelations. Environmental scientists utilize this concept to investigate the dispersion of pollutants within ecosystems and their repercussions on both human health and the environment. In the realm of urban planning, spatial distribution assists in pinpointing regions characterized by high population density and traffic congestion, thereby guiding decisions related to transportation infrastructure and land-use strategies. Ultimately, a thorough understanding of spatial distribution is essential for informed decision-making across a multitude of sectors and academic fields.

- **Ecology:** Analyzing the spatial distribution of species is vital for effective conservation and biodiversity strategies.

- **Geography:** Examining patterns of population density can enhance urban planning and the allocation of public services.

- **Economics:** The spatial distribution of industries and resources is critical for effective infrastructure planning and supply chain management.

The spatial arrangement of distribution yields significant insights into the fundamental dynamics of a system and its interactions with both natural and anthropogenic environments.

5.5 NEAREST-NEIGHBOUR ANALYSIS

The Nearest Neighbor Analysis (NNA) method, originally developed by botanists P.J. Clark and F.C. Evans in 1954, is a statistical tool that quantifies the spatial arrangement of plants, particularly trees. It aims to describe the distribution patterns of vegetation within forest ecosystems, and over time, this technique has been adapted for use in geography. The analysis is now commonly employed to examine the distribution of various phenomena, including human settlements, schools, hospitals, and natural features like mountains or wells. It is particularly useful in studying how these elements cluster, disperse, or are randomly distributed across a given area.

In geography, point patterns are central to understanding spatial distribution. Points, often represented as dots on maps, help illustrate the locations of various features. Nearest Neighbor Analysis is one of the key methods for analyzing these patterns. By measuring the distances between a point and its nearest neighbor, the NNA provides insights into whether the points are more regularly spaced, clustered together, or randomly distributed. The method is versatile, allowing it to be applied to both human and physical features, thereby facilitating an understanding of the spatial relationships that influence the arrangement of settlements, vegetation, and other phenomena.

The underlying concept in geography is the study of spatial relationships between different phenomena. This includes the location of human activities, which vary based on socio-economic and cultural factors. The non-uniform nature of human activity distribution prompts the need to understand the factors that influence the location choices. Nearest Neighbor Analysis aids in this by assessing how human settlements, for instance, are spatially distributed, considering the environmental factors like climate, soil, and natural vegetation, as well as socio-cultural influences. It helps identify the patterns of activity distribution, revealing whether they follow regular, clustered, or random patterns.

A regular pattern is characterized by evenly spaced points, while a clustered pattern has points grouped together with larger gaps between them. Random patterns are those where the points are irregularly spaced, potentially by chance. These patterns are not mutually exclusive, and one can observe clustering within what appears to be a regular pattern. NNA helps discern such subtle differences by providing a quantitative comparison of observed and theoretical random distributions.

The Nearest Neighbor Index (NNI), introduced by Clark and Evans, is central to the analysis. It calculates the distances between points, compares them with a random distribution, and provides an index value that indicates how clustered or dispersed the points are. If the points are clustered, the mean distance between them will be smaller, while a more dispersed arrangement results in larger distances. The method uses an overall density measure to normalize the results, allowing comparisons across different spatial areas. This helps determine whether the point distribution is significantly different from random, providing a clearer understanding of the spatial dynamics of various phenomena.

The figure presented below illustrates three hypothetical patterns depicting the distribution of points across a specified area. One pattern features loosely clustered points, another exhibits a regular arrangement, while the third demonstrates a random distribution of points. In this context, 'random' refers to the outcome of locational processes whereby each point possesses an equal probability of occurrence at any given location on the map, indicating that every location or point has an identical likelihood of experiencing an event. However, the placement of each point is independent of the others, with points remaining fixed within the spatial framework. The nearest neighbour index yields results that range from a minimum value of 0 to a maximum of 2.15, with the various distribution patterns forming a continuum:

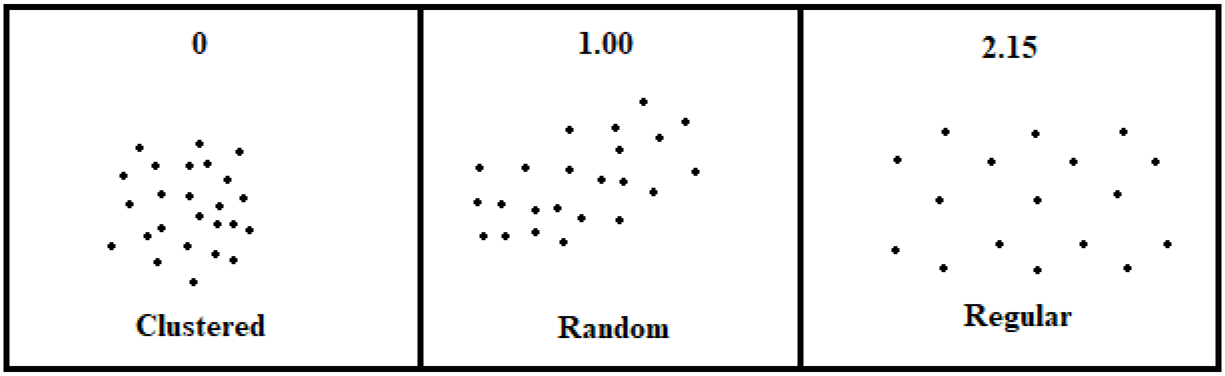


Figure 1: Three imaginary location patterns measured as clustered, regular and random

The criteria for determining the distribution pattern are illustrated in Figure 2. A value of Rn that is near 0 indicates a clustered distribution pattern. Conversely, an Rn value that hovers around 1.00 (specifically between 0.5 and 1.5) suggests a random distribution. As the Rn value approaches 2.0, the distribution pattern becomes uniform, and an Rn value that is very close to 2.15, which represents the maximum, indicates a perfectly uniform distribution.

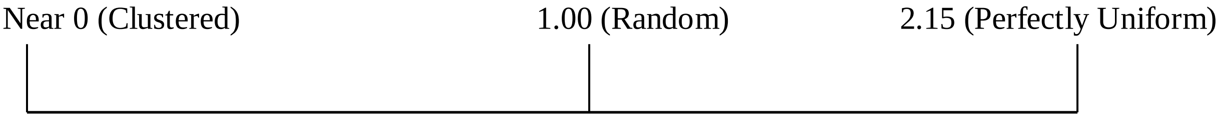


Figure 2: Rn scale

The Nearest Neighbor Index (NNI) is a complicated tool to measure precisely the spatial distribution of a patter and see if it is regularly dispersed (= probably planned), randomly dispersed, or clustered. It is used for spatial geography (study of landscapes, human settlements, CBDs, etc).

5.5.1. Understanding the Nearest Neighbor Index (NNI)

The **Nearest Neighbor Index (NNI)** is a key metric in nearest neighborhood analysis. It measures the degree to which points are clustered or dispersed. This index is calculated as the ratio of the observed mean distance between each point and its closest neighbor to the expected mean distance in a hypothetical random distribution.

Steps to Calculate Nearest Neighbor Analysis

1. **Calculate Observed Mean Distance** ($\bar{D}_{observed}$):
   - For each point in your dataset, find the distance to its closest neighboring point.
   - Calculate the average of all these nearest neighbor distances.

$$\bar{D}_{observed} = \frac{\sum_{i=1}^{n} \text{di}}{n}$$

where:

- n = total number of points
- d_i = distance from point iii to its nearest neighbor

2. **Calculate Expected Mean Distance** ($\bar{D}_{expected}$):

- In a random spatial distribution, the expected mean distance between nearest neighbors in an area A is given by:

$$\frac{1}{2\sqrt{\frac{n}{A}}}$$

where:

A = area of the study region, n = number of points

3. **Calculate the Nearest Neighbor Index (NNI)**:
   - NNI is the ratio of observed mean distance to the expected mean distance:

$$\text{NNI} = \frac{\bar{\text{D}}_{observed}}{\bar{\text{D}}_{expected}}$$

Interpretation of the NNI

- **NNI = 1**: The point distribution is **random**.
- **NNI < 1**: The point distribution is **clustered** (points are closer together than if they were randomly distributed).
- **NNI > 1**: The point distribution is **dispersed** (points are more evenly spaced).

1.5.2. Example: Suppose we have a study area of 100 km² and five points representing locations of trees in this area. The coordinates of these five trees are as follows:

1. Tree A: (2, 3)
2. Tree B: (5, 8)
3. Tree C: (7, 6)
4. Tree D: (3, 7)
5. Tree E: (6, 2)

We will calculate the observed mean distance, the expected mean distance, and finally the NNI.

Step 1: Calculate Observed Mean Distance

1. **Find the distance between each point and its nearest neighbor**:

- Use the Euclidean distance formula to find the distance between points:

$$\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

- For each tree, calculate the distance to its nearest neighbor:
- **Tree A** (2, 3):

  Distance to Tree D (3, 7) = $\sqrt{(3-2)^2 + (7-3)^2}$ = $\sqrt{1+16}$ = $\sqrt{17} = 4.12$

- **Nearest neighbor for Tree A** is Tree D with distance **4.12 km**.
- **Tree B** (5, 8):
- Distance to Tree D (3, 7) = $\sqrt{(3-5)^2 + (7-8)^2}$ = $\sqrt{4+1}$ = $\sqrt{5} = 2.24$
- **Nearest neighbor for Tree B** is Tree D with distance **2.24 km**.
- **Tree C** (7, 6):
- Distance to Tree E (6, 2) = $\sqrt{(6-2)^2 + (2-6)^2}$ = $\sqrt{1+16}$ = $\sqrt{17} = 4.12$
- **Nearest neighbor for Tree C** is Tree E with distance **4.12 km**.
- **Tree D** (3, 7):
- Distance to Tree A (2, 3) = 4.12 (as calculated above)
- **Nearest neighbor for Tree D** is Tree A with distance **4.12 km**.
- **Tree E** (6, 2):
- Distance to Tree C (7, 6) = 4.12 (as calculated above)
- **Nearest neighbor for Tree E** is Tree C with distance **4.12 km**.

2. **Calculate the observed mean distance**:

$$\bar{D}_{observed} = \frac{4.12 + 2.24 + 4.12 + 4.12 + 4.12}{5} = \frac{18.72}{5} = 3.744$$

Step 2: Calculate Expected Mean Distance ($\bar{D}_{expected}$)

Using the formula:

$$\bar{D}_{expected} = \frac{1}{2\sqrt{\frac{n}{A}}}$$

where:

n = 5 (number of points), A = 100 km² (area)

1. Calculate the density of points:

$$\frac{n}{A} = \frac{5}{100} = 0.05$$

2. Substitute into the expected mean distance formula:

$$\bar{D}_{expected} = \frac{1}{2\sqrt{\frac{n}{A}}} = \frac{1}{2\sqrt{0.05}} = \frac{1}{2\times0.2236} = \frac{1}{0.4472} = 2.236\ km$$

Step 3: Calculate the Nearest Neighbor Index (NNI)

$$NNI = \frac{\bar{D}_{observed}}{\bar{D}_{expected}} = \frac{3.744}{2.236} = 1.675$$

Interpretation of NNI

Since NNI > 1, the points (trees) are more dispersed than if they were randomly distributed. In this example, an NNI of approximately 1.675 suggests that the tree locations are somewhat evenly spaced or dispersed across the study area.

5.6 SUMMARY

Spatial patterns serve as fundamental analytical instruments for geographers and analysts, enabling the evaluation of the distribution and interrelationships of physical locations or entities within a given space. These patterns are often depicted through colour-coded maps, which visually represent quantifiable variables, thereby facilitating the identification of changes and trends by experts. Essential components of spatial patterns include geographic location, characteristics of spatial features, and relationships such as proximity and clustering. Various types of spatial patterns exist, including random, clustered, and uniform distributions. The factors that affect spatial distribution encompass environmental and biological interactions, as well as human influences and the availability of resources. Measurement methodologies such as Nearest Neighbor Analysis, Moran's I, and Kernel Density Estimation are employed to quantify spatial arrangements, which are vital in fields such as ecology, urban planning, and economics. Through the analysis of spatial distribution, professionals acquire critical insights necessary for effective conservation efforts, urban infrastructure development, and resource management across a range of sectors.

Nearest Neighbor Analysis (NNA) is a quantitative method designed to evaluate spatial distribution patterns. Originally employed in botany to investigate the arrangement of plant species, it has since been adapted for geographical studies to analyze clustering or dispersion phenomena. Introduced by Clark and Evans in 1954, this analytical technique focuses on the spatial configuration of points—such as trees, settlements, or educational institutions—by measuring the distances between each point and its closest neighbour. The Nearest Neighbor Index (NNI) is utilized to juxtapose the observed distribution with a theoretically expected random distribution, thereby categorizing the patterns as clustered, uniform, or random. Additionally, the NNA generates a randomness index (Rn) that indicates the degree of clustering or dispersion present in the distribution. This methodology finds extensive application in fields such as urban planning, geography, and ecology, facilitating a deeper understanding of the spatial interactions among human and natural elements and supporting comparative analyses and strategic decision-making.

5.7 GLOSSARY

- **Anthropogenic elements**: Human-made or human-influenced components in the environment, such as buildings, roads, and pollution.
- **Geographic Information Systems (GIS)**: Technology that captures, analyzes, and visualizes geographic data to understand spatial patterns and relationships.
- **Earthquakes**: Sudden shaking or movement of the Earth's surface caused by the release of energy along faults or tectonic plate boundaries.
- **Landscape**: The visible features of an area of land, including natural elements (mountains, rivers) and human-made features (cities, roads).
- **Climate**: The long-term patterns of temperature, precipitation, and other atmospheric conditions in a particular region.
- **Temporal**: Relating to time, often used in geographic or environmental studies to indicate changes or patterns over a specific time period.

- **Natural resources**: Raw materials and energy sources found in nature, such as water, minerals, forests, and fossil fuels.
- **Environmental risks**: Potential threats to the environment and human health, such as pollution, deforestation, and climate change.
- **Ecology**: The study of interactions between organisms and their environment, focusing on ecosystems, biodiversity, and the flow of energy.
- **Meteorites:** Meteorites are celestial bodies composed of rock or metal that endure the journey through the Earth's atmosphere, ultimately reaching the surface of the planet.
- **Tectonic Plate Boundaries:** It refer to the interfaces where two tectonic plates converge, diverge, or slide past one another, often resulting in seismic events, volcanic eruptions, and the uplift of mountain ranges.

5.8 ANSWER TO CHECK YOUR PROGRESS

1. What is the primary purpose of analyzing spatial patterns in geography?

(A) To map weather patterns
(B) To study historical events
(C) To assess distances and relationships among locations
(D) To measure economic activity levels

Answer: C.

2. Which spatial pattern is characterized by points distributed unpredictably and irregularly across space?

(A) Random Pattern
(B) Clustered Pattern
(C) Uniform Pattern
(D) Linear Pattern

Answer: A

3. What type of spatial pattern is often seen in city layouts or the spread of diseases, where objects radiate from a central point?

(A) Grid Pattern
(B) Radial Pattern
(C) Clustered Pattern
(D) Uniform Pattern

Answer: B

4. Which factor influencing spatial distribution includes elements like climate, landscape, and soil types?

(A) Resource Availability
(B) Abiotic Factors
(C) Environmental Factors
(D) Social Interactions

Answer: C

5. In the measurement of spatial patterns, what does the Nearest Neighbor Analysis (NNA) assess?

(A) The uniformity of all objects in an area
(B) The density of buildings in an urban area
(C) The average distance between each point and its nearest neighbor
(D) The total number of points in a given area

Answer: C

6. Which spatial analysis method is commonly used to detect clusters or "hot spots" in crime and health research?

(A) Ripley's K-Function

(B) Getis-Ord Gi Statistic
(C) Quadrat Analysis
(D) Kernel Density Estimation

Answer: B

7. **Which element of spatial analysis refers to the precise or relative position of a feature?**

(A) Attributes
(B) Spatial Relationships
(C) Geographic Location
(D) Spatial Distribution

Answer: C) Geographic Location

8. **Who originally developed the Nearest Neighbor Analysis (NNA) method, and what was its initial purpose?**

(A) Clark and Evans, to analyze the distribution of human settlements
(B) Clark and Evans, to examine the spatial distribution patterns of plants
(C) King and Dacey, to investigate geographic features
(D) Fotheringham and Woulder, to study the distribution of urban infrastructure

Answer: B

9. **In the context of Nearest Neighbor Analysis, what does a low Nearest Neighbor Index (NNI) value indicate about a distribution pattern?**

(A) A uniform distribution
(B) A clustered distribution
(C) A random distribution
(D) An evenly spaced distribution

Answer: B

10. What two key assumptions underlie the Nearest Neighbor Analysis (NNA)?

(A) All events are independent and evenly spaced

(B) All locations have equal event probability, and events are independent

(C) Events occur at regular intervals, and all locations have varying probabilitie

(D) Events are randomly dispersed, and distances between points are equal

Answer: B

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5.10 TERMINAL QUESTIONS

1. What is the significance of spatial patterns in geographic analysis?

2. What are the essential elements of spatial analysis, and why are they important?

3. Can you explain the differences between random, clustered, and uniform spatial patterns?

4. How does the spatial relationship between features, such as proximity and distance, impact geographic analysis?

5. What factors influence spatial distribution, and how do they shape the arrangement of organisms or human activities?

6. How does the Nearest Neighbor Analysis (NNA) method help in understanding spatial patterns?

7. What is the Nearest Neighbor Index (NNI), and how is it used to determine spatial distribution patterns?

8. How do human activities, such as urban development and industrialization, affect spatial distribution?

9. In what ways can spatial analysis methods be applied in different disciplines like ecology, urban planning, and economics?

10. Suppose we have a study area of 80 square kilometers (km^2) and six points representing locations of houses in this area. The coordinates (in km) of these six houses are as follows:

- House A: (4, 5)
- House B: (9, 12)
- House C: (13, 8)
- House D: (6, 10)
- House E: (7, 3)
- House F: (11, 6)

Calculate the Observed Mean Distance, the Expected Mean Distance, and the Nearest Neighbor Index (NNI) for these houses.

11. In a study area of 50 square kilometers (km²), there are four points representing the locations of water wells. The coordinates (in km) of the wells are as follows:

- Well A: (1, 2)
- Well B: (5, 6)
- Well C: (8, 7)
- Well D: (4, 10)

Using the Euclidean distance formula, calculate the Observed Mean Distance, the Expected Mean Distance, and the Nearest Neighbor Index (NNI) for the wells.

12. You have a 120 square kilometer (km²) study area with seven points representing the locations of schools. The coordinates (in km) of these schools are as follows:

- School A: (3, 3)
- School B: (10, 10)
- School C: (15, 7)
- School D: (7, 12)
- School E: (5, 2)
- School F: (11, 8)
- School G: (6, 6)

Calculate the Observed Mean Distance, the Expected Mean Distance, and the Nearest Neighbor Index (NNI) for the schools.

13. Consider a study area of 200 square kilometers (km²) with five points representing the locations of mountains. The coordinates (in km) of these mountains are as follows:

- Mountain A: (10, 15)
- Mountain B: (30, 40)
- Mountain C: (50, 20)
- Mountain D: (70, 60)
- Mountain E: (90, 80)

Using the Euclidean distance formula, calculate the Observed Mean Distance, the Expected Mean Distance, and the Nearest Neighbor Index (NNI) for the mountains.

UNIT-6 SCALING TECHNIQUES, RANK SCORE, WEIGHTED SCORE.

6.1 OBJECTIVE

After going through this unit you will be able to learn about:

- Know about scaling and its techniques.
- Understanding the Rank Scores.
- Know about Weighted Scores.

6.2 INTRODUCTION

In today's data-driven world, effective evaluation and comparison are crucial for informed decision-making across various domains such as business, education, research, and machine learning. However, raw data alone often lacks the structure to derive meaningful insights. To bridge this gap, techniques such as scaling, ranking, and scoring are employed to process data into actionable forms. These methods are essential in transforming complex datasets into formats that can be easily interpreted, compared, and utilized for making critical decisions.

Scaling Techniques help in normalizing or standardizing data, making it easier to compare values that may originally exist on different scales. Whether we are analyzing financial metrics, exam results, or performance indicators, data often needs to be scaled to avoid bias introduced by differing units of measurement or wide variations in value.

Rank Score provides a way to assess and compare entities based on their relative positions in a dataset. By assigning ranks to values, we can identify how entities perform in relation to others, which is valuable in scenarios like academic evaluations, search engine results, or sports standings.

Weighted Score allows decision-makers to account for the relative importance of different factors in a final assessment. Unlike simple scores, weighted scores incorporate the idea that not all criteria are equally important, which ensures a more accurate and tailored evaluation. This is especially relevant in multi-criteria decision-making processes, such as hiring, product selection, or project prioritization.

Finally, a Score is the simplest form of evaluation—often a raw value or a measurement of performance or outcome. However, by applying scaling, ranking, and weighting techniques, we can enhance the usefulness of scores and derive deeper insights.

This chapter explores these core concepts—scaling techniques, rank scores, weighted scores, and scores—providing the tools necessary for effective data processing and evaluation. By the end of this chapter, you will understand how to apply these techniques to diverse datasets to make informed and equitable decisions across various contexts.

6.3 SCALING

Definition of Scaling

Scaling is the process of transforming or adjusting data values to fit within a specific range or standard. It is often used when data points are expressed in different units or have widely varying magnitudes, making direct comparison difficult. By applying scaling techniques, raw data is normalized or standardized to bring it into a comparable format, ensuring that each data point is assessed fairly relative to others.

Scaling is particularly useful in:

Machine Learning: where features need to be brought to the same range for algorithms to function effectively.

Data Analysis: when working with variables of different units or magnitudes (e.g., income in dollars and age in years).

Performance Metrics: to avoid bias introduced by varying scales in evaluations (e.g., comparing speed in meters per second vs. distance in kilometres).

There are several techniques for scaling, such as min-max scaling, z-score normalization, and logarithmic scaling, each designed for specific situations depending on the nature of the data and the goal of the analysis.

Why Raw Data Needs to Be Scaled

Raw data often comes in various forms with different units, scales, and ranges, which can make it difficult to use effectively in analysis, comparison, and decision-making. Without scaling, these variations can lead to biased outcomes or misinterpretations, especially in data-driven fields like machine learning, statistics, and business analytics. Below are detailed reasons why raw data needs to be scaled:

1. Data in Different Units

In many datasets, variables are measured in different units, which makes a direct comparison impossible without scaling. For example:

- Income might be measured in dollars.
- Age might be measured in years.
- Height could be measured in centimetres or feet.

Since these variables have different units, treating them as-is during analysis could lead to distorted conclusions. For instance, in regression models or machine learning algorithms, variables with larger numerical values (like income in the thousands) might dominate smaller-scaled variables (like age or height), leading to biased results. Scaling brings all variables into a common range, enabling fair comparison and ensuring that no single variable disproportionately influences the analysis.

Large Value Ranges

Some datasets have variables that span a large range of values, with some numbers being extremely small and others very large. For example:

1. House prices may range from thousands to millions of dollars.
2. Product ratings might range from 1 to 5 stars

If such variables are left unscaled, those with larger ranges can dominate the outcome of statistical models, rendering smaller-range variables less significant or invisible. This is particularly problematic in machine learning models like k-nearest neighbours (KNN), support vector machines (SVM), and neural networks, where distance-based calculations or gradient-based optimizations are sensitive to value magnitudes.

By scaling variables to a common range (e.g., between 0 and 1), the importance of each variable is normalized, preventing the model from giving undue weight to those with larger value ranges.

Proving Algorithm Efficiency

Many machine learning and statistical algorithms work more efficiently when the data is scaled. This is especially true for algorithms that rely on distance-based measures or gradient descent optimization. Two examples:

Distance-Based Algorithms: Algorithms like KNN and K-Means Clustering rely on distance calculations between data points. If variables are not scaled, those with large ranges will dominate distance calculations, making the algorithm focus more on some features and ignore others.

For instance, in clustering customer data, if the age ranges from 20 to 70 years and income ranges from 20,000 to 200,000, the income feature would dominate the distance calculation, making age seem less relevant.

Gradient Descent Algorithms: Models such as neural networks and linear regression use gradient-based optimization techniques. If the data has large variations in magnitude, the algorithm can take longer to converge (or might not converge at all), leading to poor performance. This happens because the learning rate would have to be adjusted very carefully for features with high ranges, slowing down the optimization process.

Scaling ensures that all features contribute equally to the model’s learning process, leading to faster and more stable convergence.

Improving Model Performance and Accuracy

Some models, like linear regression and logistic regression, assume that the data is centred around a particular range, usually 0, and may assume that it follows a standard distribution. When features are not scaled:

Outliers and high-range features can disproportionately affect the model's predictions.Coefficients in models like regression will be scaled according to the range of the input features, leading to misleading interpretations of the model’s coefficients.

For example, if a model predicts house prices based on square footage and the number of bedrooms, without scaling, square footage (which has a much larger range) might unduly influence the model’s predictions, while the number of bedrooms (a smaller-range variable) might be underweighted.

By scaling, we give all variables equal importance, which improves the model’s overall performance, making it more accurate and interpretable.

Handling Outliers More Effectively

Outliers, or data points that fall far outside the expected range of values, can severely skew the results of analysis or machine learning models, especially when the data is not scaled. For example, in financial data:

A dataset might contain one or two extremely high values (e.g., one millionaire in a dataset of middle-income individuals).

These outliers can:

Distort statistical measures, such as the mean and standard deviation, Dominate the learning process in machine learning algorithms, leading to poor predictions or decisions.

Scaling techniques like Z-Score normalization or logarithmic scaling help mitigate the effect of outliers by transforming the data to a more standardized or compressed scale, reducing their influence on the overall analysis.

Enhancing Interpretability of Data

When variables have very different scales, it can be hard for humans to interpret the relationships between them. For example, suppose you have two features—test scores ranging from 0 to 100 and hours studied ranging from 0 to 10. The test score feature would seem numerically dominant, even though the number of hours studied might be equally important.

Scaling both features to a common range (e.g., between 0 and 1) not only improves model accuracy but also makes it easier for analysts to interpret patterns and correlations in the data. It allows decision-makers to compare the contributions of different features more easily and understand how each variable affects the output.

Improving Visual Representations

In data visualization, scaling is often necessary to produce clear and meaningful graphs. When different variables have vastly different ranges, visualizations like scatter plots, line graphs, or heat maps can be misleading or unreadable. For example:

If one axis represents population (in millions) and another represents literacy rate (in percentages), the large difference in scale can make the graph difficult to interpret.

Scaling these variables to a common range can produce clearer, more insightful visual representations that make it easier to identify patterns, trends, or correlations.

Types of Scaling Techniques

Scaling techniques are used to transform data into a comparable format, ensuring that the features contribute equally to the analysis. Depending on the nature of the dataset, different scaling techniques can be applied. Here’s a detailed breakdown of the most commonly used scaling techniques, along with references to relevant studies and applications.

Min-Max Scaling (Normalization)

Min-max scaling is one of the most widely used techniques for scaling data. It transforms the data by adjusting it within a fixed range, typically between 0 and 1. This method is useful when the distribution of data does not follow a Gaussian (normal) distribution and when preserving the original range of the data is essential.

Formula:

$$X' = \frac{X - Xmin}{Xmax - Xmin}$$

Where:

- X X is the original value.
- X min X min and X max X max are the minimum and maximum values of the feature, respectively.

Advantages:

Preserves the relationships between data points.

Scales all data to a common range, which is particularly useful for algorithms that are sensitive to magnitude (e.g., k-nearest neighbours, support vector machines).

Disadvantages:

Sensitive to outliers: If there are extreme values in the dataset, they can heavily influence the scaling process, leading to distorted results.

Use Cases:

- Used in image processing where pixel intensity values range from 0 to 255, and normalization is required to bring them to a range of 0 to 1.
- Machine Learning: Min-max scaling is used to normalize features when using gradient descent-based algorithms such as logistic regression or neural networks.

Z-Score Normalization (Standardization)

Z-Score Normalization, also known as Standardization, transforms data into a distribution with a mean of 0 and a standard deviation of 1. This technique is particularly useful when the data is normally distributed (Gaussian distribution).

Formula:

$$z = \frac{x - \mu}{\sigma}$$

Where:

- X- X is the original value.
- μ- μ is the mean of the feature.
- σ-σ is the standard deviation of the feature.

Advantages:

- Centers the data at zero and scales it by its standard deviation, making it easier to detect patterns in normally distributed data.
- Less sensitive to outliers compared to Min-Max scaling because it considers the spread of the entire dataset.

Disadvantages:

- Not suitable for datasets with skewed distributions (i.e., when data is not normally distributed).
- The scale is dependent on the data, which means newly added data points could shift the mean and standard deviation, requiring re-scaling.

Use Cases:

- Commonly used in linear regression, logistic regression, and principal component analysis (PCA) to ensure that features with different units or scales contribute equally to the analysis.
- Useful for algorithms that rely on distance metrics, such as K-means clustering and SVM.

Robust Scaling

Robust Scaling uses the interquartile range (IQR) to scale data, making it less sensitive to outliers. It centres the data by subtracting the median and scales it according to the IQR, which is the range between the first quartile (25th percentile) and the third quartile (75th percentile).

Formula:

$$X_{new} = \frac{X - X_{median}}{IQR}$$

Advantages:

- More robust to outliers compared to Min-Max scaling or Z-Score normalization.
- Focuses on the distribution of the middle 50% of the data, reducing the impact of extreme values.

Disadvantages:

Discards the influence of outliers, which may be relevant in some applications where outliers carry important information (e.g., fraud detection, medical anomalies).

Use Cases:

- Used in financial data, where outliers (such as sudden spikes or drops in stock prices) can skew the analysis.
- Useful in robust machine learning algorithms that need to ignore extreme values.

Logarithmic Scaling

Logarithmic Scaling is a non-linear scaling technique that applies a logarithmic transformation to data. This is often used when the data exhibits exponential growth or when there are large ranges of values that need to be compressed.

Formula: X scaled =log(X)

Advantages:

- Compresses large positive values while expanding small positive values.
- Effective in handling skewed data where large values dominate small ones.

Disadvantages:

- Cannot be applied to negative values or zero.
- May distort relationships between features if the data is not suited for logarithmic transformation.

Use Cases:

- Commonly used in financial data to deal with exponential growth in prices or sales figures.
- Applied in machine learning when dealing with features that have long tails or skewed distributions, such as income data, population growth, or publication counts.

Decimal Scaling

Decimal Scaling is a simple scaling technique that shifts the decimal point of values based on the maximum absolute value in the dataset. It is mainly used when large numbers dominate the dataset, and simpler scaling methods like min-max scaling are not ideal.

Formula:

$$U_i = \frac{V_i}{10^j}$$

Where

- j is the smallest integer such that the scaled value is less than 1.

Advantages:

- Simple and easy to implement.
- Ensures that all data points are adjusted based on the largest value.

Disadvantages:

- Does not account for the distribution of data, which can lead to suboptimal scaling in datasets with significant variations.

Use Cases:

- Applied in scenarios where data has a large spread but remains within known limits, such as demographic data or historical records.

6.4 RANK SCORES

Rank scores are numerical values assigned to items or entities based on their relative positions in a dataset. Ranking involves ordering the data points from the highest to the lowest (or vice versa) based on a particular criterion or metric, such as performance, value, or frequency. The resulting rank score reflects the item’s position in comparison to others, rather than its absolute value.

Rank scores are commonly used in scenarios where the relative standing of an entity is more important than the raw data itself. For example, in competitive settings such as sports, academic exams, or product comparisons, rank scores indicate which entity performed better relative to others.

Key Features of Rank Scores:

Relative Position: Rank scores show how one item compares to others rather than its standalone value.

Ordinal Nature: The rank score provides an ordinal measure, indicating order but not the magnitude of difference between ranks.

Tie Handling: If multiple items have the same value, ranking methods must decide how to handle ties (e.g., assigning the same rank to tied items or averaging the rank positions).

Examples:

Academic Ranks: In an exam, a rank score would indicate whether a student placed first, second, third, etc., based on their score.

Product Rankings: Products might be ranked based on customer ratings, where the highest-ranked product is the one with the best reviews.

Search Engine Results: Webpages are ranked based on relevance to a query, with rank scores determining the order of presentation.

Applications of Rank Scores:

Competitive Evaluations: Sports tournaments, academic exams, or performance-based tasks.

Data Analysis: Helps in understanding how items or individuals compare to each other based on a specific criterion.

Search Engines: Rank scores are central to ranking webpages based on search relevance.

Ranking data refers to the process of organizing or ordering data points based on a particular criterion, assigning each item or entity a position relative to others in the dataset. The goal of ranking is to establish a hierarchy or ordinal relationship between data points, where each data point is compared against others and placed in an ordered sequence. Ranking helps in identifying the top or bottom performers, most frequent or rare occurrences, and other forms of relative importance in a dataset.

This process is used extensively in fields such as statistics, decision-making, data analysis, economics, and sports, where understanding the relative position of data points can provide valuable insights.

Key Concepts of Ranking Data

Relative Ordering:

Ranking focuses on relative comparison rather than absolute values. For example, in a set of exam scores, rather than looking at the actual marks each student scored, ranking orders students by who performed best to worst.

Ordinal Data:

Ranking creates ordinal data, meaning the values represent the order of items rather than the magnitude of difference between them. For instance, the difference between the first and second-ranked entities might not be the same as between the second and third, but the rank only tells you their relative positions.

Ties (Equal Ranks):

When multiple data points have the same value, ties occur. There are several ways to handle ties in ranking:

Standard Competition Ranking ("1224" ranking): Tied items get the same rank, but the next item gets the rank as if there were no tie (e.g., if two people tie for second place, the next rank will be fourth).

Modified Competition Ranking: Tied items get the same rank, but the next rank takes the position immediately after the tie (e.g., two tied for second, the next person is ranked third).

Fractional Ranking (or Dense Ranking): Tied items are assigned the average of their potential positions (e.g., two tied for second place would get a rank of 2.5).

Direction of Ranking:

Rankings can be done in ascending or descending order, depending on the context:

Ascending Ranking: Items are ordered from smallest to largest (e.g., ranking students from lowest to highest marks).

Descending Ranking: Items are ordered from largest to smallest (e.g., ranking athletes based on their scores, where the highest score is ranked first).

Handling of Missing Data:

In some cases, datasets may have missing values. When ranking data, missing values can either be excluded from the ranking or ranked as the lowest (or highest) depending on the context.

Methods of Ranking Data

Simple Ranking:

Simple Ranking orders data points from highest to lowest (or lowest to highest) based on a single variable. For example, ordering a list of employees by their annual sales figures results in a simple rank from the top to the bottom performer.

Ranking with Multiple Criteria:

- In some cases, ranking is done based on multiple criteria or factors. For example, in hiring decisions, candidates might be ranked based on their qualifications, interview performance, and relevant experience. This can involve:
- Weighted Ranking: Different criteria are assigned different levels of importance (weights), and these weighted values are used to determine the final rank.
- Composite Ranking: An aggregate score is created by combining multiple criteria, and the final ranking is based on this composite score.

Rank Aggregation:

Rank Aggregation involves combining multiple rankings from different sources or criteria into a single rank. For example, in a multi-judge sports event (e.g., figure skating), rankings from multiple judges are aggregated to arrive at a final score for each participant.

Examples of Ranking Data

Sports Competitions:

In most competitive sports, athletes or teams are ranked based on their performance in various events or matches. For example, in tennis, players are ranked globally based on their performance in tournaments throughout the year. The ranking reflects how they compare to other players over time.

Academic Performance:

In schools and universities, students are often ranked based on their exam scores. Ranking allows educators to see who performed the best or identify students who may need additional support. For example, the top-performing student might be ranked first, followed by others in descending order based on their scores.

Search Engines:

One of the most well-known applications of ranking is in search engine algorithms. When a user types a query, the search engine ranks webpages based on relevance to the query. Various factors such as keyword match, page authority, and content quality are considered, and webpages are ranked in order of relevance for the user.

Product Reviews and Rankings:

Online shopping platforms often rank products based on reviews, ratings, and sales performance. Products with higher customer ratings and sales are ranked higher in search results, improving their visibility and likelihood of purchase.

Importance of Ranking Data

Simplifies Decision-Making:

Ranking helps in simplifying complex data by highlighting the most important or relevant items, making it easier for decision-makers to prioritize or focus on top performers. For example, ranking job applicants based on their qualifications and experience helps employers quickly identify the best candidates.

Comparison Across Categories:

Ranking allows for easy comparison across entities, even when they are measured on different scales or units. For example, ranking students in a class based on their total performance in different subjects provides an overall comparison that may not be clear from individual subject scores.

Resource Allocation:

Organizations often use rankings to allocate resources effectively. For instance, universities may rank departments or research projects based on performance metrics and distribute funding accordingly.

Motivation and Recognition:

Ranking can also serve as a motivational tool. In sports or academia, achieving a high rank often comes with recognition, awards, or incentives, motivating participants to perform better.

Types of Ranking Models

Deterministic Ranking:

This type of ranking is based on precise calculations or scores where the rank is directly tied to an objective measurement. For example, students ranked by their exam scores or companies ranked by annual revenue use deterministic ranking models.

Probabilistic Ranking:

In some cases, rankings are probabilistic, meaning that the rank is based on probabilities rather than fixed values. For example, in machine learning models like PageRank (used by Google), webpages are ranked probabilistically based on how likely they are to be visited given the structure of hyperlinks between pages.

Challenges in Ranking Data

Ties and Ambiguities:

When multiple items have the same value, ties can occur, complicating the ranking process. Determining how to handle ties (whether to assign the same rank or calculate an average) is a common challenge.

Subjectivity in Multi-Criteria Ranking:

When multiple criteria are used to rank items, determining the appropriate weight for each criterion can be subjective and may vary depending on the decision-maker’s goals or preferences.

Data Quality Issues:

Ranking depends on the quality and completeness of data. Missing values, outliers, or inaccurate measurements can distort rankings and lead to incorrect conclusions.

6.5 WEIGHTED SCORES

Weighted scores are calculated by assigning different levels of importance, or weights, to various components of a dataset before combining them to obtain a final score. This technique is commonly used in decision-making, evaluations, and analyses where not all factors carry the same importance. By applying weights, analysts can emphasize certain factors over others based on their relevance to the specific context or objective.

1. Understanding Weighted Scores
2. Applications of Weighted Scores
3. Education and Grading Systems:

Many academic institutions use weighted scores in grading, where different components such as quizzes, assignments, projects, and exams are given different weights based on their importance in the overall evaluation.

Multi-Criteria Decision-Making (MCDM):

Weighted scores are widely used in MCDM approaches like the Analytic Hierarchy Process (AHP), where alternatives are evaluated based on multiple criteria, each assigned a specific weight. For example, when selecting a new supplier, criteria such as cost, quality, and delivery time may have different weights.

Performance Evaluations:

In performance evaluations, an employee’s score may be weighted based on various aspects such as attendance, quality of work, and teamwork. If quality of work is deemed most important, it may receive a higher weight compared to other criteria.

Weighted Average Cost of Capital (WACC):

In finance, the WACC is a calculation that assigns weights to different sources of capital (like equity and debt) to determine the overall cost of capital for a firm. The weighted score here reflects the proportional contribution of each capital source to the overall cost.

Consumer Ratings and Product Rankings:

E-commerce sites may use weighted ratings based on factors such as recency and helpfulness of reviews, where recent reviews might be weighted more heavily to give a more accurate reflection of current customer satisfaction.

Importance of Weighted Scores

Reflects Relative Importance:

Weighted scores capture the relative importance of each criterion in a way that aligns with the specific goals or values of the analysis. This makes the scoring process more relevant and realistic.

Improves Decision-Making Accuracy:

By considering the different levels of impact of each factor, weighted scores improve the accuracy and relevance of decision-making. For example, in hiring, giving more weight to role-specific skills over general skills can yield better candidate evaluations.

Facilitates Comparison:

Weighted scores allow for a clear comparison between alternatives even when multiple criteria are involved, each with different units or scales.

Provides Flexibility:

Weighting is adjustable, meaning the model can be tailored to fit changing conditions, such as adjusting weights for different project phases or modifying criteria importance based on stakeholder preferences.

Challenges in Using Weighted Scores

Subjectivity in Weight Assignment:

Determining appropriate weights for each criterion can be subjective, often based on expert judgment or stakeholder opinion. This subjectivity may introduce bias if not done systematically.

Complexity in Calculation:

For large datasets with numerous criteria, calculating weighted scores can be complex, particularly if different stakeholders disagree on the importance of certain factors.

Sensitivity to Weight Changes:

Even minor changes in weights can significantly alter the final score. This makes the system highly sensitive and requires careful calibration to avoid unintended impacts.

Data Quality and Consistency:

Weighted scoring models rely on accurate and consistent data. Any inconsistency or error in the data could distort the weighted scores, potentially leading to incorrect decisions.

Examples and Use Cases of Weighted Scoring Techniques

Case Study: Student Grading Systems

Problem: A university wants to ensure that students are evaluated based on various components like assignments (20%), midterms (30%), and final exams (50%).

Solution: Each component is assigned a weight based on its significance. Student scores in each category are multiplied by these weights and summed to produce a final weighted score.

Result: The final score reflects the student's overall performance, with emphasis on exams, making it a fairer and more meaningful assessment.

Case Study: Investment Portfolios

Problem: An investor wants to create a balanced portfolio where stocks are weighted at 60%, bonds at 30%, and alternative assets at 10%.

Solution: Each asset type is given a weight based on the investor's goals (e.g., growth vs. stability), and returns are calculated based on these weighted allocations.

Result: The portfolio achieves an overall score that reflects the investor's preferences, providing a tailored measure of portfolio performance.

Methods for Determining Weights in Weighted Scoring Models

Equal Weighting:

Assigns equal importance to all criteria. This method is often used when there's no strong rationale for assigning different weights to various factors.

Expert Judgment:

Weights are determined by experts familiar with the domain, leveraging their knowledge to assess which criteria should have more influence.

Analytic Hierarchy Process (AHP):

A structured technique that involves pairwise comparisons of criteria, enabling a systematic and consistent approach to weight assignment. AHP is particularly useful when there are multiple conflicting criteria.

Data-Driven Weighting:

Weights are derived from statistical or historical data, such as the variance or importance of factors over time. For instance, in a regression model, weights might reflect the predictive power of each independent variable.

6.6 SUMMARY

Scaling techniques rank scores, and weighted scores are essential tools in data analysis that enhance comparability, improve decision-making, and facilitate meaningful insights. Scaling techniques are used to standardize data, especially when data points come from different units or have varying ranges. Methods like normalization (which rescales data to a [0,1] range) and standardization (which adjusts data to a mean of 0 and standard deviation of 1) make data from different sources compatible and easy to compare. This process is vital in data modeling and machine learning, where unscaled data may skew analysis, and accurate comparisons across varied data sources are required. Scaling also helps ensure consistent metric use in analytics, creating more interpretable and actionable outputs.

Rank scores provide a method for organizing data by assigning a rank based on relative position rather than raw scores. This ordinal ranking approach is useful when the precise difference between ranks isn’t as important as the order itself. For example, ranking products by customer satisfaction or students by test scores allows us to quickly see who performs best or worst. Rank scores are particularly helpful in competitive settings, like sports or performance evaluations, where determining relative performance is crucial. Ranking can also address scenarios with skewed data, allowing for a straightforward comparison across a dataset without needing to consider absolute values.

Lastly, weighted scores bring another layer of refinement, enabling analysts to prioritize factors within multi-criteria assessments by assigning different levels of importance, or weights, to each component. Weighted scores are particularly valuable in decision-making scenarios where factors are not equally important, such as hiring decisions, product evaluations, or performance assessments. By assigning a higher weight to critical factors, a weighted scoring model provides a balanced overall score that reflects priorities accurately. However, assigning weights can introduce subjectivity, so methods like the Analytic Hierarchy Process (AHP) help ensure weights are systematically derived. Together, scaling techniques, rank scores, and weighted scores provide robust tools to make data-driven decisions more accurate, fair, and contextually relevant.

6.7 GLOSSARY

- **Scaling:** A process of transforming data to a specific range or scale, typically to make it comparable across different metrics, units, or magnitudes.
- **Normalization:** A scaling technique that adjusts data to a specified range, usually [0,1], to allow for comparison between values of different ranges or units.
- **Standardization:** A scaling technique that transforms data to have a mean of 0 and a standard deviation of 1, often used in machine learning and statistical analysis to handle varying data distributions.
- **Rank Score:** An ordinal method that organizes data points by assigning a relative position or rank based on value comparison, without indicating the magnitude of difference between ranks.
- **Ordinal Data:** Data that has a specific order or rank but lacks information about the actual distance or difference between each rank, such as ranking from "first" to "last."
- **Weighted Score:** A composite score obtained by assigning different levels of importance (weights) to criteria and multiplying each factor by its corresponding weight, allowing more significant factors to impact the final score more heavily.
- **Weight:** A numeric value assigned to a criterion or factor in weighted scoring models, reflecting its relative importance in the overall calculation.
- **Tie Handling:** In ranking, methods for managing cases where two or more items have the same value. Common approaches include assigning the same rank to tied items or using fractional ranks.
- **Analytic Hierarchy Process (AHP):** A decision-making framework for determining weights in weighted scoring models based on systematic pairwise comparisons, widely used in multi-criteria decision-making.
- **Weighted Average:** A calculation that multiplies each component by a weight and averages the result, emphasizing more significant components, commonly used in financial analysis and performance evaluations.

6.8 ANSWER TO CHECK YOUR PROGRESS

1. Which of the following scaling techniques adjusts data so that it has a mean of 0 and a standard deviation of 1?

A) Normalization

B) Standardization

C) Ranking

D) Weighting

Answer: B) Standardization

2. In which scenario is rank scoring particularly useful?

A) When comparing data with different units

B) When absolute differences are not needed, and order is more important

C) When each criterion has a different level of importance

D) When data values need to be scaled between 0 and 1

Answer: B) When absolute differences are not needed, and order is more important

3. What is the main purpose of using a weighted score?

A) To make all values fit into a common range

B) To prioritize certain criteria over others based on importance

C) To assign ranks to items in a dataset

D) To convert all data to a standard metric

Answer: B) To prioritize certain criteria over others based on importance

4. Which of the following is a typical range used in normalization?

A) -1 to 1

B) 0 to 1

C) 1 to 10

D) Mean of 0 and standard deviation of 1

Answer: B) 0 to 1

5. In a weighted scoring model, the sum of all weights should typically be:

A) Greater than 1

B) Equal to 1 (or 100%)

C) Less than 1

D) Variable, based on the number of factors

Answer: B) Equal to 1 (or 100%)

6. Which of the following best describes the Analytic Hierarchy Process (AHP)?

A) A scaling technique for standardizing data

B) A method for assigning ranks in order

C) A systematic way to assign weights to criteria using pairwise comparisons

D) A technique for normalizing data between 0 and 1

Answer: C) A systematic way to assign weights to criteria using pairwise comparisons

7. When two or more data points have the same rank score, this is called a:

A) Tie

B) Standardization

C) Normalization

D) Weight assignment

Answer: A) Tie

8. What is the main difference between normalization and standardization?

A) Normalization adjusts data to a mean of 0, while standardization scales

B) Normalization rescales data to a specified range, while standardization adjusts data to have a mean of 0 and standard deviation of 1

C) Standardization only applies to large datasets

D) There is no difference; they are the same technique

Answer: B) Normalization rescales data to a specified range, while standardization adjusts data to have a mean of 0 and standard deviation of 1

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6.10 TERMINAL QUESTIONS

1. Explain the difference between nominal, ordinal, interval, and ratio scaling techniques. Why is it important to select an appropriate scaling technique for data analysis?
2. How does scaling data help in data comparison and model performance improvement? Give examples of scenarios where scaling is essential.
3. Define rank score and discuss how it differs from raw scoring. In which situations would using a rank score be more beneficial than using raw scores?
4. Describe how you would handle ties in ranking data and discuss the potential impact of different tie-handling methods on the results.
5. What is a weighted score, and how is it calculated? Provide a scenario where weighted scoring would be essential for accurate decision-making.
6. Discuss the advantages and challenges of using weighted scores in decision-making. What factors should be considered when assigning weights to different criteria?
7. Describe a situation in which scaling techniques (e.g., normalization or standardization) would improve the comparability of scores across different units or magnitudes.
8. How would you decide on the appropriate weights for criteria in a multi-criteria decision-making (MCDM) model? Explain at least two methods for determining weights.
9. Compare and contrast rank scores and weighted scores. Under what circumstances would one approach be more appropriate than the other?

10. What are some potential limitations or biases that can arise from improperly scaled, ranked, or weighted data? How can these be mitigated in data analysis?

UNIT -7 SHAPE ANALYSIS, GRAVITY MODAL, TOPOGRAPHICAL PROPERTIES OF TRANSPORT NETWORK

7.1 OBJECTIVES

After studying this chapter you will be able to

- You will learn about shape analysis
- You will learn in detail about the basic concepts of gravity model.
- You will understand in detail about topographical properties of transport networks.

7.2 INTRODUCTION

Shape analysis is useful in a variety of geographic situations, including evaluating the consequences of urban growth, quantifying geographic properties of drainage basins, and investigating the patterns of geologic formations.

Shape analysis in geography, particularly when studying gravity models, entails understanding how the shape of geographical features and their spatial relationships influence a variety of events. The gravity model is a mathematical formula that estimates and analyses the interaction of locations depending on their size and distance. Here's a more extensive explanation of how form analysis and gravity models come into play.

The gravity model in geography and social sciences states that the interaction between two places (e.g., trade, migration, travel) is proportional to their sizes (e.g., population, economic activity) and inversely proportionate to their distance.

The topographical characteristics of a transport network are critical in influencing how efficiently and successfully transport networks operate. These qualities include the network's layout, connection, accessibility, and gradient. Here's a thorough look at several significant topographical features.

7.3 SHAPE ANALYSIS, GRAVITY MODAL, TOPOGRAPHICAL PROPERTIES OF TRANSPORT NETWORK

7.3.1 (A) SHAPE ANALYSIS

Shape analysis in geography entails investigating the spatial qualities and patterns of geographical features. This approach can shed light on natural landscapes, urban development, and spatial interactions among different geographic entities. Here is an in-depth look of how form analysis is used in geography:

1. Geographic Features and Shape Representation

Landforms: Analyzing the shapes of mountains, valleys, plains, and plateaus.

Hydrological Features: Investigating the forms of rivers, lakes, and watersheds.

Urban Areas: Investigate the layout and geometry of cities, neighborhoods', and infrastructure.

Administrative Boundaries: Examining the shapes of political and administrative regions.

2. Shape Analysis Techniques

Spatial metrics: Spatial metrics include compactness, elongation, and fractal dimension, which are used to define shapes.

Morph metric analysis: Morph metric analysis involves quantifying and analyzing landform shapes and their geographical distribution.

Geo statistics: Geo statistics is the use of statistical approaches to the analysis of spatial patterns and relationships.

3. Applications of Shape Analysis in Geography

Land Use Planning: Understanding landform shapes can help with zoning and development decisions.

Environmental management: Environmental management entails analyzing the morphologies of natural features to determine their ecological impact and conservation needs.

Disaster management: include studying the morphologies of river basins and floodplains in order to predict and mitigate flood risks.

Transportation planning: Transportation planning is the process of evaluating the shapes and layouts of transportation networks in order to maximize efficiency and connection.

4. Shape Analysis Tools and Methods

Geographic Information Systems (GIS): Software that collects, stores, analyses, and visualizes geographic data.

Remote sensing: Remote sensing is the analysis and mapping of geographic shapes using satellite or aircraft photography.

Spatial analysis: Spatial analysis uses techniques like buffering overlay analysis and spatial interpolation to investigate geographic linkages.

5. Shape Descriptors and Metrics

Compactness: How closely a form resembles a circle; useful for determining land use efficiency.

Elongation Ratio: The length-to-width ratio of a form; useful for analyzing linear features such as river valleys.

Fractal Dimension: Measures the intricacy and roughness of shapes; applied to natural landforms.

6. Challenges in Geographic Shape Analysis

Resolution and Scale: The detail and accuracy of form analysis can differ based on data resolution and scale.

Data Accuracy: Inaccuracies in geographic data can impair the reliability of shape analysis.

Complexity: Both natural and man-made features can have extremely complex and irregular shapes.

7. Recent Advances

Machine learning and artificial intelligence: Automating feature recognition and pattern detection to improve form analysis.

3D Terrain Modeling: Advanced methods of analyzing and visualizing three-dimensional landscapes.

Big Data Integration: Big Data Integration is the process of combining enormous datasets from many sources in order to conduct more extensive shape analyses.

8. Case Studies

Metropolitan Growth: Examining the forms of expanding metropolitan regions to determine patterns of sprawl and density.

River Basin Management: Using shape analysis to comprehend watershed dynamics and manage water resources.

Climate Change Impact: Assessing changes in geographic forms caused by variables such as sea level rise and glacial melting.

Shape analysis in geography provides useful information on how physical and man-made elements interact and change over time. It supports a wide range of applications, from environmental management to urban planning, and it is always evolving to keep up with technological and data analytic improvements.

The gravity model is a crucial instrument in geography and social sciences that predicts and analyses the movement and interaction of locations. It is inspired by Newton's law of universal gravitation, which defines how objects attract each other based on their masses and distance between them. Here's a full explanation of the gravity model, its uses, and how it works.

7.3.2 (B) GRAVITY MODEL

1. **Basic Concept**

The basic formula is:

The formula is typically expressed as:

$$I_{ij} = \frac{P_i P_j}{d_{ij}^b}$$

I_{ij} = interaction between location i and location j

Pi and Pj = masses (such as populations) of locations i and j

dij = distance between locations i and j

b = distance decay parameter (often empirically determined)

2. **Applications**

Trade: Trade involves estimating trade flows between countries or regions. Larger economies tend to trade more with one another, while trade volume declines with distance.

Migration: Predicting migration patterns based on the population size of the origin and destination areas, as well as their distance.

Travel and Transportation: Modeling travel behavior and demand for transportation services using destination attractiveness and journey costs.

Urban Planning: Understanding the relationships between diverse urban areas is essential for designing infrastructure, services, and policy.

3. **Key Components**

Attraction Factors: Characterize the size or appeal of an area, such as population, economic activity, or facilities.

Distance Decay: Captures the idea that interaction reduces as distance increases. The value bbb controls how fast this decay occurs.

Resistance elements: Some models use extra elements such as travel costs, hurdles, or other impediments to improve forecasts.

4. **Extended Models**

Gravity Model with Friction: Adjusts the fundamental gravity model by incorporating elements such as transportation expenses or journey time, sometimes known as "friction of distance."

Multi-Regional Gravity Model: The Multi-Regional Gravity Model employs many regions and interactions to capture more complex spatial dynamics.

Generalized Gravity Models: Add new variables or change the distance decay function to better suit specific settings or datasets.

5. **Model Calibration**

Parameter Estimation: Parameter estimation is the process of determining the distance decay parameter (bbb) and other coefficients using statistical approaches such as regression analysis.

Validation: Validation entails comparing model predictions to real-world data to determine accuracy and make improvements as needed.

6. **Limitations**

Simplicity: The fundamental approach may oversimplify complicated interactions by focussing just on size and distance.

Data Quality: Accurate forecasts are dependent on valid data for sizes, distances, and interaction metrics.

Dynamic Factors: Changes in economic conditions, politics, or technology can all have an impact on interactions that the fundamental model does not account for.

7. **Recent Advances**

Integration with Geographic Information Systems (GIS): Gravity models are being combined with GIS to provide spatial analysis and visualization.

Incorporation of Big Data: Using massive datasets and powerful analytics to improve and enhance gravity model applications.

Behavioral Insights: Using insights from behavioral economics and social science to improve model accuracy and relevance.

The gravity model remains an effective tool for understanding spatial dynamics and planning in a variety of domains. Its versatility and capacity to combine with modern data and technology make it an important framework for studying geographical and social issues.

7.3.3 (C) GRAVITY MODEL REFERENCE IN GEOGRAPHY

The gravity model is a fundamental idea in geography and other sciences that is often used to analyze and forecast spatial interactions. Here are some foundational sources and essential literature on the gravity model's application, development, and theoretical underpinning in geography:

1. William J. Berry and William M. Garrison, “Gravity Models in Spatial Interaction” (1958). This paper provides a framework for understanding the use of gravity models in spatial interaction studies such as trade, migration, and transportation. Berry, W. J. and Garrison, W. M. (1958). “Gravity Models in Spatial Interaction” Masahisa Fujita, Paul R. Krugman, and Anthony J. Venables' 1999 book “The Spatial Economy: Cities, Regions, and International Trade” discusses spatial interaction theory and planning models. This book uses gravity models and economic theory to explain spatial distribution and trade patterns. It gives a solid theoretical foundation for how gravity models fit into spatial economics. Fujita, M., Krugman, P. R., & Venables, A. J. (1999). *The Spatial Economy: Cities, Regions, and International Trade.*

2. Peter Nijkamp and Jacques Poot (2004) proposed the Gravity Model of Spatial Interaction. This study presents a thorough examination of the gravity model, including its theoretical basis, applications, and extensions. It also addresses empirical applications and model constraints. Nijkamp, P., and Poot, J. (2004). “The Gravity Model of Spatial Interaction” Jeffrey A. Houghton’s article “The Gravity Model: A Review of Its Use and Abuses” is in the Handbook of Regional and Urban Economics (2000). This article examines and evaluates the gravity model, providing insights into its usefulness and potential flaws. Houghton, J. (2000). “The Gravity Model: A Review of Its Use and Abuses.”

3. “Spatial Interaction Models: Formulations and Applications” by M. E. Cliff and P. Haggett (1986). This book investigates numerous spatial interaction models, including gravity models, through extensive case studies and geographical applications.

4. Peter Nijkamp and Jacques Poot's 2012 book “Regional Science: Theory and Practice” provides a complete review of regional science, including the use of gravity models in regional research and planning.

5. “Urban and Regional Planning” by Peter Hall and Mark Tewdwr-Jones (2010). This book discusses the use of gravity models in urban and regional planning to better understand spatial dynamics and build infrastructure.

These references provide a comprehensive overview of the gravity model's theoretical foundations, practical applications, and advances. They are vital for anyone studying or researching spatial relationships in geography and other related fields.

Integrating Shape Analysis with Gravity Models

1. Model Adjustments:

Distance Calculation Adjustments: Add geographic elements and impediments to distance computations. To better reflect real-world trade costs, consider using journey distance or cost measures rather than straight-line lengths.

Economic Impact of Shape: Adjust the gravity model to reflect how a country's shape affects its economic relationships. For example, an elongated country may have different trade dynamics than a compact country.

2. Empirical Studies:

Case Studies: Examine specific cases in which geographical form has had a substantial impact on trade. For example, consider how the shape of island states influences their trade patterns in comparison to continental ones.

Data Integration: Combine commerce and geographical data with GIS to visually and quantitatively examine how shape affects trade flows.

3. Policy Implications:

Infrastructure Investment: Shape analysis can help you find locations where infrastructure investment could boost trade efficiency, such as establishing new or enhancing current transport links.

Strategic Planning: Customize trade methods based on the geographic characteristics of trading partners, such as improving access to or from places with difficult geographical features.

Topographical properties of transport network

1. Network Layout

Grid Patterns: which are common in cities, are made up of streets connecting at right angles, allowing for easy navigation and minimizing travel distance?

Radial Patterns: Radiate from a central point, such as a city centre or a large transit terminus. They improve access to central locations but can cause congestion in the hub area.

Loop Patterns: Form closed circuits to enable efficient traffic flow and multiple route options, minimizing congestion and increasing redundancy.

Hierarchical Patterns: Organize roads or routes in a hierarchy, such as local streets, collectors, and arterial roads. This arrangement aids in regulating traffic flow and increasing efficiency.

2. Connectivity

Intersections and Junctions: The design and frequency of intersections affect traffic flow and congestion. Efficient junction designs can help to reduce bottlenecks.

Linkages: The quality of links between different elements of the network, such as major roads and minor streets, has an impact on overall network performance.

Integration with Other Modes: The integration of the transportation network with other modes of transportation (for example, buses, trains, and bicycles) has an impact on total connectedness.

3. Accessibility

Proximity to Destinations: The accessibility of residential, commercial, and industrial sectors is influenced by their proximity to transportation hubs or major roadways.

Equity in Access: Ensure that diverse socioeconomic groups have equal access to transport resources is a critical part of network design.

Barrier Crossings: Natural and man-made barriers like rivers, roadways, and railways can all have an impact on accessibility.

4. Gradient and Topography

Elevation Changes: Steep grades can impair vehicle performance, fuel consumption, and safety. Hills and mountains may necessitate particular design considerations for roads.

Landforms: Natural elements such as rivers, valleys, and hills can influence the course of transportation networks, necessitating engineering solutions such as tunnels, bridges, and elevated highways.

5. Capacity and Flow

Road Capacity: The ability of a road or route to manage high traffic volumes without experiencing significant delays or congestion. This comprises lane width, the number of lanes, and intersection capacity.

Flow Characteristics: Traffic signal timings, speed limits, and road conditions all have an impact on how smoothly traffic moves around the network.

6. Safety and Reliability

Accident Hotspots: Identifying places with high accident rates can aid in revamping portions of the network to improve safety.

Maintenance: The network's ease of maintenance and repair, including the availability of space for maintenance activities and the state of the infrastructure.

7. Environmental and Aesthetic Considerations

Impact on Surroundings: How the network affects the natural environment, such as pollution and habitat disruption.

Aesthetic Integration: Ensuring that the transport network enhances the visual environment and urban design.

8. Economic and Social Impacts

Economic Activity: How the transport network promotes economic activity by opening up markets, lowering transport costs, and influencing property values.

Social Interaction: The network's contribution to promoting social relationships and movement within communities.

9. Adaptability and Resilience

Response to Changes: How well the network responds to changes such as increased traffic, technological developments, and shifting urban patterns.

Disaster Resilience: The network's capacity to endure and rapidly recover from disruptions caused by natural disasters or other catastrophes.

Understanding these features enables planners, engineers, and policymakers to build and operate efficient, safe, and sustainable transportation networks.

7.4 SUMMARY

Shape Analysis Shape analysis examines the geometric configuration and organization of transportation networks. Regular street designs with right-angle intersections make for easier travel. Roads spreading from a central hub, which promotes access to central locations but may cause congestion. Roads form closed circuits, providing many route alternatives and efficient traffic flow, and are organized into tiers such as local streets, collectors, and arterials to control traffic flow.

Gravity models forecast and analyze traffic flow based on the relative "masses" (e.g., population or economic activity) and distances between different sites. Larger or more appealing destinations (e.g., commercial centers) draw more traffic, but distance acts as a barrier, lowering traffic flow; Useful for projecting traffic trends, building infrastructure, and comprehending regional interconnectedness.

Topographical features are the physical qualities of the terrain that influence the design and operation of transportation networks. Steep slopes affect vehicle performance and safety, necessitating specific design solutions such as gradients, tunnels, and bridges. Natural elements (e.g., rivers, hills) shape the route and design of transportation infrastructure, which is influenced by natural obstacles and integration with other modes of transportation; Affects the network's ease of maintenance and user safety.

These parts work together to help comprehend, construct, and manage efficient and functioning transportation networks while taking into account both human characteristics and natural conditions.

7.5 GLOSSARY

Grid Pattern: A network layout where streets intersect at right angles, forming a grid. It facilitates easy navigation and efficient traffic flow.

Radial Pattern: A network layout where roads radiate outward from a central point, such as a city center or major hub, creating a star-like shape.

Loop Pattern: A network layout where roads form circular or looped routes, often enhancing connectivity and providing multiple travel options.

Hierarchical Pattern: A structured network layout with different levels or tiers of roads, such as local streets, collector roads, and arterial roads, designed to manage traffic flow efficiently.

Gravity Model: A mathematical model used to predict traffic flow between locations based on their relative attractiveness (e.g., population, economic activity) and distance between them.

Attraction: The capacity of a location to draw people or traffic often based on factors like economic activity, population size, or amenities.

Repulsion: The tendency for the flow of traffic to decrease with increasing distance between origin and destination.

Flow Prediction: The use of gravity models to estimate the volume and direction of traffic between different points in a network.

Gradient: The slope or incline of a road or terrain, impacting vehicle performance and safety. Steeper gradients may require special design considerations.

Elevation: The height of a location relative to sea level. Significant elevation changes can influence road design and construction, including the need for tunnels or bridges.

Landforms: Natural features such as hills, valleys, rivers, and mountains that affect the routing and design of transport networks.

Accessibility: The ease with which various locations can be reached from other points within the network. It considers factors such as proximity to transport routes and integration with other transport modes.

Connectivity: The degree to which different parts of the transport network are linked, affecting the efficiency of travel and the overall functionality of the network.

Safety: Considerations related to the potential hazards and risks within the transport network, including the design of intersections, road conditions, and the impact of topographical features.

Maintenance: The ease and feasibility of performing upkeep and repairs on the transport network, influenced by the topographical challenges and infrastructure design.

7.6 ANSWER TO CHECK YOUR PROGRESS

1. What is a primary characteristic of a grid pattern in transport networks?

A. Roads radiate from a central hub.

B. Roads form circular routes.

C. Streets intersect at right angles.

D. Roads follow natural landforms.

Answer: C.

2. Which transport network pattern is most likely to cause congestion around a central hub?

A. Grid Pattern

B. Radial Pattern

C. Loop Pattern

D. Hierarchical Pattern

Answer: B.

3. In which type of network layout are roads organized into different tiers such as local streets, collectors, and arterials?

A. Grid Pattern

B. Radial Pattern

C. Loop Pattern

D. Hierarchical Pattern

Answer: D.

4. What does the gravity model in transport planning primarily predict?

A. The geographic layout of roads.

B. Traffic flow between locations.

C. The elevation of different areas.

D. The structural integrity of transport infrastructure.

Answer: B.

5. In a gravity model, what factor typically reduces the traffic flow between two locations?

A. Increased economic activity.

B. Decreased population size.

C. Increased distance.

D. Improved road quality.

Answer: C

6. Which term describes the tendency for a location to draw more traffic due to its economic activity or amenities in a gravity model?

A. Repulsion

B. Attraction

C. Flow Prediction

D. Gradient

Answer: B.

7. What is a key consideration when designing roads in areas with steep gradients?

A. Road width.

B. Intersection design.

C. Vehicle performance and safety.

D. Proximity to public transport.

Answer: C.

8. Which topographical feature may necessitate the construction of tunnels or bridges in a transport network?

A. Flat terrain.

B. Urban density.

C. Rivers or deep valleys.

D. Dense traffic congestion.

Answer: C.

9. How does elevation typically affect road design in mountainous areas?

A. It requires fewer road signs.

B. It necessitates more frequent intersections.

C. It may require more complex road structures like switchbacks or tunnels.

D. It simplifies the road construction process.

Answer: C.

7.7 REFERENCES

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“Transportation Engineering and Planning” by C.S. Papacostas and P.D. Prevedouros

“Principles of Transportation Engineering” by P. K. K. S. and D. A. G.

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7.8 TERMINAL QUESTIONS

(A) Long Questions

1. Discuss the advantages and disadvantages of using a grid pattern for urban transport networks.

2. Explain how a hierarchical pattern improves traffic flow in a transportation network. Include examples of different levels of roads and their functions.

3. Describe the principles behind the gravity model used in transportation planning. How does it help in predicting traffic patterns?

4. Evaluate the limitations of gravity models in transport planning and suggest possible improvements or alternative methods.

5. Analyze the impact of natural landforms on the design and construction of transport networks. Provide examples of how different landforms influence transport infrastructure.

6. Discuss how elevation changes influence road design and safety. What engineering solutions are used to address challenges posed by varying elevations?

(B) Short Questions

1. What is a grid pattern in transport network design?

2. How does a radial pattern affect traffic flow in a city?

3. What is the advantage of a loop pattern in a transport network?

4. Describe the hierarchical pattern of a transport network.

5. What does the gravity model help predict in transport planning?

6. In a gravity model, what effect does increasing distance have on traffic flow?

7. How is the concept of 'attraction' used in gravity models?

8. What role does the gravity model play in transportation planning?

9. How does a steep gradient affect road design?

10. Why might a transport network need tunnels or bridges in hilly areas?

11. What is the impact of elevation changes on road construction?

12. How does topography influence the accessibility of a transport network?

BLOCK 4: SURVEYING

UNIT 8: NATURE, PRINCIPLES AND TYPES OF SURVEYING

8.1 OBJECTIVES

- Learners will be able to describe what surveying is and understand its purpose in collecting and analyzing spatial data for mapping and construction.
- Learners will be able to Identify and distinguish between plane and geodetic surveying, as well as understand when to apply each type based on project requirements.
- Learners will be able to Understand Key Surveying Principles.
- Learners will be able to identify and understand the purpose of primary surveying instruments, including chains, tapes, compasses, theodolites.
- Learners will be able to describe various surveying methods (e.g., chain tape surveying, compass surveying, plane table surveying) and understand how they are applied in different scenarios.

8.2 INTRODUCTION

Surveying in geography is the practice of accurately measuring and mapping the Earth's surface, forming the backbone of spatial analysis and geographic studies. It involves a systematic approach to determine the relative positions of natural and man-made features, providing essential data for applications such as land development, environmental management, and urban planning. Rooted in fundamental principles like precision, consistency, and error reduction, surveying employs various techniques ranging from traditional land measurements to advanced remote sensing technologies. Understanding the nature, principles, and types of surveying is crucial for effectively managing and analyzing geographic spaces in an increasingly complex world.

8.3 NATURE,PRINCIPLES AND TYPES OF SURVEYING

Nature of Surveying

Surveying is the science, art, and technology of determining the relative positions of points on, above, or beneath the Earth's surface. The primary goal of surveying is to create accurate representations of the physical world, such as maps and plans. Surveying is critical in geography because it lays the groundwork for spatial analysis, modelling, and decision-making.

Survey involves:

a) Field Work
b) Office works
c) Care and adjustment of instrument

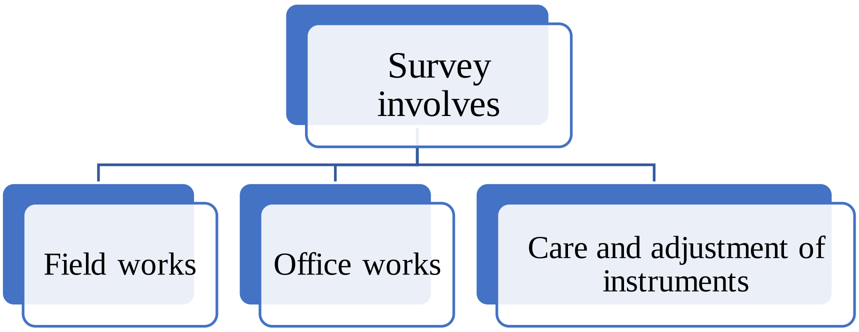

Fig 8.1: Survey Involves

a) Field Work: Essentially field work consists of (i)measuring directions and angles, (ii)recording field notes
b) Office work: The indoor work consists chiefly of (i)computing, (ii) drawing, and (iii)finishing up the map.
c) Cure and adjustment of instruments: A surveyor should be thoroughly acquainted with the instruments, their case and adjustment.

Key Characteristics of surveying:

a. Precision: Surveying requires high levels of accuracy and precision to ensure that measurements reflect true distances, angles, and positions.
b. Systematic Process: Surveying follows a systematic process, including planning, data collection, data processing, and map creation.
c. Interdisciplinary Nature: It incorporates principles from mathematics, physics, engineering, and computer science.

Objectives of Surveying:

a) Preparation of Maps and Plans: The primary objective of surveying is to create accurate maps and plans that depict the relative positions and layout of natural and man-made features on the Earth's surface. These maps serve as fundamental tools for navigation, planning, and resource management.
b) Determining Land Boundaries: Surveying plays a crucial role in establishing the legal boundaries of land parcels. Accurate boundary determination is essential for

property ownership, land division, real estate transactions, and resolving disputes over land ownership.

c) **Design and Planning of Engineering Projects:** Surveying provides critical data for the design and planning of various engineering projects, including dams, canals, roads, railways, bridges, and other infrastructure. The detailed information obtained from surveying ensures that these projects are designed with precision, taking into account the topography and existing land features.

d) **Ensuring Accuracy in Engineering Projects:** The successful execution of any engineering project largely depends on the accuracy of the initial survey. Accurate surveying minimizes errors, reduces the risk of project delays, and ensures that the project is completed within budget and to the required specifications.

e) **Resource Management and Environmental Monitoring:** In addition to its role in construction and land management, surveying is essential for effective resource management and environmental monitoring. By providing precise data on land use, natural resources, and environmental changes, surveying helps in making informed decisions about conservation, resource allocation, and sustainable development.

f) **Urban and Regional Planning:** Surveying is a cornerstone of urban and regional planning. It provides the detailed spatial data needed to plan cities, manage urban growth, design transportation networks, and allocate land for residential, commercial, and industrial uses.

g) **Disaster Management and Risk Assessment:** Surveying is also vital in disaster management and risk assessment. By mapping flood-prone areas, fault lines, and other hazards, surveying enables the development of strategies to mitigate the impact of natural disasters and protect vulnerable communities.

h) **Scientific Research and Exploration:** Surveying supports scientific research and exploration by providing accurate measurements and representations of the Earth's surface. This data is invaluable for studies in geology, hydrology, environmental science, and other fields that require precise geographic information.

i) **Navigation and Transportation:** The accuracy of modern navigation and transportation systems relies heavily on precise survey data. Surveying provides the coordinates and spatial data necessary for developing and maintaining transportation routes, whether for air, sea, or land travel.

j) **Legal and Administrative Functions:** Beyond its technical applications, surveying also serves important legal and administrative functions. It helps governments and organizations establish jurisdictional boundaries, manage public lands, and implement land use regulations effectively.

Principles of Surveying

The principles of surveying are the fundamental guidelines that govern the practice and ensure accurate and consistent results.

Twobasicprinciplesofsurveyingare:

i. Alwaysworkfromwholetothepart,and (to work from the whole to the part)

ii. Tolocateanewstationbyat leasttwomeasurements(Linearorangular)fromfixedreferencepoints.The area is then divided into a number of parts by forming well-conditioned triangles. The main survey lines are measured very accurately with a standard chain and then the sides of triangles are measured.

1.**To work from the whole to the part:** According to the first principle, the whole area is first enclosed by main stations (controlling stations) and main survey lines (controlling lines).The area is then divided into a number of parts by forming well-conditioned triangles. The main survey lines are measured very accurately with a standard chain and then the sides of triangles are measured.

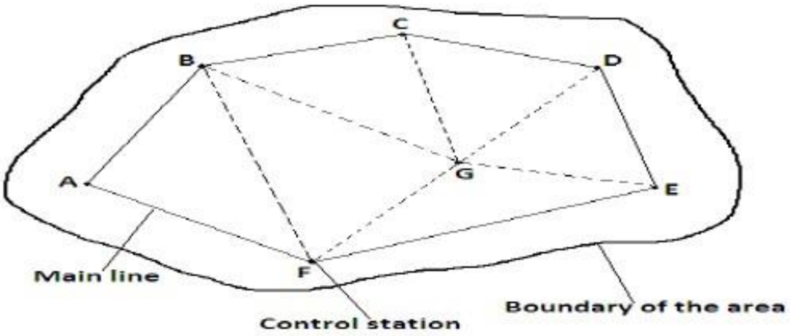

Fig 8.2.: To work from the whole to the part, Source: Google

To work from the whole to the part: The purpose of this process of working is to prevent accumulation of error. During this procedure, if there is any error in the measurement of any side of a triangle, then it will not affect the whole work. The error can always be detected and eliminated.

But, if the reverse process (from the part to the whole) is followed, then the minor error in measurement will be magnified in the process of expansion and these errors will become absolutely uncontrollable.

2. To locate a new station by at least two measurements (linear or angular) from fixed reference points.

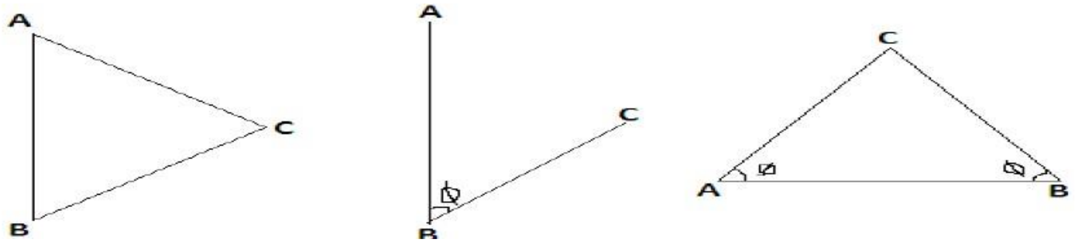

Fig 8.3:Tolocateanewstationbyat leasttwomeasurements, Source: Google

According to the second principle, the new stations should always be fixed by at least two measurements from fixed reference points. Linear measurements refer to horizontal distances measured by chain or tape. Angular measurements refer to the magnetic bearing or horizontal angle taken by a prismatic compass or theodolite.

Types of Surveying

1.Primary Division of surveying: Plane Surveying and Geodetic Surveying

2. Secondary Classification: SecondarySurvey can be classified into various categories depending on methods used and nature of the filed.

(i) Based on instrument

- a) Chain Survey
- b) Compass Survey
- c) Plane Table Survey
- d) Theodolite Survey
- e) Tacheometric Survey
- f) Photographic Survey

(ii) Based on methods

- a) Triangulation Survey
- b) Traverse Survey

(iii) Based on nature of field

- a) Land Survey
- b) Marine Survey
- c) Astronomical Survey

Other Types of Surveys

a) Photogrammetry- mapping utilizing data obtained by camera or other sensors carried in airplanes or satellites.

b) Boundary Surveying-establishing property corners, boundaries, and areas of land parcels.

c) Control Surveying- establishing a network of horizontal and vertical monuments that serve as a reference framework for other survey projects.

d) Engineering Surveying- providing points and elevations for the building Civil Engineering projects.

e) Topographic Surveying- collecting data and preparing maps showing the locations of natural man-made features and elevations of points of the ground for multiple uses.

f) Route Surveys- topographic and other surveys for long-narrow projects associated with Civil Engineering projects.

Primary Division of Surveying

On the basis of whether the curvature of the earth is taken into account or not, surveying can be divided into two main categories:

i. Plane Surveying

ii. Geodetic Surveying

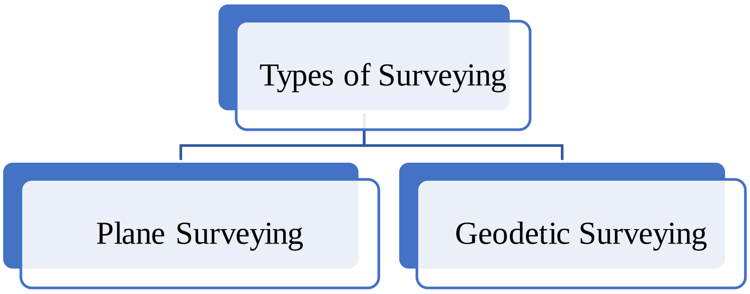

Fig 8.4: Types of Surveying

i. Plane surveying: Plane Surveying in Cartography refers to the process of measuring small areas on the Earth's surface while assuming the Earth is flat, or planar. It is based on the principle that, for small portions of the Earth's surface, the curvature of the Earth is negligible, allowing for simpler calculations than those required in geodetic surveying (which accounts for the Earth's curvature).

In cartography, **plane surveying** refers to surveying methods where the Earth's surface is treated as a flat plane rather than as a curved, spherical surface. This approach is generally suitable for mapping small areas, where the Earth's curvature has negligible effect on measurements and accuracy.

Key Points of Plane Surveying in Cartography

a) **Assumption of Flatness:** Plane surveying assumes that the area being surveyed is small enough that the Earth’s curvature can be ignored. This simplification allows surveyors to work with linear measurements and straightforward geometrical calculations, avoiding the need for complex spherical trigonometry or corrections for curvature.

b) **Use for Small Areas:** Plane surveying is ideal for mapping areas typically under 250 square kilometers (about 100 square miles). For example, it is commonly used in creating maps for small towns, city planning, local land boundaries, and construction projects. This makes it suitable for regional and city maps where precision over short distances is more important than accounting for the Earth's curvature.

c) **Accuracy in Local Mapping:** The technique provides high accuracy for local maps, as any distortions due to ignoring the Earth's curvature are minimal and do not significantly affect results at smaller scales. In fact, over short distances, plane surveying can often be as accurate as more complex methods, making it a practical choice for cartographers and surveyors alike.

d) **Simplified Calculations:** Because it treats the Earth as a flat surface, plane surveying uses basic trigonometric and algebraic calculations. This reduces the computational complexity and cost, allowing surveyors to complete projects more efficiently. It also allows for easier adjustments and overlays with existing maps or cartographic data for areas where precise measurements are critical but limited to a small geographic region.

Applications in Cartography: In cartography, plane surveying supports various applications like creating cadastral maps (detailed property boundaries), infrastructure layout maps, and urban planning maps. These maps provide important local geographic information that does not require accounting for the Earth's curvature, and thus plane surveying offers a fast, reliable, and cost-effective approach.

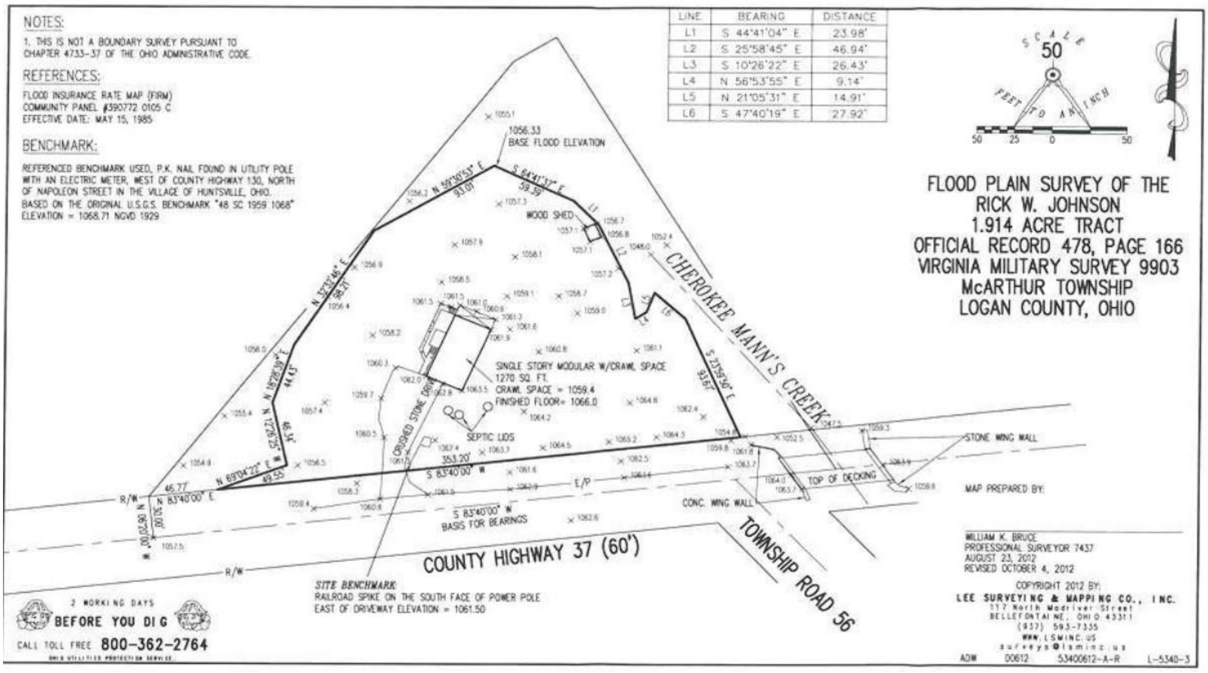

Fig. 8.5: Plane Survey, Source: Google

ii.Geodetic surveying: is that branch of surveying, which takes into account the true shape of the earth (spheroid).

Geodetic surveying: Geodetic surveying is a branch of surveying that deals with the precise measurement and determination of the earth's shape, size, and the exact positions of points on its surface. It involves considering the earth as a curved, ellipsoidal shape rather than a flat plane, which makes it distinct from plane surveying, where the curvature of the earth is neglected over short distances.

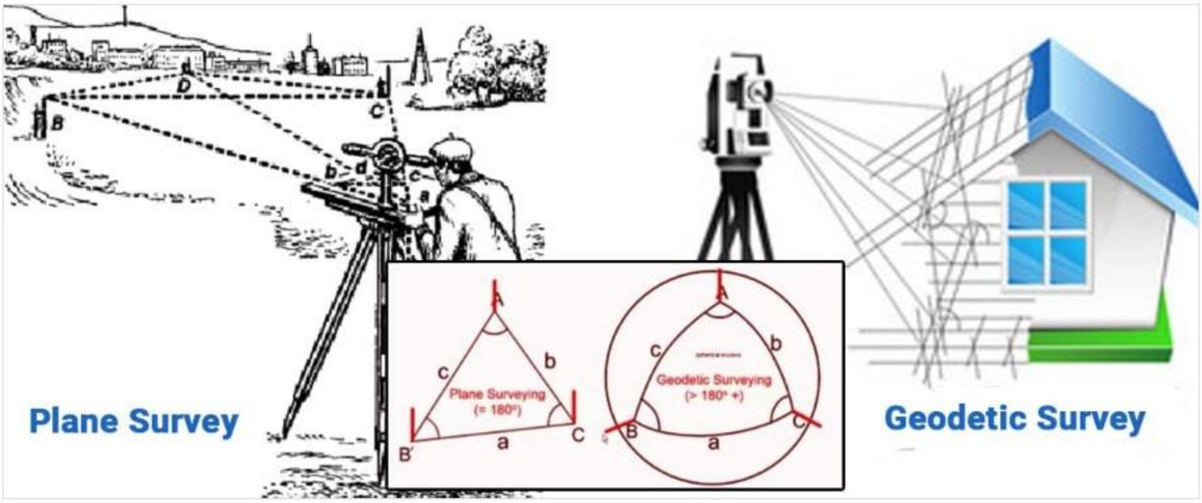

Fig 8.6: Plane Survey vs Geodetic Survey, Source: Google

Plain Surveying VsGeodetic Surveying

The key difference between plane surveying and geodetic surveying lies in the size of the area surveyed and how they account for the earth's curvature. Here’s a detailed comparison:

1. Consideration of Earth's Curvature

Plane Surveying:

a) Assumes the earth is flat over small areas.

b) The curvature of the earth is ignored because the surveyed area is relatively small, making the effect of curvature negligible.

Geodetic Surveying:

a) Takes into account the curvature of the earth.

b) Uses mathematical models of the earth (like the ellipsoid or geoid) to correct for the earth's curvature over larger areas.

2. Area Covered

Plane Surveying:

a) Used for small areas (typically less than 250 km^2).

b) Suitable for local projects like small property boundaries, construction sites, and city planning.

Geodetic Surveying:

a) Used for large areas where curvature of the earth significantly impacts accuracy.

b) Required for national or international boundaries, large infrastructure projects (highways, railways), and mapping large geographic regions.

3. Accuracy and Precision

Plane Surveying:

a) Precision is generally lower due to smaller-scale measurements and the assumption of a flat surface.

b) Suitable for tasks where very high precision isn’t necessary.

Geodetic Surveying:

a) Involves high precision due to large-scale measurements over long distances.

b) Uses sophisticated instruments and methods to achieve accuracy, often to sub-centimeter levels, correcting for curvature, atmospheric refraction, and more.

4. Coordinate Systems

Plane Surveying:

a) Uses a simple rectangular or Cartesian coordinate system (X, Y, Z) assuming a flat surface.
b) Local grid systems are often applied.

Geodetic Surveying:

a) Uses geodetic coordinates (latitude, longitude, and ellipsoidal height) on an ellipsoidal model of the earth.
b) Global coordinate systems like WGS84 are used for consistent reference across large distances.

5. Instruments Used

Plane Surveying:

a) Simple instruments like chains, tapes, levels, theodolites, and total stations.
b) GPS may be used but is often unnecessary for small projects.

Geodetic Surveying:

a) Advanced instruments like GNSS receivers (for GPS), total stations, geodetic-grade theodolites, and precise levelling instruments.
b) These instruments ensure high precision over long distances.

6. Applications

Plane Surveying: Suitable for small engineering works, road construction, building sites, local boundary demarcations, and cadastral surveys.

Geodetic Surveying: Essential for large-scale projects like national and state boundary surveys, large infrastructure development (e.g., highways, railways, pipelines), mapping entire countries, and monitoring tectonic plate movements.

7. Mathematical Models and Corrections

Plane Surveying:

a) Simplified calculations due to the assumption of a flat surface.
b) Little to no need for corrections related to curvature or earth’s shape.

Geodetic Surveying:

a) Requires complex mathematical models such as ellipsoids and geoids.

b) Involves corrections for curvature, refraction, and atmospheric effects.

8. Cost and Time

Plane Surveying: Generally quicker and cheaper as it deals with smaller areas and requires less complex instruments and calculations.

Geodetic Surveying: More expensive and time-consuming due to the precision required, the use of advanced technology, and the need for complex data processing.

Differences in brief:

Aspect	**Plane Surveying**	**Geodetic Surveying**
Earth's Curvature	Ignored (Assumed flat)	Considered (Curved Earth)
Area Covered	Small Areas (e.g., less than 250 km²)	Large Areas (National/Global scales)
Accuracy	Lower Precision	High Precision (Corrects for curvature)
Coordinate System	Cartesian (Local grids)	Geodetic (Latitude, Longitude, Height)
Instruments	Simple tools (Theodolites, Tapes, etc.)	Advanced tools (GNSS, Total Stations, etc.)
Applications	Local Projects (Construction, Cadastral)	Large-Scale Projects(Infrastructure, Maps)
Cost and Complexity	Lower Cost, Less Complex	Higher Cost, Complex Models and Corrections

2. Secondary Classification

Secondary Classification: SecondarySurvey can be classified into various categories depending on methods used and nature of the field.

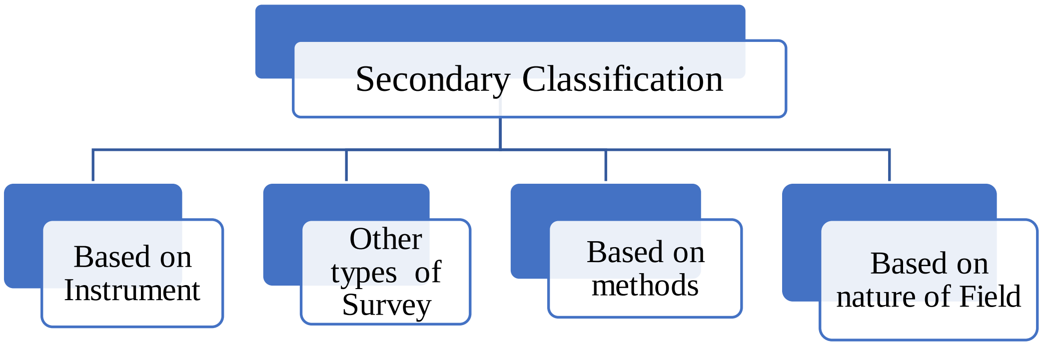

Fig 8.7: Secondary Classification of Surveying

(i) Based on instrument

g) Chain Survey
h) Compass Survey
i) Plane Table Survey
j) Theodolite Survey
k) Tacheometric Survey
l) Photographic Survey

(ii) Based on methods

c) Triangulation Survey
d) Traverse Survey

(iii) Based on nature of field

d) Land Survey
e) Marine Survey
f) Astronomical Survey

Based on instrument

a) Chain tape surveys: Chain tape surveying is one of the oldest and simplest forms of land surveying, used to measure linear distances. In this method, a chain or tape is used as the primary instrument to measure the distance between two points on the earth's surface. It is especially useful for small-scale surveys or when a relatively low level of precision is acceptable.

Equipment Used

Chain:

a)Gunter's Chain: Historically, a chain was 66 feet long and consisted of 100 links. Each link was 0.66 feet (7.92 inches) long. The Gunter's chain was widely used for surveying in early times.

Fig8.8: Gunter Chain, Source: Google

a) **Engineer’s Chain:** A 100-foot chain with 100 links, each link being 1 foot long. This type of chain is used for more modern surveys.

Tapes:

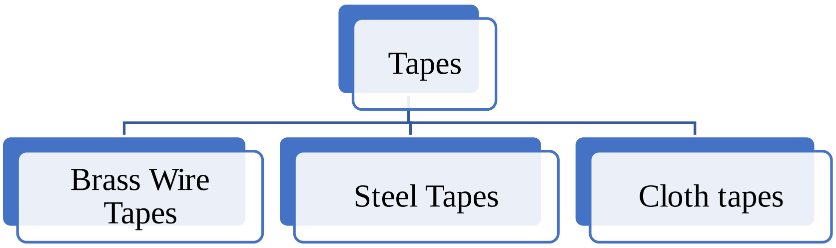

Fig 8.9: Types Tapes

Arrows (Pins):Metal pins (arrows) are used to mark the positions at measured intervals. They help keep track of how much distance has been covered.

Ranging Rods: Tall poles used to mark the endpoints of the line being measured. They help surveyors keep a straight line when measuring over long distances.

Plumb Bob: Used to ensure vertical alignment during the survey, especially when measuring uneven ground or slopes.

Chain Tape Surveying Process

1.Preparation:

i) Identify the line or distance to be measured and mark the start and end points with ranging rods. Surveyors position the ranging rods at intervals to guide the measurement along a straight line.

2. Laying the Chain/Tape:

i) The survey team consists of two people: a leader and a follower.

ii) The leader holds one end of the chain or tape and moves forward while the follower stays at the starting point.

iii) The chain or tape is laid out on the ground between the two points, with the leader driving in arrows at every full length of the chain or tape (e.g., after every 30 meters or 100 feet).

3. Measuring the Distance:

i)The leader pulls the chain or tape taut to ensure accuracy.

ii) For distances that exceed the length of the chain or tape, the process is repeated by moving the ranging rods forward and measuring the remaining distance.

iii) For shorter distances, the measurement is made directly using the chain or tape.

4. Recording Measurements:

i)The total distance is recorded based on the number of full chain lengths plus any fractional lengths measured by the tape.

ii)In case of uneven ground, corrections are made to account for any vertical distance (slope correction).

5.Error Checking:

i) Tension: The chain or tape must be pulled taut to avoid sagging, which would introduce errors.

ii) Alignment: Proper alignment along the straight line is crucial. Ranging rods help in keeping the survey on track.

iii) Temperature: Metal chains or tapes expand and contract with temperature changes, so corrections may need to be applied.

Methods of Chain Tape Surveying

Direct Method:

The chain or tape is laid out along the entire length of the line to be measured, and measurements are recorded directly.

Obstacles:

When the line to be measured passes through obstacles (e.g., buildings or trees), the surveyor uses triangulation or offsets to measure around the obstacles.

Offset Method:

For measuring the distance of features (like boundaries or buildings) that are not on the main survey line, perpendicular offsets are taken from the survey line, and their distances are measured.

Sources of Errors in Chain Tape Surveying

Incorrect Chain Length: Chains or tapes can wear down over time or stretch, leading to inaccuracies. Regular calibration is necessary.

Temperature Changes: Metal tapes expand in heat and contract in cold weather, requiring temperature correction factors to be applied to measurements.

Improper Tension: Insufficient or excessive pulling on the chain or tape may cause incorrect readings due to slack or elongation.

Sagging: If the tape or chain is not held at the correct height, it may sag, especially over long distances, leading to overestimated distances.

Human Errors: Inaccurate placement of ranging rods or reading of measurements can lead to errors in the recorded distance.

b)Compass Surveying

In compass surveying the magnetic bearing of a line is found with the help of a compass and the length of the line is measured with a chain or tape.Thus, the direction and length being known the line can be easily plotted.

By the term magnetic bearing we mean the angle which a line joining the observer with the object makes with the magnetic north-south line at the place, measured from the latter in a clockwise direction. It should be distinguished from true bearing which means the angular inclination of a line from the geographical north-south line, i.e., the line joining the NorthPoleWith the South Pole. Thus, we have a true north- south line and a magnetic north-south line. The angle between these two lines is known as the magnetic declination. But since the position of the magnetic north-south line at any place shows diurnal, monthly and annual changes, the declination is also variable and this variation in declination is called magnetic variation. It is obvious that if the declination is known, the direction of true north at a place can be ascertained with the help of a magnetic compass.

Prismatic compass:

A prismatic compass is an essential tool in cartography and surveying for measuring horizontal angles or bearings with respect to magnetic north. It’s commonly used in compass surveying to determine directions of lines for mapping and creating plans. The prismatic compass is particularly favoured due to its portability, ease of use, and ability to take accurate bearings quickly in the field.

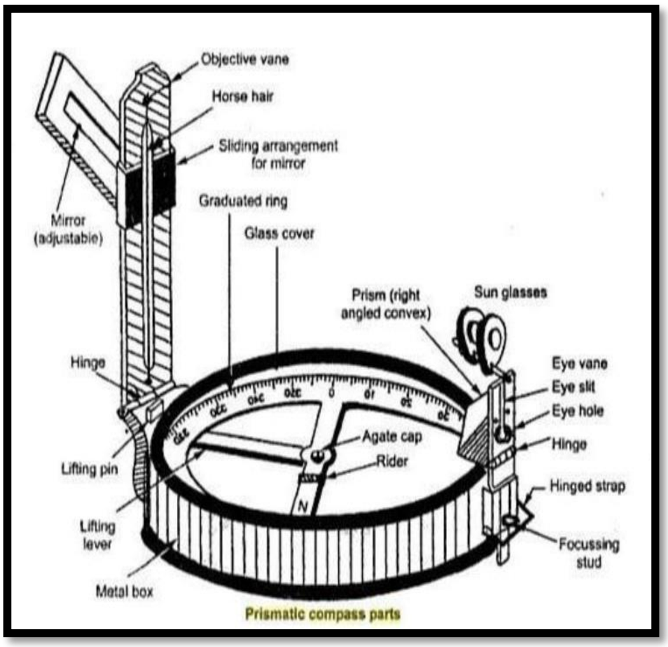

Fig 8.9:Prismatic Compass, Source: Google

How the Prismatic Compass is Used in Cartography

i) Bearing Measurement: The prismatic compass is primarily used for taking bearings of lines relative to magnetic north. This is critical in cartography for establishing the direction of features like roads, boundaries, rivers, and other landmarks.

ii) Traversing:A traverse consists of a series of connected lines whose directions (bearings) and lengths are measured. The prismatic compass is often used in this context to measure the bearings of lines at different survey points.

For example, in mapping a property or creating a topographical map, a surveyor moves from one station to the next, taking bearings at each point to build a network of interconnected lines.

iii)Plotting Data on Maps: Once bearings are taken in the field, they are plotted on a map using the recorded angles and distances. The prismatic compass allows for accurate angular measurements, which, when combined with distance measurements (from chains or tapes), help accurately position features on a map.

iv)Magnetic North vs. True North: Since the prismatic compass measures directions relative to magnetic north, cartographers must often apply a correction to account for the difference between magnetic north and true north (known as magnetic declination). This correction ensures that the final map is aligned with geographic coordinates rather than magnetic fields, which can vary by location.

v)Field Mapping: The prismatic compass is often used in the field to map physical features quickly. For example, surveyors can walk along the boundary of a plot or track a river's course, taking bearings and distances at regular intervals. This data is then translated into a scaled map.

Applications:

i) Topographical Surveys: Used to map land features and determine their orientation.

ii) Boundary Mapping: Helps establish property lines and landmarks for cadastral maps.

iii) Field Mapping: Quickly measures directions and positions of physical features.

Advantages:

i) Portable and Lightweight.
ii) Simultaneous Sighting and Reading.
Iii) Simple and Quick to Use.

Limitations:

i) Susceptible to Magnetic Interference.
ii) Requires Correction for Magnetic Declination.

c) Plane table surveys

Plane table surveying is a field-based technique used in geography and surveying to create maps directly on the field. It involves drawing a map on a **plane table**, a flat drawing board mounted on a tripod, while observing features in the landscape. This method is ideal for small-to-medium-scale surveys and provides a quick way to plot topographical features and boundaries.

Key Components of a Plane Table Survey

Plane Table:A flat, smooth drawing board mounted on a tripod, used for drawing maps in the field.

Alidade:A sighting device used to take bearings and align the plane table with the objects or features to be mapped.

It helps measure angles and draw lines on the map in relation to the direction of objects in the field.

Tripod: The table is mounted on a tripod, allowing it to rotate and be leveled for accurate measurements.

Spirit Level: Ensures the table is perfectly horizontal before starting the survey.

Drawing Paper:A sheet of paper is fixed to the table, on which the surveyor directly plots the features being surveyed.

Goals and Objectives of Plane Table Surveying

i)To create real-time maps directly in the field by plotting observed features without the need for post-fieldwork calculations.

ii)To visually represent land features such as topography, boundaries, and landmarks with immediate on-site verification.

iii)To perform quick and cost-effective surveys for small to medium areas where high precision is not essential.

iv)To provide a simple and portable surveying method that allows for easy adjustments and corrections during the survey process.

v)To offer a practical method for boundary and cadastral surveys, especially in rural or undeveloped areas.

vi)To facilitate reconnaissance surveys by providing a preliminary map for larger or more detailed future surveys.

vii)To help in triangulating positions of distant objects or features using multiple stations through resection or intersection methods.

viii) To support topographical mapping by accurately representing natural and man-made features such as hills, rivers, roads, and buildings.

Plane table surveying: Types of equipment used

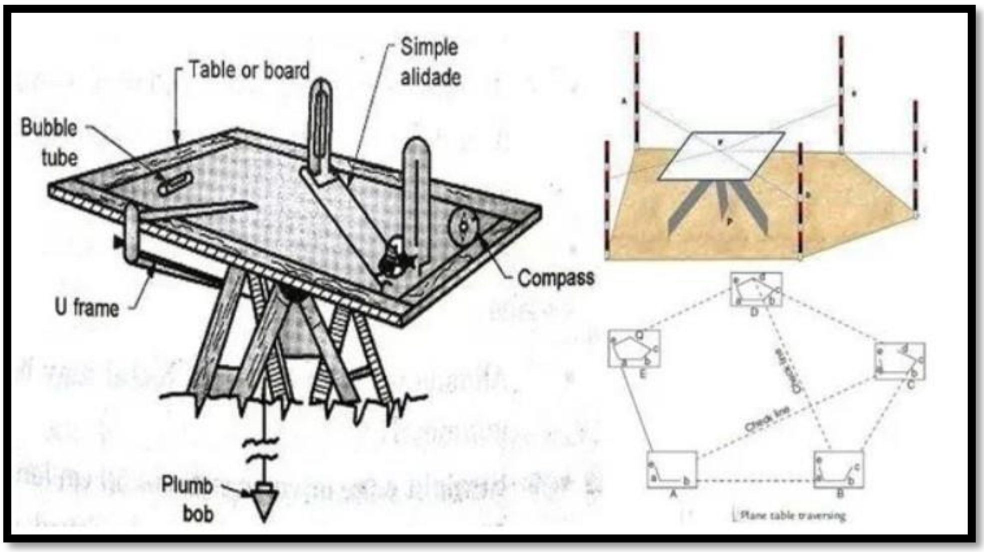

Fig 8.10: Plane Table Survey, Source: Google

The following types of general equipment are used for carrying out plane table surveys:

a) Plane table

b) Alidade for sighting (telescopic or simple)

c) Plumb bob and plumb fork

d) Compass

e) Spirit level

f) Chain

g) Ranging rods

h) Tripod

i) Drawing sheet and drawing tools

j) Paper clips or screws

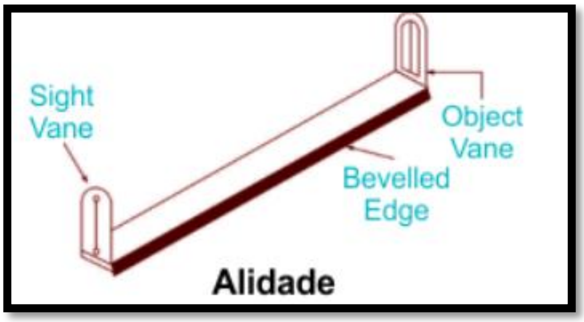

Fig 8.11: Alidade, Source: Google

Applications of Plane Table Surveying

Topographical Mapping: Used for mapping features like hills, rivers, roads, and buildings directly on-site.

Cadastral Surveys: Ideal for boundary mapping in land and property surveys, particularly when high precision is not required.

Reconnaissance Surveys: Useful for quick preliminary surveys before more detailed work is done.

Architectural and Archaeological Mapping: Employed to map smaller, detailed areas such as archaeological sites or building layouts.

Advantages of Plane Table Surveying

Direct Field Mapping: The map is drawn in real-time during the survey, reducing post-survey calculations and interpretation errors.

Simple and Cost-Effective: No complex instruments or technology required, making it easy to use and affordable.

Visual Representation: Provides a visual representation of the area while in the field, allowing immediate corrections and adjustments.

Real-Time Adjustments: Errors can be corrected on-site by comparing the map with the actual landscape.

For easy understanding of surveying and the various components of the subject, we need a deep understanding of the various ways of classifying it.

ii)Based on The Method Used

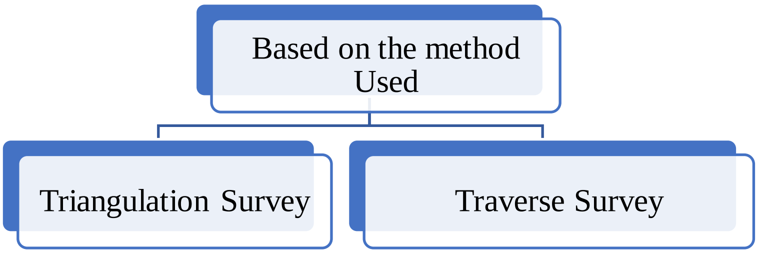

Fig: 8.12: Survey type based on method used

1. **Triangulation Survey:**In order to make the survey, manageable, the area to be surveyed is first covered with series of triangles. Lines are first run round the perimeter of the plot, then the details fixed in relation to the established lines. This process is called triangulation. The triangle is preferred as it is the only shape that can completely over an irregularly shaped area with minimum space left.

ii. Traverse survey:

If the bearing and distance of a place of a known point is known: it is possible to establish the position of that point on the ground. From this point, the bearing and distances of other surrounding points may be established. In the process, positions of points linked with lines linking them emerge. The traversing is the process of establishing these lines, is called traversing, while the connecting lines joining two points on the ground. Joining two while bearing and distance is known as traverse. A traverse station is each of the points of the traverse, while the traverse leg is the straight line between consecutive stations. Traverses may either be open or closed.

1. Closed Traverse: When a series of connected lines forms a closed circuit, i.e. when the finishing point coincides with the starting point of a survey, it is called as a closed traverse, here ABCDEA represents a closed traverse.

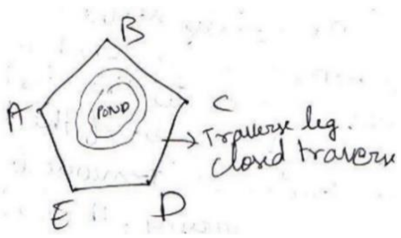

Fig:8.13: Closed traverse survey,Source: Google

2. Open Traverse: When a sequence of connected lines extends along a general direction and does not return to the starting point, it is known as open traverse or (unclosed traverse). Here ABCDE represents an open traverse.

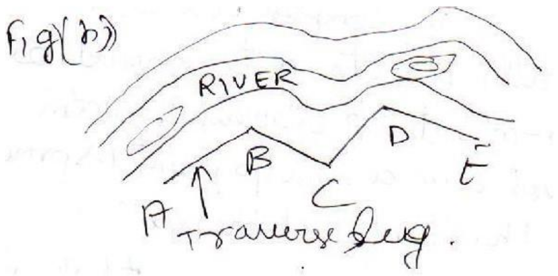

Fig: 8.14: Open traverse survey Source: Google

8.4 SUMMARY

Surveying is the science and technique of determining the position of points and the distances and angles between them, which is essential for creating accurate representations of the Earth's surface. The nature of surveying involves gathering data about landforms, boundaries, and geographic features to produce maps, construction layouts, and other spatial documents. Key principles of surveying include "working from whole to part"—starting with a broad framework and then refining smaller areas to ensure accuracy—and using at least two measurements from fixed reference points to confirm new positions. Surveying is categorized into two main types: plane surveying and geodetic surveying. In plane surveying, the Earth's surface is treated as flat, making it suitable for small-area mapping where curvature can be ignored. In contrast, geodetic surveying accounts for the Earth's curvature, using complex calculations for accurate mapping over large distances, such as national or global scales. Other specialized types of surveying include topographic surveying, which focuses on the natural and man-made features of an area; cadastral surveying, which defines property boundaries; and hydrographic surveying, which maps bodies of water. Surveying is fundamental to civil engineering, urban planning, cartography, and many other fields that require spatial accuracy and reliable geographic data.

8.5 GLOSSARY

Compass: A compass is a navigational instrument that shows direction relative to the Earth's magnetic poles, typically pointing north, and is used in surveying, navigation, and orientation.

Tripod: The table is mounted on a tripod, allowing it to rotate and be leveled for accurate measurements.

Topographical Surveys: Surveys that map the natural and man-made features of an area, including elevation, terrain, and landmarks, creating detailed contour maps.

Plane Surveying: A surveying method assuming the Earth’s surface is flat, suitable for small areas where curvature is negligible.

Geodetic Surveying: A type of surveying that accounts for the Earth's curvature, used for large areas to maintain high accuracy across long distances.

Triangulation Survey: A surveying method that determines positions by measuring angles in a series of interconnected triangles, often used for establishing control networks.

Traverse Survey: A surveying technique that involves a series of connected lines with measured lengths and angles, useful for boundary and route mapping.

8.6 ANSWERS TO CHECK YOUR PROGRESS

Do you know that Spirit LevelEnsures the table is perfectly horizontal before starting the survey.

Do you know that Geodetic surveyingis a branch of surveying, which takes into account the true shape of the earth (spheroid).

Do you know that Plane Surveying in Cartography refers to the process of measuring small areas on the Earth's surface while assuming the Earth is flat, or planar.

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8.8 TERMINAL QUESTIONS

LONG QUESTIONS

1. Explain the Primary Division of Surveying in detail.
2. Explain the Secondary division of surveying in detail.
3. What is Plane table survey describing it in detail?

SHORT QUESTIONS

1. What does the principle "working from whole to the part" mean in surveying, and why is it important?
2. List and briefly describe the three main stages involved in the surveying process.
3. What are two basic principles of surveying, and how do they help ensure accuracy?
4. What is geodetic surveying, and how does it differ from plane surveying?
5. Name three types of surveys based on the nature of the field and briefly describe each.
6. What is Triangulation Survey?
7. Explain Traverse Survey?
8. Explain the difference between Plane surveying and Geodetic Surveying?
9. What do you mean by Plane Surveying in cartography. Explain it.

MCQ'S

1. What is the primary purpose of surveying?

A) To measure time

B) To analyze weather patterns

C) To create accurate representations of the physical world

D) To determine chemical properties of soil

2. Which of the following stages is NOT a part of the surveying process?

A) Taking a general view

B) Observation and measurement

C) Data presentation

D) Chemical testing

3. What is the primary goal of working from the whole to the part in surveying?

A) To save time

B) To prevent the accumulation of errors

C) To increase fieldwork

D) To simplify instrument calibration

4. In surveying, what does the term "linear measurement" refer to?

A) Measuring vertical distances only

B) Measuring horizontal distances with a chain or tape

C) Calculating angles between points

D) Finding the height of tall buildings

5. Which type of error in surveying is predictable and can often be corrected?

A) Systematic error

B) Random error

C) Blunder

D) Gross error

6. Which coordinate system is commonly used for accurate referencing in surveying?

A) Polar coordinates

B) Latitude-Longitude or UTM

C) Cartesian system

D) Geographic Information System (GIS)

7. Which type of survey method involves mapping natural and man-made features along with elevation data?

A) Boundary Survey

B) Engineering Survey

C) Topographic Survey

D) Route Survey

8. In secondary classification based on instruments, which survey method uses angles and distances measured by a prismatic compass?

A) Theodolite Survey

B) Chain Survey

C) Compass Survey

D) Photographic Survey

9. What is the primary difference between plane surveying and geodetic surveying in terms of the Earth's curvature?

A) Plane surveying considers the Earth's curvature, while geodetic surveying does not.

B) Geodetic surveying ignores the Earth's curvature due to small areas covered.

C) Plane surveying ignores the Earth's curvature, while geodetic surveying accounts for it.

D) Both types of surveying ignore the Earth's curvature.

10. Which surveying method is more suitable for small local projects, such as construction sites or property boundaries?

A) Geodetic Surveying

B) Plane Surveying

C) Compass Surveying

D) Photographic Surveying

11. Which tool is commonly used in chain tape surveys to ensure vertical alignment on uneven ground?

A) Ranging Rod

B) Plumb Bob

C) Prismatic Compass

D) Theodolite

12. In compass surveying, what term describes the angle between a line and the magnetic north-south direction?

A) True Bearing

B) Magnetic Declination

C) Magnetic Bearing

D) Geodetic Angle

13. Which type of surveying requires advanced mathematical models and complex corrections, such as accounting for atmospheric refraction and Earth's curvature?

A) Chain Tape Surveying

B) Plane Surveying

C) Geodetic Surveying

D) Plane Table Surveying

14. What is the main use of a prismatic compass in surveying?

A) To measure distances directly

B) To align the surveyor’s position with true north

C) To measure angles and bearings relative to magnetic north

D) To ensure the surveyor maintains a straight line

Answer) 1.c, 2.d, 3.b, 4. b, 5.a, 6.b, 7.c, 8.c, 9.c, 10.b, 11.b, 12.c, 13.c, 14.c

UNIT- 9 SURVEY WITH DUMPY LEVEL & THEODOLITE

9.1 OBJECTIVES

After having the detailed study of this unit you will be able to

- You will learn how to survey from the dumpy level.
- You will understand how angle measurement is done from a Theodolite.

9.2 INTRODUCTION

This gadget allows you to easily measure the heights of various places. It is a basic, compact, and stable instrument. (“The Dumpy Level is a simple, compact and stable instrument.”) Other places' heights are determined through surveying using a known-height station. In this instrument, a telescope is tightly linked to the support, so it cannot easily spin about the longitudinal axis or be detached from it.

A theodolite survey is a method for measuring angles in both horizontal and vertical planes. This tool, known as a theodolite, is required for exact angle measurements and is widely used in fields such as surveying, building, and engineering. The basic goal of a theodolite survey is to measure angles precisely. These measures are critical for determining property boundaries, planning infrastructure, and mapping. A theodolite is an optical device comprised of a telescope set on a spinning platform. It can measure horizontal and vertical angles. Modern theodolites frequently include electronic equipment for more accurate measurements and data recording.

9.3 DUMPY LEVEL

This instrument consists of the following equipment or parts.

1. Leveling Head

2. Telescope

3. Eye Piece

4. Diaphragm

5. Focusing Screw

6. Ray Shade

7. Level Tube

8. Level Tube Nuts

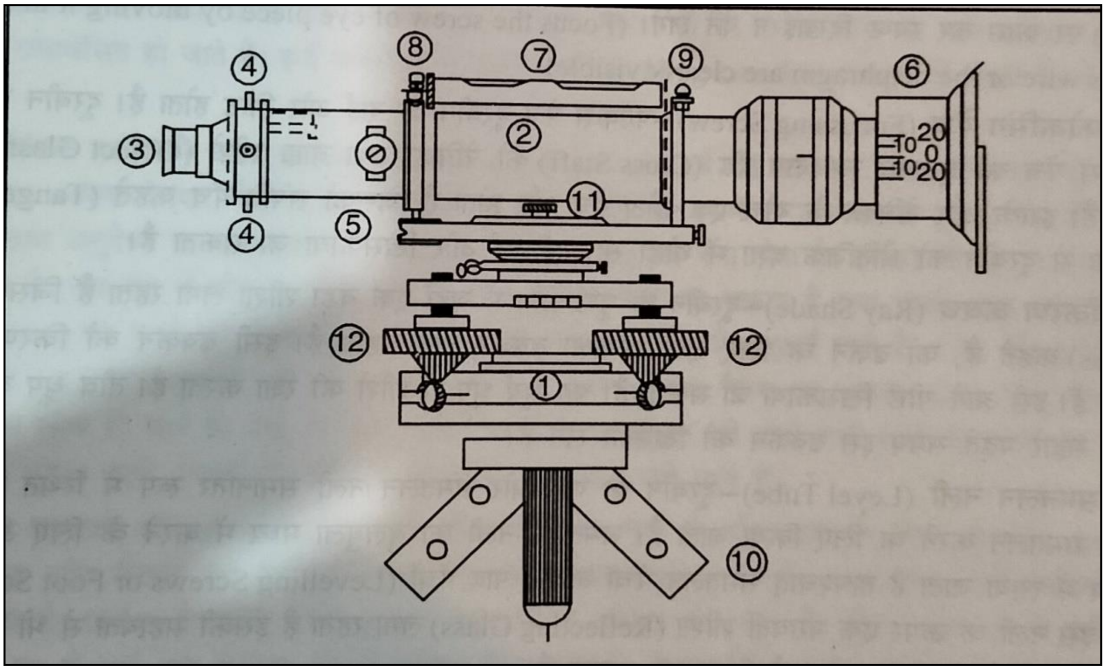
9. Cross Bubble Tube

10. Tripod

11. Prismatic Compass

12. Leveling Screws

Fig. 9.1 Dumpy Level



Source: Google

1. Leveling Head – The leveling head is the section above the tripod that connects to the main instrument, as well as the bottom section of the main instrument. Round bangles are cut in the centre to attach the main instrument to the tripod. The upper half of the leveling head is fastened with three leveling screws.

2. Telescope – The telescope is mounted to the primary instrument's frame above the horizontal level. The telescope has a small mirror attached to one end, known as the eye piece. There is a large mirror at the other end. This glass is known as "object glass." Two fine transverse or cross wires are affixed to the telescope's outer glass (object glass). These wires meet and divide at right angles. Two smaller wires are attached parallel to the horizontal cross wires, however only the central wire is used to read the numerals.

3. Eye Piece - A small, specific form of glass with a small mouth is put on one side of the telescope and is known as the Eye Piece. This allows us to visualize the target point. Moving it back and forth focuses the cross wires of the object glass. When the eyes are weak, the cross wires may not be visible. In such cases, shifting the eyepiece back and forth makes the cross wires visible.

4. Diaphragm - The diaphragm is located behind the eyepiece. Focusing and crossing helps to visualize the wire. To focus, move the eyepiece back and forth until the cross wire is visible on the diaphragm. (Focus on the screw of the eye piece by moving it in and out such that the cross wire or diaphragm is plainly visible.)

5. Focusing Screw – The telescope's focus screw is located on its right side. After stabilizing the telescope, focus by moving the focus screw while staring at the cross staff through the eyepiece and external mirror (object glass). It is connected to the eyepiece by another little screw known as the Tangent Screw. It allows the telescope to be shifted slightly left or right in the horizontal position.

6. Ray Shade - A hollow cover is placed to the rear of the telescope, where a large mirror, known as the objective glass, is mounted. The cover is named Ray Shade. It can be shifted back and forth. It protects the glass from sunshine. During harsh sunlight, this cover is moved while reading using a height measuring rod.

7. Level Tube – The leveling tube is located parallel to the right side of the telescope. It's used to level the instrument. To centre the bubble of the leveling tube, first bring the transverse bubble to the centre before tightening the leveling screws or foot screws. A reflecting glass is placed on top of this tube; by adjusting the screw, the tube's bubble can be centered.

8. Leveling Tube Nuts – A screw is fastened to one side in front of the leveling tube, which is known as the leveling tube or adjusting nuts. These can be adjusted mechanically or permanently by turning them.

9. Cross Bubble Tube – A round tube is located on the right side of the telescope. This tube's spring contains a bubble. The bubble is positioned in the centre of the tube by lowering the dumpy level's tripods.

10. Tripod - The dumpy level is positioned using a tripod, which is a three-legged wooden structure on which the instrument is placed or fastened. Screws hold the main instrument and tripod together. When storage, keep them separate. The tripod includes a place to hang the plumb line.

11. Prismatic Compass – A prismatic compass is positioned beneath the telescope. This method is used to take and mark bearings from various locations.

12. Leveling Screws – There are two of them. Leveling is accomplished by spinning these independently or combined inward or outward, then bringing the bubble to the centre.

All of the above-mentioned equipment is retained under the dumpy label solely. Aside from this, various instruments are required for surveying and determining heights. What are the following?

1. The Leveling Staff or Stave

2. Field Book

3. Metallic Tape

4. Chain

5. Arrows

6. Ranging Rod

Temperature penalty

The Leveling Staff or Stave

The measuring rod has a rectangular cross section. ("Leveling staff is a rod of rectangular cross section.") Its average height is 4-6 meters or 10-15 feet. Its middle section is hollow, and other little rods are incorporated. These are also known as folding leveling staff. These are of several types.

1. Folding Type Leveling Staff – These bars are normally four meters high. They are fashioned from high-quality timbers such as Cyprus pine and cedar. It is made up of parts measuring 2-2 meters. Each piece consists of a longitudinal or parallel strip with no joints. Its width is 75 millimeters. It appears with a thickness of 18 mm. This bar has a bent joint that may be detached, and a locking device in the back to keep it closed. The joint of the rod has the following characteristics: (a) The rod bends to a length of two meters. (b) The components can be separated if necessary. (c) After joining, both pieces are hard and straight. The rod's top and bottom ends each have a brass cap. To close it, two folding handles are attached along with a spring.

Division System (Graduations) – Every meter is divided into 200 pieces. Each portion measures 5 mm and reveals thickness. There is a unique method for writing marks on the stick. The fractions representing the meter are highlighted in red, whereas the other units are represented in black. Each unit is expressed in the corresponding unit. Meters are indicated successively with red on the right side, and decimeters with black on the left. In the division system, the numbers are written upside down so that they may be seen directly with binoculars.

2. Sop with Staff – It is widely used in Britain and other Western countries. Its length is 4 meters (14 feet). The complete sentence consists of three pieces. The first top half is 4 feet 6 inches long, while the second enters the hollow chamber, which is also 4 feet 6 inches long. The third portion, 5 feet long, 4 inches wide, and 2 inches thick, is fully made out of the upper two sections. When pulled up, each stands on a brass spring. It is divisible into tenths and hundredths of a meter or foot. The meter or foot is printed in red on the left side, and the remaining tenth sub-digits are written in black on the right. Every hundredth digit is displayed in white and black. The white upper edge represents odd hundredths and the black upper edge represents even hundredths.

When viewed via binoculars, the upper section of the measuring rod appears below, so the numbers are read top to bottom. When the rod is held close, the red color frequently becomes unclear. When the measurement bar is increased, the problem becomes evident.

3. Target Staff or Philadelphia Staff - Philadelphia is separated into two sections that slide against each other and are held together by a brass spring. A long rod is one that is fully stretched, whereas a short rod is one that is compressed. The front section is divided into tenths and hundredths of a meter or foot. The surface of the upward rising bar is still separated from top to bottom. It can read up to 0.001 meter (thousandth part of a foot) using a vernier. For counts of less than 2 meters, the goal bar is added to the bottom part of the bar. The stick bearer repeatedly moves it out of sight until it is separated into two sections. It is set to 3 meters for calculations that are longer than that. When the target site is within visual range, the sliding bar is raised. When a substance is divided into two parts, the thousandth component is determined.

4. Self-recording staff - The surveyor reads the height while getting readings from the dumpy level. Autograph bar is used to calculate the altitude of neighboring locations. Target Cha is used for distances longer than 120 meters.

Field Book

The heights are documented in the field book. Other tools have been discussed in subsequent chapters of the study.

Precautions while taking out the Instrument from the Box

While taking out the instrument, the following things should be checked to ensure that there is no trouble when putting the instrument back into the box:

1. Observation of the Eye Piece.

2. Observation of Object Glass,

3. Screws (Clamping Screw), if any.

4. Tangent Screw

Procedure of Leveling

Dumpy leveling requires additional stages, as do other surveying tools. First and foremost, the instrument's tripod is kept on hard, flat ground. After that, the device is secured to the tripod. The instrument's height should be kept at a level that allows the transverse bubble to be viewed visually. All leveling screws should be turned and brought to their axis between the bangles. To bring the transverse bubble to the centre, stabilize two of the tripod's legs and move the third back and forth. The instrument is initially leveled.

Adjustment of Dumpy Level

This happens in the following way-

1. Temporary Adjustment

(i) Setting up the Level

(a) Planting of the tripod

(b) Leveling up

(ii) Focusing – (a) Focusing of the Eye Piece (b) Focusing of Object Glass

2. Permanent Adjustment

1. Temporary Adjustment - Temporary leveling is performed at each instrument installation centre. These must be completed prior to the instrument's readings.

(1) Setting up the level-

(a) Planting of the tripod - To tighten the instrument on the tripod, first loosen the screw and hold it in your right hand. The instrument is mounted on a tripod and rotated using the left hand. Aside from that, the tripod's arms are moved back and forth to bring the transverse bubble into the centre.

(b) Leveling up - In this second step, the bubble is brought to the centre by rotating one or both of the punches in or out while keeping the telescope parallel to the foot screws. After that, the telescope is turned at a right angle to the present direction, and the bubble is brought to the centre by rotating the third foot screw. Again, without flipping the eyepiece or objective, return the telescope to its original position and centre the bubble. If the bubble is not in the centre, level the instrument by spinning both punches. When the bubble remains in the centre at a straight angle or 180°, leveling is deemed complete.

(i) Focusing-

(a) Focusing of the Eye Piece – While focusing the eyepiece, remove the objective cover and lay a piece of white paper in front of it, then slide the eyepiece back and forth. Move the eyepiece back and forth until the transverse wires are plainly visible. While sliding, take care not to pull the eyepiece entirely out.

(b) Focusing of the Object Glass – Pointing the telescope towards the target bar and peering through the eyepiece, lightly tap the telescope until the diaphragm's transverse line is plainly visible. If the instrument contains screws and a tangent screw, use them for leveling. The target is stabilized by rotating the focus screw. When the transverse wire is plainly visible, its number is read and entered into the field book.

Height reference mark or bench mark

The reference mark for spatial height is known as a bench mark. These are of the following types-

1. GTS (G.T.S. Great Trigonometrically Survey) Bench Mark

2. Permanent Bench Mark

3. Temporary Bench Mark

4. Arbitrary Bench Mark

1. GTS Bench Mark (Great Trigonometrically Survey Bench Mark)- G.T.S. Bench marks are extremely accurately computed heights during the survey that have been marked at various places by the Survey of India at different distances from the verified datum line.

2. Permanent Bench Mark – GTS represents the government through its agencies. The height itself is permanently marked at numerous locations; these are known as permanent benchmarks. These government agencies are Railways and PWD. There are saws.

3. Temporary Bench Mark – At the end of the survey day, heights are indicated in a few locations for reference in the following day's survey. The next day, work begins with the same reference, known as a temporary bench mark.

4. Arbitrary Bench Mark – Whenever if verified height reference marks are not obtained, the imaginary height is used to complete the task; these are known as imaginary bench marks.

Parallax

Often, because to poor focusing, the image of the object flickers on the eye in relation to the diaphragm’s transverse wires, a phenomenon known as parallax. Sharp focus eliminates parallax.

Change Point

It is an intermediate station (point) (intermediate personnel station). Two points are taken from which the instrument's position can be changed. Its height is precisely measured and will be utilized in future leveling tests. Great attention should be given while reading the inflection point. Any errors in this calculation could have an impact on other heights. From here, the forward and backward directions of both stations are marked.

For Sight Reading

The height or reading of the leveling staff, at which the measuring rod is positioned at a location whose decreased level is unknown and must be discovered, is called. It is also known as negative sight. This is the final reading obtained while measuring height with the dumpy level.

Back Sight Reading

When a location's decreased level is known and the reading is obtained by placing a measuring bar on it, this is referred to as back sight. This is the first reading obtained throughout the height measurement process. It's also called Plus Sight. In other terms, back sight refers to the process of reading marks by placing the height measuring bar on a bench mark or known level plane. The height of the dumpy level is determined by adding the level plane of that location to the acquired volume.

To determine the parallel plane, we place a rod there and look ahead. Subtracting the first number from the instrument's height yields the plane of symmetry is found. The formulas to calculate these are as follows:

Height of Instrument: Decreased level of a point + Staff reading on the point where the decreased level or rearward sight is known. Similarly, to find a point's isoplane, apply the forward formula. Reduced level of the point Height of the Instrument Staff reading at the point where the decreased level is to be determined or predicted

Inter Sight

When the dumpy level is established in one location and a measuring staff is positioned at various spots and measurements are taken to determine their level plane, these points are known as midpoints. The centre and front numbers represent the same volume, however the front number ratio is referred to as the final volume.

Position of Level: There is no special relevance to where the instrument is placed while leveling. Still, when installing the instrument, keep in mind that it should be placed in a flat and solid location from where maximum aiming points may be obtained simply. The instrument should be situated roughly halfway between the change point and the goal point so that the markings on the measurement strip may be easily identified. This distance should only be about 100 meters. The installation should not be placed in an extremely high or low location.

Holding of the Staff: The level measuring rod is carefully installed. The level measuring rod must be kept upright; else, erroneous Redding may occur. The staff member should stand behind the bar, holding the staff with his hands between his toes. Reading lobo requires extreme caution. Some employees have a plumb bob to keep them upright.

Reading of the Staff- The measuring bar should read the following:

1. First, after mounting and leveling the instrument, turn the telescope to the target point and focus it.

2. Carefully hold the measuring staff vertically.

3. Bring the measuring rod vertically between the crossed wires.

4. The bubble should be centered. To achieve this in the centre, a foot screw should be used.

5. Note the red marks first, followed by the black marks.

6. If the markings on the staff are reversed, they appear straight when examined with binoculars. At that point, the staff should read the preceding.

7. However, when the marks are straight, they seem upside down through binoculars; in this instance, the staff should read top to bottom.

Principles of Leveling

The following are the principles of measurement:

1. Simple Leveling

2. Differential Leveling

1. Simple Leveling

This is a basic leveling process. This approach is used to determine the height difference between any two places that are visible from the instrument position. That is, when the difference between two areas is determined by placing a dumpy level in one of them. The level measuring device has been installed at a point roughly in the middle of the target points A and B, and the height difference between them is to be measured.

Now we'll properly place and level the hydrometer in position ‘M’. After leveling, swivel the binoculars to the target position 'A'. The staff member will position the metronome bar vertically at 'A'. Focus on the metronome bar via binoculars and read the readout. Let the reading be 5.25

meters. While reading, keep in mind if the diaphragm's transverse wire is cutting the metronome rod or not, and whether the bubble is in the centre. After then, the metronome rod will be kept vertically at position ‘B’. We will rotate the telescope towards 'B' and examine this spot again to ensure that the bubble is in the centre. If the bubble is not in the centre, it can be centered by twisting the instrument's foot screw. Focus the binoculars and read the results. Let the reading at 'B' be 2.75 meters. As a result, the height difference between 'A' and 'B' will be 5.25 m (2.75 m) = 2.50 m.

If we know the lowered level of 'A', we can also know 'B'. Assume the parallel plane of 'A' is 500 meters. The corresponding level of position 'B' is computed as follows: The comparable level of location 'A' (R.L. Reduced Level). 500 meters

'M' Height of Dumpy Level at point (D.L.) 500m +5.25m = 505.25 meters

‘B’ Parallel plane (R.L.) of point 505.25 meters -2.75 meters = 502.50 meters

Generally, at the time of level measurement, a station should be chosen whose level is known. This station can be a bench mark. In the absence of height, imaginary height can be considered.

2. Differential Leveling

This strategy is appropriate for situations where two locations are far apart.

2. If there is a significant height difference between the two areas.

3. If extremely high and low areas need to be leveled.

4. If there is a pronunciation barrier between the two locations.

5. In such cases, leveling is accomplished by putting dumpy levels at various locations.

6. During this operation, leveling is accomplished by connecting numerous more substations between two main stations.

7. During this leveling, the simple leveling method is done several times.

8. This procedure is also known as compound or continuous leveling.

Suppose we need to measure the difference in heights between stations 'A' and 'B'. It will take more action for-

1. First, substations C and D will be built between stations 'A' and 'B'.

2. Leveling will begin by installing the dumpy level at point 'A'.

3. After leveling, ensure that the instrument's bubble is in the centre and the metronome rod is perpendicular to its position (at A).

4. Will read the reading for Station ‘A’. Let the reading be 5.75 meters. This will be the back number for the 'K' station.

5. The second sub-station 'C' will be chosen, which will be nearly equal distance from station 'A'. This distance is typically not covered in steps. Because the Earth is square, the error on both sides is equal when the distance is equal.

6. After leveling and bubbles are fixed, the reading at 'C' is read and recorded. This will be the first number. Let the reading be 3.25 meters.

7. Set the level of station ‘A’ to 350 meters.

As a result, the instrument's height at the centre 'A' is the parallel plane of the place 'A', as is its reading (Pashyank) at the same location.

(R.L. of K+ Reading of Staff of 'K' at ‘A’ 350 +5.75-355.75 m

Level (R.L.) of ‘C’ station 355.75 - 3.25 352.50 meters.

The difference in heights of stations A and C is 5.75 - 3.25 - 2.50 meters.

8. The dumpy level will now be installed at centre 'B', which is about in the middle of substations 'C' and 'D'. It will level and centre the bubble.

9. Using the hydrometer rod, read the readings of stations 'C' and 'D' from centre 'B'. Let the readings be 4.50 and 4.60 meters, respectively.

10. The parallel plane (R.L.) of 'C' is known to be 352.75 meters. As a result, we may use it to calculate the plane of symmetry of 'G', as well as the height of the bottom at the centre, which is 352.75 + 4.50-357.25 meters. Parallel plane of 'D' (R.L.) 357.25-4.60–352.65 meters

Precautions-

1. Substations C and D are referred to as change points, with readings taken twice each.

2. The instrument is withdrawn from the changing point, but the metro meter rod remains.

3. The turning point should be a consistent and unambiguous goal.

4. The instrument should be located no more than 100 meters from the changing point.

Reduced Level

The perpendicular distance refers to the height of a point above or below the datum line. This is synonymous with It is said. The height of any point can be positive or negative depending on whether it is above or below the datum line. “The elevation of a point is the vertical distance above or below the datum. It's also known as the reduced level (R.L.). The elevation of a point is positive or negative depending on whether it is above or below the datum.”

Generally, the height of any place above sea level can be called datum.

Systems of determining the Reduced Level

1. The Collimation System of Leveling or the Instrument Height System

2. The Rise and Fall System of Leveling

1. The Collimation System of Leveling – This procedure is comparable to the traditional leveling method. This determines parallel planes and heights. This method involves installing the device at any station. The depth bar is used to take the reference point at another location where the parallel plane or bench mark is known. The height of the instrument is calculated by adding this reading to the bench mark. For example, in Figure 22.6, the instrument is in position 'A'. A depth gauge was placed at station 'A', and the back sight reading was 5.75 meters. Because the collimation plane of site 'A' is estimated to be 350 meters, then the height of the instrument (Height of the Instrument or Height of the Line of Collimation) at place 'A' will be -350+5.75-355.75 meters.

After that, if there are any more substations, such as C, G, or B, their readings are collected from ‘A’ subtracting these measurements from the mechanical height (Height of the Instrument) at station ‘A’ yields the matching level of the other stations.

For example, the parallel floor of space ‘A’ = 350 meters

'Back Sight' of ‘A’ = 5.75 meters

Height of the instrument at place ‘A’ = 355.75 meters

Number from ‘A’ to ‘C’ = 3.25 meters

Number from ‘A’ to ‘D’ = 4.60 meters

Therefore, we will find the plane equivalent to ‘C’ (R.L. of C) in the following manner –

Parallel plane of ‘C’ (R.L. of 'C') Mechanical height of 'A' Reading or mean number of ‘C’ (I.S.)

= 355.74-3.25- 352.50 m

Parallel plane of ‘D’ (R.L. of D) 355.74 - 4.60 = 351.15 meters

When the dumpy level is moved from one location to another, a new storage facility is constructed. The levels of the first and second search planes are the same at the inflection point because they are linked by the rear and front numbers. In the plane parallel to the first point, the height of those points is calculated by adding the new reference point acquired from the second point to the inflection point.

Arithmetical Check – The difference between the sums of the final and first digits equals the difference between the first and last parallel planes. This test validates the calculation of the coordinate line and parallel plane of the inflection points. This can be read as "Agra Sutra."

∑ B.S. - ∑ F.S. = ∑ First RL - Last R.L.

∑ = Sum

B.S. = (Back Sight)

F.S. = Fore Sight

R.L. = Reduced Level

2. The Rise and Fall System of Leveling – The following steps must be taken when using this approach. First and foremost, a location is chosen with a certain height as a benchmark. Following this, the common ground between the stations is found. Let us know the corresponding planes of stations A, B, and C. Now we'll take a station ‘A’, lay our dumpy level on it, and level it, etc. The metronome rod’s last point (2.50 m) will be read from the ‘A’ station after it is placed on the bench mark. Assume the parallel plane of the benchmark is 200 meters. We will calculate the instrument's height, which will be 200 + 2.50202.50 meters. As a result, the comparable level for ‘A’ station (instrument station) will be 202.50 meters. To determine the corresponding level of other stations, we will place a metronome rod on each station and read its initial number. For example, placing the hydrometer rod at a station will result in a forward number (F.S.) of 2.75 meters. The leading points of A station will be subtracted from 2.75 meters, and the resulting difference of 25 meters will be referred to as fall, with the corresponding level of 'A' station being 202.50-2.75-199.75 meters. To determine the level plane of another station, we shall set the dumpy level at any centre ‘B’ between A and B and level it. From here, the back number (B.S.) of ‘A’ station will be read as 2.75 meters, while the front number (B.S.) of ‘B’ station will be read as 2.35 meters. This difference will be referred to as ground elevation (2.75 meters, 2.35 meters, and 0.40 meters). Similarly, by placing the instrument at any centre ‘C’ between B and C, the back and front numbers will be displayed. Let them be 2.15.2.35 meters each. Their differential will be 2.35 meters in the front and 2.15 meters in the back. The slope between B and C will be 20 meters.

Now 'A', 'B' and 'C' stations the uniform plane of will be found in the following way:

Parallel plane of 'A' (R.L.) = 202.50-2.75 199.75 meters

The height of the instrument at 'B' station is the leading number of 'B' = Equal bottom of 'B' (R.L.)

Height of instrument at 'B' = Identical plane of 'B' =k the plane corresponding to 'K' is the posterior plane of 'K'. = 199.75 +2.50 m = 202.25 m

(Height of instrument at B) = 202.25 - 2.35 (first digit of B) plane of 'c'

= 199.90 meter height of the instrument at 'c' is the first digit of 'c'

= 199.90 m (R. L. 'b') +2.15 (background of 'b') -2.35 thick = 202.05 -2.35 m - 199.70 m.

Mathematical Check- The correctness becomes evident because the difference of three units is equal to each other. In this strategy, the difference between the sums of all posterior digits is equal. The difference between the total of highs and lows is the same as the difference between the first and last parallel planes. This can be read from the following formula:

∑ B.S. - ∑.F.S. = ∑ Rise - ∑ Fall = Last R.L.- First R.L.

Σ = sum

B.S. = (Back Sight)

F.S. = (Fore Sight)

R.L. = Reduced Level

Comparison of the two Systems-Collimation & the Rise and fall system

The Collimation System		The Rise and Fall System
1.	This method is easy.	This method is more difficult than the trace line measurement method.
2.	In this the work is done quickly.	It takes relatively more time.
3.	Under this, less calculation has to be done.	Calculation is relatively more in this.
4.	Error occurring at intermediate stations The possibility remains. No test can be done for this.	In this method each intermediate station complete testing takes place.
5.	This method is often used for leveling	This method is used for differential floor

	profiles Leveling is done to ensure leveling of pulling and constructional works the Rise and Fall System	measurement (Differential Leveling), check leveling and other important works.

Booking of the Staff Reading - When writing volumes, observe the following precautions:

1. Measurements should be entered in separate columns based on inspection order.

2. The back number refers to the first volume or volume to be written on the page.

3. The final loudness is always in the foreground.

4. When converting measures from one page to another, if the final measurement is Intermediate Sight, it is entered into both the Intermediate (I.S.) and Fore Sight columns. The true measurement will be on the other sheet (B.S.), and middle marks (I.S.) will be written in the columns.

5. Project the front number (F.S.) and back number (B.S.) of the changing point onto the same straight line.

6. Parallel planes to the plane of collimation are written in the same straight line below the reference point.

7. Take brief but accurate notes on benchmarks, change points, and other significant points. Remarks are recorded in the column.

Classification of Leveling

Leveling is classified into the following forms:

1. Differential Leveling,

2. Check Leveling,

3. Profile Leveling,

4. Cross Sectioning Leveling,

5. Reciprocal Leveling,

6. Barometric Leveling,

7. Hypsometry Leveling,

8. Trigonometric Leveling,

1. Differential Leveling: This method uses benchmarks to mark the height points. This procedure has been described before. It is also known as Continuous or Compound Leveling and Taking Flying Levels.

2. Check Leveling – In this system, the height points are marked with benchmarks. This process has been discussed previously. Continuous or compound leveling, as well as taking flying levels, is other terms for the same thing.

3. Profile Leveling – The heights of target points at set intervals along a line. This method marks. This yields a pure contour of the surface. It is also known as longitudinal leveling or sectioning. In procedural form, paragraphs are created in the following forms:

The minimal uniform plane is determined by noting all of the parameters in the field book. Let us call this the Datum Surface. The rise and fall technique applies a minimum equivalent tax. As a result, the base level was determined to be 199 meters. Draw a line AB to represent the base line. Assume that 19970 markings are to be marked on the other fixed planes, and they will be cut according to their horizontal distance with the ruler. We will now establish a vertical chalk and the letter ‘c’ at the point ‘a’ of the line ‘ab’ by drawing a vertical ruler equal to the volume of the last leveled surface above the conduct water. The vertical and area scales have a ratio of 1/10, meaning that if 1 cm = 10 meters, the base scale is 10 meters. If the perpendicular scale is one centimeter, the horizontal scale will be 100 meters. We will now mark the vertical ruler with measurements ranging from 199 to 200 meters.

We will now mark stations A, B, and C on the horizontal scale. By drawing perpendiculars to A, B, and C, we will remove a distance equal to their parallel plane from the base plane line. By connecting these points that represent the same plane, the level profile line of that area is drawn.

4. Cross Sectioning Leveling - Cross sectioning is the process of drawing a surface's undulations or contour perpendicular to a specified line. Lateral drawings are ones that can be drawn perpendicularly (at a 90-degree angle) to the centre line and on any side of the surface to determine its lateral contour. The length of the background varies with the type of the piece.

If the background image is short in length, such as a road or railway line, it is rectified visually. However, when it is long, an Optical Square, Box Sextant, or Theodolite is used to draw it. These are indicated in a sequence beginning with the centre line and taken concurrently with the vertical profile. The profile picture can be made with any tool, such as a Dumpy Level, Hand Level, Abney Level, or Theodolite.

5. Reciprocal Leveling – This leveling procedure properly determines the height difference between two places. When the leveling instrument cannot be mounted between the two points at that time, the height is determined by establishing two observation sets.

6. Barometer Leveling- This procedure involves determining heights using a barometer device.

7. Hypsometric Leveling - This approach determines mountain heights by watching the temperature at which water begins to boil.

8. Trigonometrical Leveling - In this procedure, height points are obtained by measuring vertical angles, whereas horizontal distances are obtained by measuring them in the field.

Factors to be kept in mind during calibration

1. When the level plane is lower, the metronome rod's reading increases.

2. Because of accurate leveling (the bubble remains in the centre), the metronome bar reading is correct.

3. If the leveling system is incorrect, use the Adjustment Screw to level.

4. When reading backward and forward numbers, whether using the differential level method or the fluctuation method, always keep the dumpy level in the centre.

5. The change point is always located on a solid, level surface.

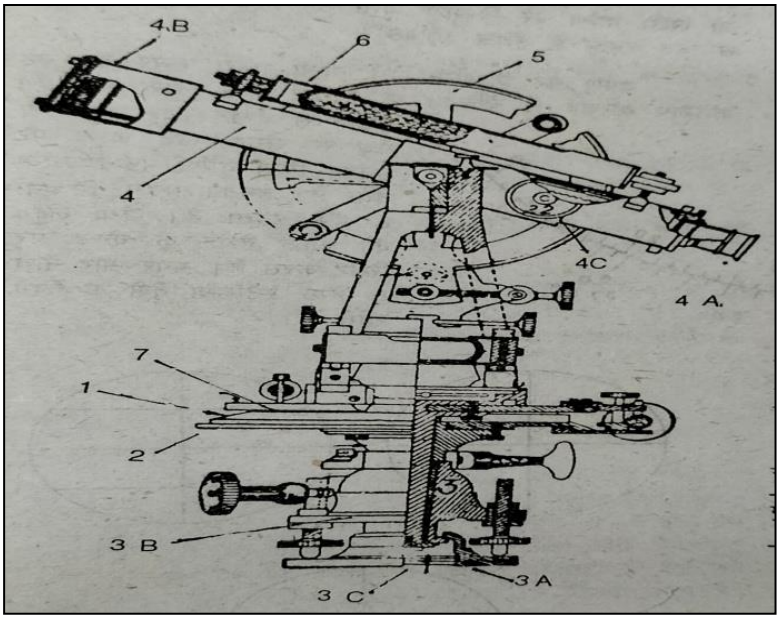
3.4 THEODOLITE

Theodolites are survey instruments that are utilized in practically every country. Although it is designed to measure horizontal and vertical angles, it may also be used to measure horizontal and vertical distances and level them. Transit is the name given to it in the United States, while Theodolite is used in Europe. On this premise, there are two types of theodolites.

(I) Transit Theodolite - The Transit Theodolite was the tool used in Europe to determine horizontal and vertical angles during theodolite surveys. The word Transit itself implies to move. That is, the Transit Theodolite can rotate horizontally in the vertical plane.

(II) Non Transit Theodolite - Theodolite telescopes cannot revolve entirely. Actually, the above-mentioned categories are European and American theodolites. The American theodolite features a graded metallic circular plate. Angles are measured using a vernier, whereas in a European theodolite, the graded plate is constructed of glass. The angular distance is measured using a vernier or micrometre.

Fig.9.2 Theodolite



Source: Dr. P.R. Chauhan

Distance measurement by theodolite- Theodolite measurements of angle and distance reveal a clear link.

Different parts of the Transit Theodolite

Upper and lower plate telescopes, leveling head, and other components are essential to a Transit Theodolite. Aside from these, there are several tiny parts that assist the previously mentioned main parts.

1- Upper Plate- It's called Vernier Plate. It's a horizontal circular plate that's attached to a spindle and revolves vertically. It has both a clamp screw and a slow motion screw. The verniers attached to it are set at 180°. In general, one can read 30°, 20°, or count up to 10 on the vernier.

2-Lower Plate- It is also known as the main plate or measuring plate since it is etched with degrees ranging from 0° to 360° in accordance with the clock hand. It has a clamp screw and a slow motion tangent screw linked to it. This plate is also mounted on a spindle.

3-Levelling Head- It includes the triangular plate fitted on the upper part of the three leveling screws and the two circular 'latches' fitted on top of it. Other parts in it are as follows

A. Trivet Plate- A triangular plate with a flat screw that is attached to the trivet.

B. Tribrach Plate-This is a triangle plate that sits over the three leveling screws.

C. Centering Plate- A plate that is mounted to the trivet and has a hole in it to centre the instrument.

4-Telescope- A telescope or viewfinder is mounted to the upper plate by A or U-shaped arms that can spin on a horizontal plane. The following are the working sections of it.

A- Eyepiece

B: Object Glass

C: Focusing Screw

5. Vertical Plate- This plate affixed to the telescope is used to measure vertical angles. It is inscribed with degrees ranging from 0° to 90°.

6. Spirit Level- One Spirit Level is fastened to the horizontal plate and the other to the vertical plate in order to level the theodolite.

Some special duties must be completed during the centering and installation of the theodolite. These can be defined using the following terminology:

1. Line of Sight- In a telescope fitted with a theodolite, the optical line connecting the centre of the diaphragm, the eyepiece, and the target is known as the Line of Collimation. When the surveyor stares at the objective through this, the line becomes his line of vision.

2- Face Right and Face Left- When the vertical plate is on the surveyor's right side, it is referred to as the right face, and when it is on the left side, it is known as the left face.

3- Repetition and Reiteration -To assure the scale's correctness, the distinct measurements are read again in the same order, and they are read in reverse order from the last target to the first target, respectively.

Angular Measurement in Theodolite

As previously stated, theodolite is used to measure both horizontal and vertical angular distances. Vertical angles are measured using degrees marked on a vertical plate and vernier, whereas horizontal angles are measured using a horizontal plate and a vernier plate. Typically, the main measuring plate is separated from 0° to 360°. Both sides include markings ranging from 0° to 360° for reading from the favorable or anticlockwise orientation. The lines carved on it represent hours and minutes based on their length. Long lines typically express 10. Again, one degree is divided into secondary portions of 30' or 20'. The number of vernier divisions is determined by these secondary divisions. Vernier plate is placed above the main measuring plate. Vernier is placed at 0° to 180° (A, B). To measure the desired angle, the vernier is read at this point A or B.

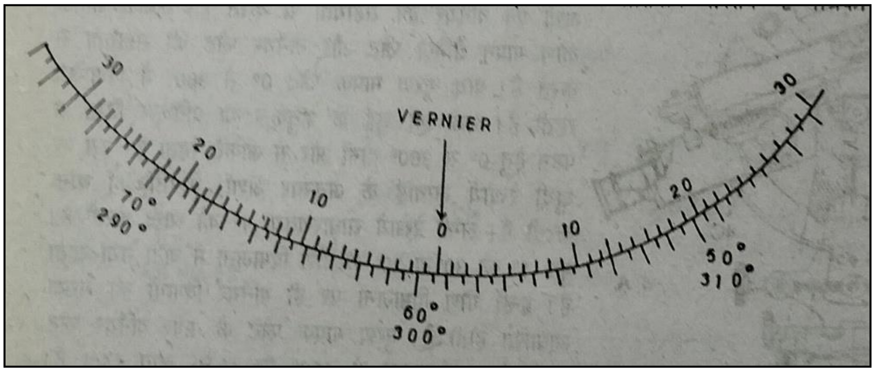
Secondary Divisions of Main Measurement	Vernier's Departments	Minority
30'	30	1'
20'	40	30"
30'	60	30"
15'	45	20"
10'	60	10"

The Vernier scale's least count and the main scale's secondary divisions are adjusted as follows.

1. According to the foregoing adjustment, if the minimum distance of 1 is to be read on the vernier, the minor division of the main ruler should be %° or 30'. Similarly, for a minimum reading of 30°, the minor division of the main ruler should be 20' and the division of the vernier should be 40, whereas for 20', the minor division of the main ruler should be 15' and the division of the vernier should be 45°.

Vernier Reading

Fig. 9.3 Theodolite Vernier



Source: Dr. P. R. Chauhan

In Figure 9.3, the degrees are marked clockwise and anticlockwise on the main scale plate. The basic division is 1°, whereas the secondary division is 12°, or 30'. Hence, the vernier (double vernier) is divided into 30 divisions. As a result, the lowest count is 1'. Here, 00 of the vernier is slightly ahead of 58° 30' in the anticlockwise orientation. In the same manner, if any division line of the vernier entirely aligns with any secondary division line of the main measuring plate, the distance from 0 to that will be added to the distance of the primary scale. If the distance on the main plate is 58° 30' and the vernier is 17th part from zero, i.e. 17 minutes, the desired angle is 58°30' + 17' = 58°47'. Similarly, 0° on the vernier is somewhat ahead of 301° in the clockwise direction. In this sequence, the 13th division of the vernier corresponds to the secondary division line of the main plate. Hence, the needed angle = 301°+13='301°13′.

The telescope is a key tool in transit theodolite. It is rotated on the horizontal plane of the vertical axis as required. Its motion is controlled by the Telescopic Clamp and Tangent Screw. The entire telescope resembles a tube. There is an eyepiece at one end. The target is adjusted using the screw attached to it and the aiming mirror. Similarly, the Focusing Screw that is attached to the telescope is similarly connected to the eyepiece and the tangent screw. The diaphragm adjusts the diaphragm. The diaphragm that appears on the objective mirror is typically organized in the following fashion.

This cross-hair pattern on the mirror is caused by wires being tightened near the eyepiece. When viewed through the eyepiece and adjusted with the focusing screw, their image appears on the mirror. Their formation goes as follows. Typically, the target is fixed in the centre of the crosshairs. The top and lower hairs indicate stadia distance.

Survey process

Before beginning angle measurement or any form of survey work with theodolite, the following activities must be completed.

(i) After deciding on the survey region, pick the appropriate objectives and establish a baseline measurement.

(ii) Before you set up the device, sketch and name the appropriate targets on paper.

(iii) To remove the machine from the box, grip the arms or supports and lift it straight up.

(iv) Different portions of the theodolite should be thoroughly examined.

(v) Tripods that are quantitatively tied to the specific instrument. The nut bolts or clamps should be tightened. Now, the survey process begins in the following manner.

Centering

Centring theodolite at a particular location is a critical task. A tripod is put in the appropriate location, its legs stretched apart, and the centering distance is estimated. The theodolite is then attached and tightened. To centre the tripod, hang a plumb line from the hook attached to the foot plate and move the legs back and forth. Generally, two methods are used in this.

(i) In the first approach, the theodolite is mounted on a tripod, and the plumb line is moved to the desired centre by moving one or two of the tripod legs in and out.

(ii) In the second approach, to centre the theodolite positioned on a tripod, one leg is held in the right hand, the other in the left, and the third is spread out with both legs and centered on the desired point.

Leveling

The theodolite is leveled using the bubble of a spirit level set on the horizontal plate. Normal leveling is usually done while centralizing using the tripod. The three leveling screws are then used to ensure more exact leveling. The bubble is centered in the centre of the spirit level by moving two leveling screws at the same time, either outward or inward. When the bubble is centered, the instrument rotates so that the bubble is at right angles to its prior position. The third screw is then rotated slightly to centre the bubble. After that, if the bubble remains centered even after rotating the instrument, and the plumb line remains centered in the intended point, the instrument is considered suitable for use. Even after adjusting the leveling screws, the bubble may not be perfectly centered. The tripod is then properly centered by moving it forward and backward, and the process is repeated by loosening the leveling screws.

Focusing the Eye Piece and Object Glass

This process begins once the instrument is leveled. First, use the focusing screw to centre the eyepiece. Because of this, the diaphragm wires can be readily seen. Following this, the target mirror is centered. As a result, the picture of the intended target beneath the diaphragm becomes plainly visible.

Measurement of Horizontal Angle- The zero setting simplifies the process of measuring horizontal angles. Before reading the desired angle, clamp the primary measurement plate with the bottom clamp. Then, loosen the vernier clamp and swivel it to centre the vernier's zero or indication mark at 0° or 360° on the main plate. This method is known as zero setting. After zeroing, release the body clamp and transfer the instrument to the main plate. After reaching the first target, the eyepiece and crosswire from the target mirror are positioned on the intended target. If we read the angles on verniers A and B, they will be 00 and 180°, respectively. Now, loosen the vernier clamp, rotate it clockwise, and position it on the second target before tightening the vernier clamp. Then read the desired angle on the first vernier, or A. It will remain the same horizontal angle. Read the desired horizontal angle on vernier B as well. If it is greater than 180°, the desired angle will be determined only after subtracting 180°.

There are two methods for measuring the horizontal angle:

1- Absolute Angle Measurement- It is the angle created by two neighboring targets in the desired centre.

2- This involves measuring the azimuthal angle. That is, the angle is measured with reference to magnetic north at both sites, and the desired angle is calculated by subtracting them. The absolute angle in the graphic above can be read as follows.

(i) Adjust the instrument to the desired centre B. After centering and leveling, centre the cross wire between the eyepiece and the objective mirror.

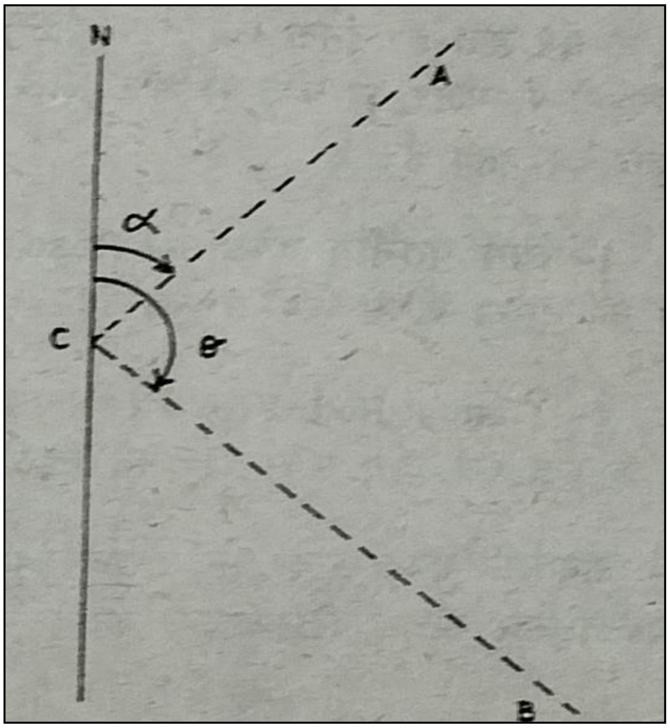
(ii) To establish zero, rotate the main measuring plate, tighten the bottom plate, and loosen the vernier clamp.

(iii) An top touch screw is utilized to align the vernier's 0 plate with the main plate's 0. After matching, both plates are tightened.

(iv) Now, loosen the body clamp and fix target A. During this procedure, the centre of the crosswire of the telescope eyepiece and the target mirror is brought into line with A and stabilised. This is known as the theodolite's orientation. Currently, the aim is on Vernier A, with a value of 0.00º and Vernier B at 180º.

(v) After that, loosen the vernier clamp and rotate the instrument till it reaches target C. Again, use the touch screw to centre the cross wire of the target mirror on target C and tighten the upper clamp. Again, if we know the value of the angle on Vernier A, the required angle will be (θ)

Fig. 9.4 azimuth angle measurement



Source: Dr. P. R. Chauhan

Azimuth angle measurement

Azimuth is the term used to describe horizontal angle measurements taken with a theodolite in reference to magnetic north. First, the magnetic needle is rotated towards north by turning the horizontal plate in relation to magnetic north. The line of sight is then set using the theodolite telescope. After that, loosen the body clamp and move it to target A.

The angle is measured at verniers A or B by centering the eyepiece and cross wire on the target. Again, loosen the upper clamp, slide the vernier plate to target B, and use the uppar tangent screw to centre the cross wire of target B and the diaphragm. Tighten the upper clamp again. The vernier then reads angle A or B. Finally, the difference between the two angles read on vernier A or vernier B at targets A and B is determined. This will be the required angle.

In the picture above, the angle read at target A corresponds to vernier A. While the angle read at target B corresponds to vernier A. Therefore, the horizontal angle ∠ACB = θ - α.

Measurement of Vertical Angle- The vertical angle is measured using a theodolite and a vertical plate mounted to the telescope. The elevation or depression angle is measured relative to the horizontal plane. After positioning the theodolite in the desired location, leveling screws are used to level the instrument. Loosen the telescopic clamp and centre the bubble of the spirit level set on the vertical plate. After that, the telescope is tightened along the trunnion axis.

Even after rotating the telescope horizontally, the bubble remains in the centre of the spirit level. The instrument is then declared ready to use. Then, by freeing the telescopic clamp at the top of any target, the crosswire of the eyepiece and diaphragm is fixed, the angles are read on the verniers C and D, and the average elevation angle with respect to the top is determined.

9.5 SUMMARY

The dumpy level and theodolite are both useful surveying equipment, with each serving a specific purpose: the dumpy level for leveling and elevation measurements, and the theodolite for complete angle measurements and alignment chores. A theodolite is a precision tool used in surveying and engineering to measure horizontal and vertical angles. It is critical in calculating the position of points on the Earth's surface, which is required for accurate map creation, property boundary establishment, and numerous building projects.

9.6 GLOSSARY

Altitude: The height of a point above a reference level, typically the mean sea level.

Angle of Elevation: The angle between the horizontal plane and the line of sight to an object above the horizontal plane.

Angle of Depression: The angle between the horizontal plane and the line of sight to an object below the horizontal plane.

Benchmark: A fixed point of known elevation used as a reference in leveling.

Collimator: A part of the telescope in a theodolite that helps to align the instrument with the line of sight.

Crosshair: The fine lines or wires in the telescope of a theodolite or dumpy level used to precisely align with a point.

Dumpy Level: A type of leveling instrument with a fixed telescope and spirit level used to measure vertical distances and establish horizontal planes.

Elevation: The height of a point relative to a reference level, often the mean sea level or the ground level.

Focusing: Adjusting the telescope of a dumpy level or theodolite to achieve a clear view of the target.

Horizontal Circle: The graduated circle on a theodolite used to measure horizontal angles.

Leveling Staff: A graduated rod used in conjunction with a dumpy level to measure vertical height differences.

Leveling Screws: Screws on the tripod or base of the dumpy level used to adjust the instrument to a perfectly horizontal position.

Plumb Bob: A weight attached to a string, used to ensure that the instrument is directly above a specific point on the ground.

Reading: The process of recording the angle or height measurement from the instrument's scales or digital display.

Spirit Level: A small glass tube containing liquid and an air bubble, used to ensure the instrument is level.

Telescope: The optical component of both the dumpy level and theodolite that is used to sight distant points.

Theodolite: A precision instrument used for measuring horizontal and vertical angles, commonly used in surveying and construction.

Transit Theodolite: A type of theodolite that allows the telescope to rotate 180 degrees, useful for measuring angles in both directions.

Vertical Circle: The graduated circle on a theodolite used to measure vertical angles.

Vertical Plane: The plane that is perpendicular to the horizontal plane, used in measuring vertical angles.

Tripod: The three-legged stand that supports the dumpy level or theodolite, providing stability for accurate measurements.

Graduated Scales: The markings on the horizontal and vertical circles of a theodolite used to measure angles.

Automatic Level: A type of leveling instrument that uses electronic sensors to automatically maintain a horizontal line.

Digital Theodolite: A theodolite with electronic readouts and data recording capabilities, offering enhanced precision and ease of use.

Surveying: The science of measuring and mapping the Earth's surface, which involves tools like dumpy levels and theodolites.

Azimuth: The angle measured clockwise from a reference direction (usually north) to the line of sight or direction of a point.

Transiting: The action of rotating the telescope of a theodolite or transit theodolite to measure angles in both directions.

Alignment: Adjusting the instrument so that it is correctly oriented for accurate measurements.

9.7 ANSWER TO CHECK YOUR PROGRESS

What is the primary purpose of a dumpy level?

A. Measuring horizontal angles

B. Measuring vertical angles

C. Ensuring horizontal alignment and measuring height differences

D. Recording data electronically

Answer: C.

2. Which component of a dumpy level helps ensure that the instrument is perfectly horizontal?

A. Telescope

B. Horizontal Circle

C. Spirit Level

D. Vertical Circle

Answer: C

3. In a dumpy level survey, what does the leveling staff measure?

A. Horizontal distance

B. Vertical distance

C. Angle of elevation

D. Horizontal angle

Answer: B

4. Which of the following is NOT a typical use of a dumpy level?

A. Establishing a level line

B. Measuring angles for property boundaries

C. Checking the elevation of different points

D. Creating topographical maps

Answer: B

5. When using a dumpy level, what is the purpose of the leveling screws?

A. To adjust the angle of the telescope

B. To align the telescope with the leveling staff

C. To ensure the instrument is horizontal

D. To measure horizontal distances

Answer: C

6. What does a theodolite primarily measure?

A. Horizontal and vertical distances

B. Horizontal and vertical angles

C. Elevation differences

D. Only horizontal angles

Answer: B

7. Which part of the theodolite is used for measuring horizontal angles?

A. Vertical Circle

B. Horizontal Circle

C. Telescope

D. Leveling Mechanism

Answer: B.

8. What is the main advantage of a digital theodolite over a manual theodolite?

A. Greater durability

B. Ability to measure horizontal angles only

C. Electronic readouts and data recording

D. Simplicity in design

Answer: C.

9. When using a theodolite, which component is aligned with a reference point to measure angles?

A. The leveling staff

B. The plumb bob

C. The telescope

D. The horizontal circle

Answer: C.

10. Which type of theodolite allows the telescope to rotate 180 degrees for measurements in both directions?

A) Digital Theodolite

B) Automatic Theodolite

C) Transit Theodolite

D) Laser Theodolite

Answer: C

9.8 REFFERENCES

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9. 9 TERMINAL QUESTIONS

(A) Long Questions

1. Describe the different types of leveling instruments used in leveling. Which one is the best among these and why?

2. Describe various components of Dumpy level pictorially.

3. Explain the difference between the following:

A. Leading and trailing numbers

B. GTS Benchmark and temporary bench mark

C. Eye and retina,

D. Median and final digits,

E. Invisibility and delay of the target.

4. Describe the temporary leveling of dumpy level.

5. Explain the following-

A. Line of reference

B. Benchmark

C. Inflection point

D. Instrument height

E. Datum line

F. Stadia.

6. What are the principles of compactness? Explain ordinary and differential measurement.

7. What is called parallel plane? What are the methods to remove it? Explain with example.

8. Describe the processes used in propels labeling and cross-examination.

9. Explain the working principle of a theodolite and describe its main components. How does each component contribute to the accurate measurement of angles in surveying?

10. Discuss the procedure for setting up and using a theodolite in the field. Include steps for leveling the instrument, taking readings, and ensuring accuracy.

11. Compare and contrast the use of a manual theodolite and a digital theodolite. Discuss their advantages and limitations in the context of modern surveying practices.

(B) Short Questions

1. What is the primary function of a dumpy level in surveying?

2. How does a dumpy level ensure it is horizontally aligned?

3. What is the purpose of the leveling staff in a dumpy level survey?

4. Why is it important to ensure the dumpy level is perfectly level before taking measurements?

5. What type of readings is taken with a dumpy level?

6. What does a theodolite measure in surveying?

7. Which part of the theodolite is used to measure horizontal angles?

8. What is the function of the vertical circle in a theodolite?

9. How does a digital theodolite differ from a manual theodolite?

10. What is a transit theodolite and how does it differ from a standard theodolite?

11. What is the purpose of the plumb bob in a theodolite setup?

12. What is the significance of the crosshair in the telescope of a theodolite?

13. In what scenarios is a theodolite preferred over a dumpy level?

14. What does the term "azimuth" refer to in the context of theodolite surveys?

15. Why is it important to calibrate a theodolite before use?

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