LAND SURVEY-II

DEPARTMENT OF CIVIL ENGG.

P.K.A.I.E.T, BARGARH

STRICTLY ACCORDING TO SCTE & VT SYLLABUS

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SCTE&VT SYLLABUS

SL NO.	CHAPTERS
1	TACHEOMETRY: (Only concepts; applications without derivation)
2	CURVES
3	BASICS ON SCALE AND BASICS OF MAP
4	SURVEY OF INDIA MAP SERIES
5	BASICS OF AERIAL PHOTOMETRY,DEM AND ORTHO IMAGES
6	MODERN SURVEYING METHODS
7	BASICS ON GPS & DGPS AND ETS
8	BASICS OF GIS AND MAP PREPARATION USING GIS

ACHEOMETRY

Tachometry is the branch of angular surveying in which the horizontal and vertical distances of points are obtained by optical means as opposed to the ordinary slower process of measurements by tape or chain. The method is very rapid and convenient. Although the accuracy of Tachometry in general compares un-favourably with that of chaining, it is best adapted in obstacles such as steep and broken ground, deep ravines, stretches of water or swamp and so on, which make chaining difficult or impossible.

The primary object of tachometry is the preparation of contoured maps or plans requiring both horizontal as well as vertical control. In addition, on surveys of higher accuracy, it provides a check on distances measured with the tape.

Tacheometer:

1. A tacheometer is nothing more than a theodolite fitted with stadia hair.
2. The stadia hairs are kept in the same vertical plane as the horizontal and vertical cross hair.
3. for short distance up to 100 m, ordinary levelling stadia may use.
4. According to measurement process system, it is classified under two categories

i.e. 1. Stadia hair system

2. Tangential system

5. The stadia hair system again divided into two categories

i.e. 1. Fixed hair method

2. Movable hair method

Fixed hair method:

In this method, the distance between the upper hair and lower hair, i.e. stadia interval i, on the Diaphragm of the lens system is fixed. The staff intercept s, therefore, changes according to the Distance D and vertical angle.

Movable hair method:

In this method, the stadia interval 'i' can be changed. The stadia hairs can be moved vertically up and down by using micrometre screws. The staff intercept s, in this case, is kept fixed. Two vanes (targets) are fixed on the staff at a fixed interval of 2 m or 3 m. The fixed hair method is the one that is commonly used and, unless otherwise mentioned, stadia method means fixed hair method. Movable hair method is not in common use due to difficulties in determining the value of accurately.

Determination of Tacheometric Constants

The stadia interval factor (K) and the stadia constant (C) are known as tacheometric constants. Before using a tacheometer for surveying work, it is required to determine these constants. These can be computed from field observation by adopting following procedure.

Step 1: Set up the tacheometer at any station say P on a flat ground.

Step 2: Select another point say Q about 200 m away. Measure the distance between P and Q accurately with a precise tape. Then, drive pegs at a uniform interval; say 50 m, along PQ. Mark the peg points as 1, 2, 3 and last peg -4 at station Q.

Step 3: Keep the staff on the peg-1, and obtain the staff intercept say s_1.

Step 4: Likewise, obtain the staff intercepts say s2, when the staff is kept at the peg 2,

Step 5: Form the simultaneous equations,

$D_1 = K.\ s_1 + C$ -------------- (i)

And $D_2 = K.\ s_2 + C$ ------------- (ii)

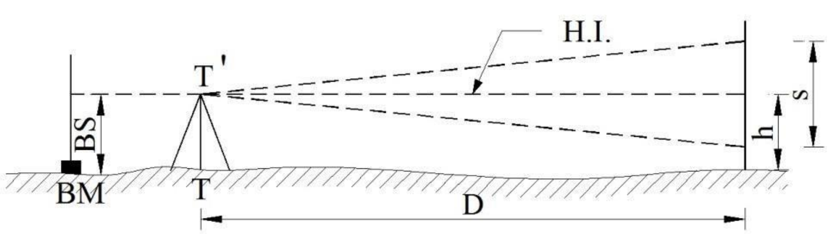
Solving Equations (i) and (ii) determine the values of K and C say K1 and C_1.

Step 6: Form another set of observations to the pegs 3 & 4, Simultaneous equations can be obtained from the staff intercepts s_3 and s_4 at the peg-3 and point Q respectively. Solving those equations, determine the values of K and C again say K2 and C_2.

Step 7: The average of the values obtained in steps (5) and (6), provide the tacheometric constants K and C of the instrument

Stadiatacheometry

Case1Whenstaffheldverticalandwithlineof collimationhorizontal



Whenthelineofsightishorizontal,thegeneraltacheometricequationfor distanceisgivenby

$$D = \frac{f}{i}s + (f + c)$$

The constant multiplying $\left(\frac{f}{i}\right)$ is100,andadditiveconstant(f+c)isgenerallyzero.

RL of staff station P = HI –

hWhereHI = RL of BM +

BSh=centralhairreading

BS=Backsight

HI=heightofinstrument

Case2When staffheldverticalandwithlineofcollimationinclined

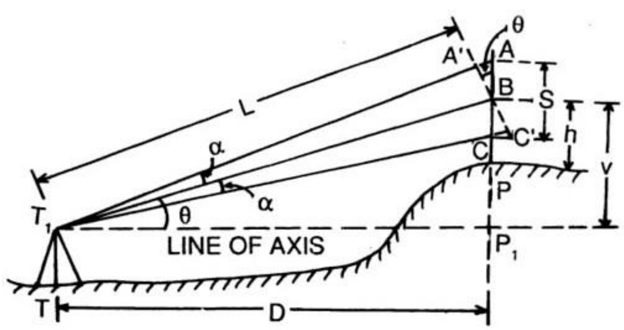
(a) ConsideringAngleofelevation

Let

T = Instrument station*T₁*= axis of instrument *P*=staff station

A,B,C=position of staff cut by hairs

S=AC =staff intercept



h=central hair reading

V=vertical distance instrument axis and central hair

D = horizontal distance between instrument and staff
L = inclined distance between instrument axis and B
θ=angle of elevation
α=angle made by outer and inner rays with central ray

$A'C'$ is drawn perpendicular to the central ray T_1B

Now, internal distance, $L = \frac{f}{i}(A'C') + (f+c)$

Horizontal distance, $D = L\cos\theta$

$$= \frac{f}{i}(A'C')\cos\theta + (f+c)\cos\theta \qquad (1)$$

Now $A'C'$ is to be expressed in terms of AC (i.e. S)

In Δs ABA' and CBC'

$\angle ABA' = \angle CBC' = \theta$

$\angle AA'B = 90^0 + \alpha$

$\angle BC'C = 90^0 - \alpha$

The angle α is very small

$\angle AA'B$ and $\angle BC'C$ may be taken equal to 90^0

So $A'C' = AC\cos\theta = S\cos\theta$

From equation *(1)*

$$D = \frac{f}{i}(S\cos\theta)\cos\theta + (f+c)\cos\theta$$

$$D = \frac{f}{i} \times S\cos^2\theta + (f+c)\cos\theta$$

Again $V = L\sin\theta$

$$= \{\frac{f}{i} \times S\cos\theta + (f+c)\}\sin\theta$$

$$= \frac{f}{i} \times S\cos\theta\sin\theta + (f+c)\sin\theta$$

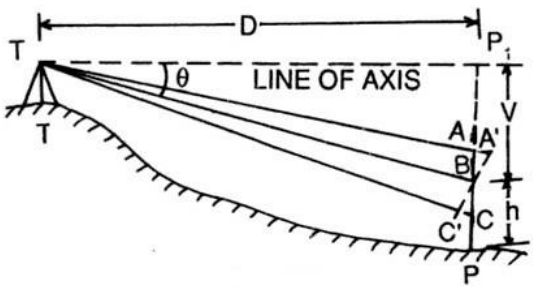
$$V = \frac{f}{i} \times \frac{S \times \sin 2\theta}{2} + (f+c)\sin\theta$$

Also $V = D\tan\theta$

RL of staff station P = RL of axis of instrument + V − h

(b) Considering Angle ofdepression

In this case also the expressions for D and V are same. That is



$$D = \frac{f}{i} \times S\cos^2\theta + (f+c)\cos\theta$$

$$V = \frac{f}{i} \times \frac{S \times \sin 2\theta}{2} + (f+c)\sin\theta$$

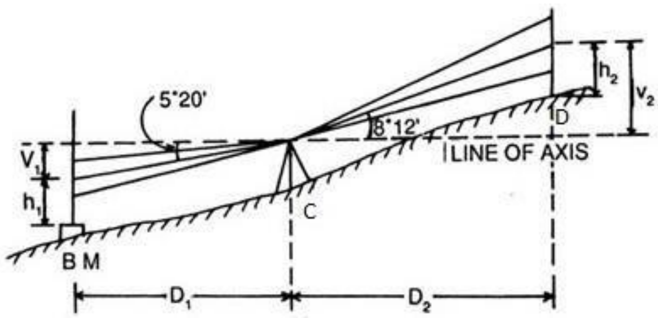
RL of staff station P = RL of axis of instrument − V − h

Problem

A tacheometer was setup at a station C and the following readings were obtained on a staff vertically held.

Inst. station	Staff station	Vertical angle	Hair readings	Remarks
C C	BM D	$-5^0 20'$ $+8^0 12'$	1.500, 1.800, 2.450 0.750, 1.500, 2.250	RLofBM = 750.50m

Calculate the horizontal distance CD and RL of D,when the constants of instrument are100and 0.15.



Solution

When the staff is held vertically, the horizontal and vertical distance are given by the relations

$D=\frac{f}{}\times S\cos^{2}\theta+(f+c)\cos\theta$

$V = \frac{f}{i} \times S \times \frac{\sin 2\theta}{2} + (f+c)\sin\theta$

Here $\frac{f}{i}$ =100and $f+c$ =0.15

In the first observation, S_1= 2.450 − 1.150 = 1.300 m $\theta_1 = 5^0 20'$ (depression)

$V_1 = 100 \times 1.300 \times \frac{\sin 10^0 40'}{2} + 0.15 \times \sin 5^0 20' = 12.045m$

In the second observation, $S_2 = 2.250 - 0.750 = 1.500m$ $\theta_2 = 8^0 12'$ (elevation)

$V_2 = 100 \times 1.500 \times \frac{\sin 16^0 24'}{2} + 0.15 \times \sin 8^0 12' = 21.197m$

$D_2 = 100 \times 1.50 \times \cos^2 8^0 12' + 0.15 \times \cos 8^0 12' = 147.097m$

RL of axis of instrument= RL of BM=$+h_1+V_1$

=750.500+1.800 +12.045=764.345 m

RLofD=RL of axis of instrument=$+V_2-h_2$

=764.345+21197 −1.500=784.042m

So,the distance CD=147.097 m and RLof D=784.042 m

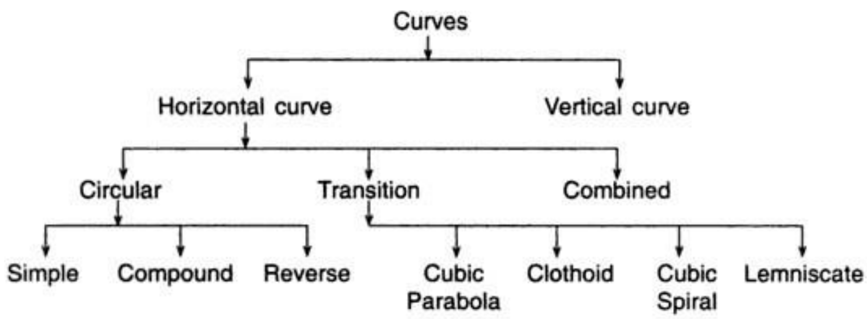
CURVES

Introduction:

Curves are required to be introduced where it is necessary to change the direction of motion from one straight section of a highway or a railway to another. These are provided due to the nature of terrain or other avoidable reasons to enable smooth passage of vehicles.

CLASSIFICATIONOFCURVES

For survey purposes, curves are classified as horizontal or vertical, depending on whether they are introduced in the horizontal or vertical plane.



Horizontal Curves

Horizontal curves can be circular or non-circular (transitional) curves. Different types of horizontal curve.

Simple Circular Curve

When a curve consists of a single arc with a constant radius connecting the two straights or tangents, it is said to be a circular curve.

Compound Curve

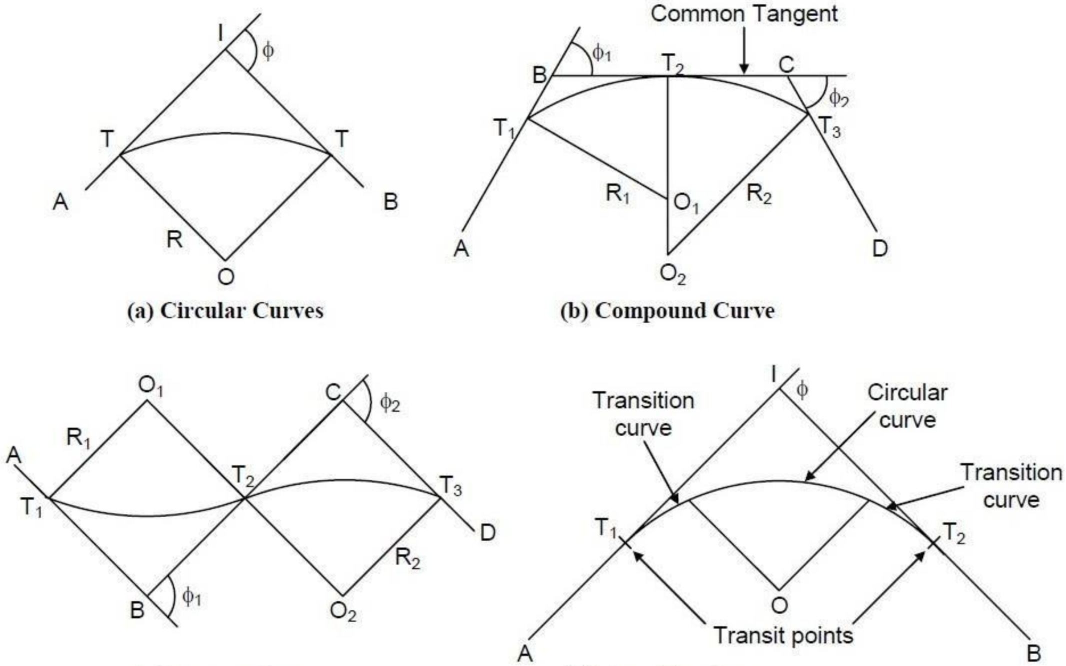
When a curve consists of two or more arcs with different radii, it is called acompoundcurve.Suchacurveliesonthesamesideofacommontangentandthecentresofthedifferentarcslieonthesamesideof their respective tangents.

Reverse Curve

A reverse curve consists of two arc bending in opposite directions. Their centres lieon opposite sides of the curve. Their radii may be either equal or different, and they have one common tangent.

TransitionCurve

A curve of variable radius is known as a transition curve. It is also called a easement curve. Such a curve is provided between a straight and a circular curve, changes. In railways,such curve is used on both sides of a circular curve to minimize superelevation.



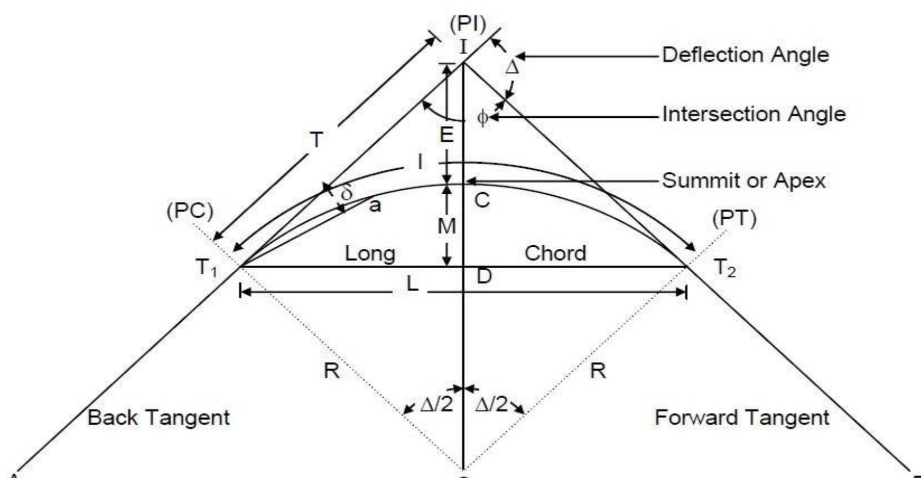
(a) Circular Curves (b) Compound Curve

(c) Reverse Curve (d) Transition Curve

Type of Horizontal Curves

SIMPLECIRCULARCURVE

Figureshowsasimplecircularcurvewithtwostraightlines*AI*and*IB*intersectatthepoint*I*.Thecurve$T_1CT_2$of radius is inserted to make a smooth change of direction from *A* to *B*.A simple circular curve has various components whose definitions are given below.



Components of a Simple Circular Curve

DefinitionofVariousComponen
tsBack Tangent

The tangent (AT_1) previous to the curve is called the back tangent or is tangent.

ForwardTangent

Thetangent(T_2B)followingthecurveiscalledtheforwardtangentorsecondtangent.

PointofIntersection

IfthetwotangentsAT_1andBT_2areproduced,theywillmeetinapoint/calledthepointofinte rsection(PI)orvertex.

PointofCurve(PC)

Itisthebeginningofthe curve(T_1)wherethealignmentchangesfromatangenttoacurve.

PointofTangency(PT)

Itistheendofthecurve (T_2)wherethealignmentchangesfromacurvetotangent.

IntersectionAngle

TheanglebetweenthetangentAT_1andBT_2iscalledtheintersectionangle(ϕ).

DeflectionAngle

The angle Δ through which the forward tangent deflects is called the deflection angle of thecurve.It maybeeithertotheleftortheright.

DeflectionAngletoanyPoint

The deflection angle δ to any point*a* on the curve is the angle at PCbetween the back tangent and the chord T_1a from PC to point on the curve.

Tangent Distance(*T*)

It is the distance between PC to PI(also the distance from PI to PT).

External Distance(*E*)

It is distance from the mid-point of the curve to PI. It is also known as the apex distance.

Length of the Curve(*l*)

L is the total length of the curve from PC to PT.

Long Chord (*L*)

It is the chord joining PC to PT.

Mid Ordinate(*M*)

Iti st heordinatefromthemid-pointofthelongchordtothemid-pointofthecurve.Itisalsocalled theversineofthecurve.

NormalChord(*C*)

Achordbetweentwosuccessiveregularstationsonacurveiscalledanormalchord.

Sub-Chord(*c*)

Sub-chordisanychordshorterthanthenormalchord.Thesegenerallyoccuratthebeginningoratthe end ofthecurve.

Right-handCurve

If the curve deflects to the right of the direction of the progress of survey, it is called theright-handcurve.

Left-handCurve

Ifthecurvedeflectstotheleftofthedirectionoftheprogressofsurvey,itiscalledtheleft-handcurve.

Elements of Simple Circular

CurveLength oftheCurve(*l*)

Length $l = T_1CT_2 = R\,\Delta$, where$\Delta$is in radians

$= (\pi R)\Delta/180^o$, whereΔ is in degrees.

TangentLength (*T*)

Tangentlength,$T = T_1I = IT_2$

$= OT_1 \tan\Delta/2 = R\tan\Delta/2$

LengthoftheLongChord(*L*)

$L = T_1T_2 = 2\,OT_1 \sin\Delta/2$

$= 2R\sin\Delta/2$

ApexDistanceorExternalDistance(*E*)

$E = CI = IO - CO$

$= R\sec\Delta/2 - R$

$= R\,(\sec\Delta/2 - I)$

$= R\,\mathrm{exsec}\,\Delta/2$

Mid-ordinate(*M*)

$M = CD = CO - DO$

$= R - R\cos\Delta/2$

$= R(1 - \cos\Delta/2) = R\,\mathrm{versin}\,\Delta/2$

Problem:

Two tangents intersectatachainage of1250.50mhavingdeflectionangleof 60°.Ifthe radius of thecurvetobelaidoutis375m,calculatetheLengthofthecurve,Tangentdistance,Lengthofthelongchord,Apex distance,Mid-ordinate,Degreeofcurve andChainage ofP.C.andP.T.

Solution :

Lengthofthecurve, $l = (\pi R)\Delta^\circ/180$, where$\Delta$is in degrees.

$= \pi \times 375 \times 60^\circ/180^\circ$

$= 392.69$m

TangentLength, $T = R \tan\Delta/2$

$= 375 \times \tan 60^\circ/2$

$= 216.50$m

Lengthofthelongchord, $L = 2R\sin \Delta/2$

$= 2 \times 375 \times \sin 60^\circ/2$

$= 375.00$m

Apexdistance, $E = R(\sec\Delta/2 - 1)$

$= 375 \times (\sec 60^\circ/2 - 1)$

$= 58.01$ m

Mid-ordinate, $M = R(1 - \cos \Delta/2)$

$= 375 \times (1 - \cos 60^\circ/2)$

$= 50.24$ m

DegreeofArc, $D_a = 1718.9^\circ/R$

$= 1718.9/375$

$= 4.58^\circ$

ChainageofPC =Chainageof*I*–*T*

=1250.50–216.50

=1034.00m

ChainageofPT =Chainageof*I*+*l*

=1250.50+392.69

=1634.19m

DesignationofCurve

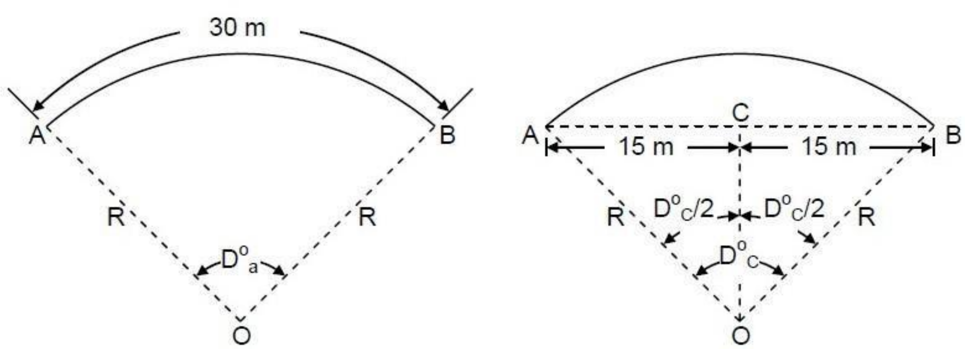
The *sharpness* of the curve is designated either by its *radius* or by its *degree of curvature*. The degree of curvature has several slightly different definitions. According to the *arc definition* generally used in highway practice, the degree of the curve(D^o_a) is defined as the central angle of The curve that is subtended by an arc *AB*of30mlength.

If the degree of curve (D^o_a)is taken in degrees, for a curve of radius meter, then

D^o_a:30=360:2π*R*

or D^o_a=10800/2π*R*

=1718.9/*R*(approximate)



(a) Arc Definition

(b) Chord Definition

Degree of Curve

According to the*chord definition* generallyused inrailwaypractice,thedegree of thecurve(D^o_c)isdefinedasthecentral angle of the curve that is subtended by its chord *AB* of 30 m length.

sin(D^o_c/2) = *AC*/*AO*

=15/*R*

R=15/sin(D^o_c/2)

SETTINGOUTSIMPLECIRCULARCURVE

A circular curve can be set out in the field by linear method and angular method. These are described below.

Linear method is also called chain and tape method. In this method only tape and chains are used and no angular measurement is carried out.

In angular method or Instrumental method, a theodolite, tacheometer or a total station
Linear Method

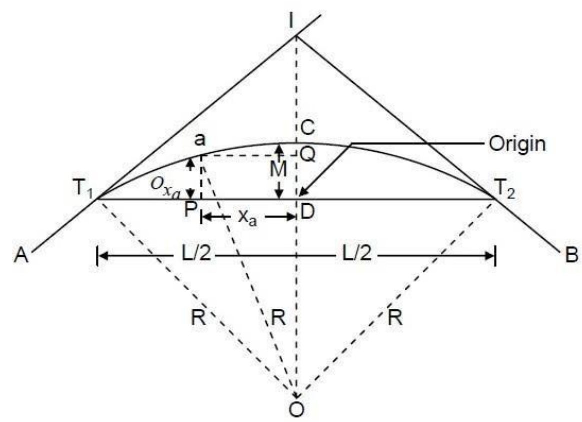
Listed below are some of the linear methods of setting out simple circular curve followed by their description :

(a) Offsets from the long chord
(b) Successive bisection of chord
(c) Offsets from the tangents
(d) Offsets from the chords produced

Offsets from the Long Chord

The method is suitable for setting out circular curves of small radius, such as those at road intersections in a city or in boundary walls. InFigurebelow, the offset O_{xa} to the point *a* on the curve is the perpendicular distance of point *a* from

The long chord T_1T_2 ,at a distance x_a from *D* along thelongchord.Consideringtheoriginat*D*,O_{xa}ist hey-coordinateofpoint*a*.



Offsets from the Long Chord

FromΔOT_1D,

$(DO)^2=(T_1O)^2-(T_1D)^2$

Or $(OC-DC)^2=(T_1O)^2-(T_1D)^2$

Or $(R-M)^2 = R^2 - (\frac{L}{2})^2$

$\sqrt{R^2}$

aw alineQaparalleltoDT$_1$cutti ngDC atQ

FromΔOaQ

$OQ=\sqrt{(Oa)^2-(Qa)^2}=\sqrt{R^2-x_a^2}$

$OQ=OD+DQ=OD+O_{x_a}$

$OQ=OD+O_{x_a}=\sqrt{R^2-x_a^2}$

$O_{x_a}=\sqrt{R^2-x_a^2}-OD$

$O_{x_a}=\sqrt{R^2-x_a^2}-(R-M)$

$O_{x_a}=\sqrt{R^2-x_a^2}-\sqrt{R^2-(\frac{L}{2})^2}$

In general $O_x=\sqrt{R^2-x^2}-\sqrt{R^2-(\frac{L}{2})^2}$

The long chord is divided into equal parts of suitable length. The offset O_{xa} corresponding to the distances x_a from *D* are calculated for different points on the long chord. These offsets are measured perpendicular to the long chord with the help of an optical square and points are located. Joining these points will produce the desired curve. The points on the right side of *CD* are set out by symmetry.

Successive Bisection of Chords

The method being approximate is suitable for small curves. It involves the location of points on the curve by bisecting the chords and erecting perpendiculars at the midpoint of the chords.

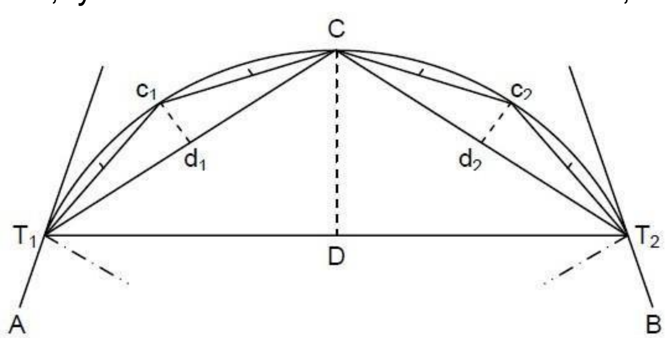
In Figure, T_1T_2 is the long chord and *D* is its midpoint. *C* is the point of intersection of the perpendicular line at *D*, with the curve. *Dc* is the mid-ordinate, which is equal to

$$M = R\left(1-\cos\left(\frac{\Delta}{2}\right)\right) = R - \sqrt{R^2-\left(\frac{L}{2}\right)^2}$$

At *D,* a perpendicular offset equal to *M* is erected and the position *C* is located. Now consider the chords T_1C and T_2C, locate their midpoints d_1 and d_2 respectively. Erect two perpendiculars at d_1 and d_2 and measure the offsets equal to d_1c_1 and d_2c_2, respectively. The offsets d_1c_1 and d_2c_2 are computed from the following formula:

$$d_1c_1 = d_2c_2 = R\left(1-\cos\left(\frac{\Delta}{2}\right)\right)$$

Now, by the successive bisection of these chords, more points can be located in a similar manner.



Successive Bisection of Chords

perpendicularoffsetDCissetoutat$D$withanopticalsquareandpoint$C$islocated.Measure T_1C,andT_2C,andlocatetheir midpoints$d_1$andd_2.The perpendicular offsets$d_1c_1$and$d_2c_2$are set outat$d_1$andd_2,andthepoints$c_1$and$c_2$areestablishedonthecurve.Theprocessiscontinuedtill sufficientnumbersofpointsonthecurvearefixed.

OffsetsfromtheTangents

Thismethodisusedwhenthedeflectionangleandtheradiusofcurvaturebotharecomparatively small. In this method, the curve is set out by measuring offsets from the tangent.Theoffsetsfrom thetangent canbe eitherperpendicularorradialto thetangent.

PerpendicularOffsetsMethod

Let the point *a* be on the curve and the perpendicular offset from the tangent T_1 to it at *P*be O_{x_a} .Let the distance of *P* from T_1 be x_a. Draw a line *Qa*perpendicular to T_1O,intersectingOT_1 at *Q*.

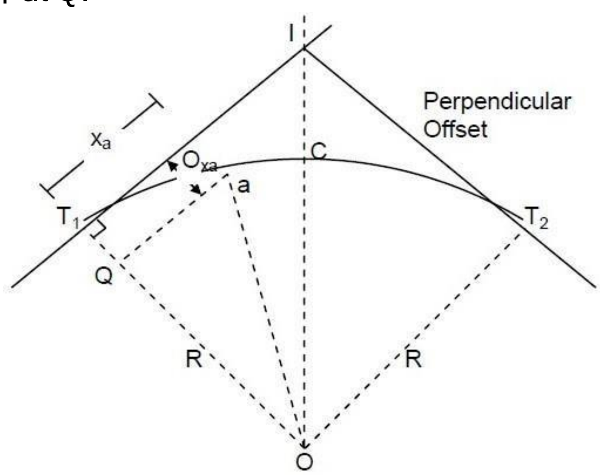
FromΔQaO

$$OQ=\sqrt{(Oa)^2-(Qa)^2}$$

$$R-O_{x_a}=\sqrt{R^2-x_a^2}$$

$$R-O_{x_a}=R-\sqrt{R^2-x_a^2}$$

Ingeneral $O_x=R-\sqrt{R^2-x^2}$



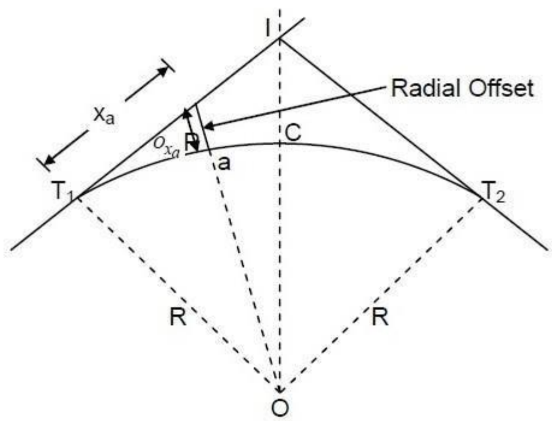
Perpendicular Offsets

Beforesettingoutacurve,atableofoffsetsfordifferentvaluesof*x*(e.g.,10m,20m,30m,etc.)ismade.ThenfromT_1thedistancesx_1,x_2,$x_3$etc.,aremeasuredalongthetangentandthe correspondingoffsetsaremeasuredontheperpendicularstothetangentwiththehelpofanopticalsquare.

Sincethe offsetsof pointsequidistantfromT_1andT_2,are equal,the same table is usedfor offsets frombooththetangents.

RadialOffsetsMethod

Lettheradialoffsettothepoint*a*onthecurvebe O_{x_a}fromthepoint*P*atadistanceof$x_a$from T_1.



Radial Offsets

From ΔOPT_1

$$OP=\sqrt{(OT_1)^2+(T_1P)^2}$$

$$R+O_{x_a}=\sqrt{R^2+x_a^2}$$

$$O_{x_a}=\sqrt{R^2+x_a^2}-R$$

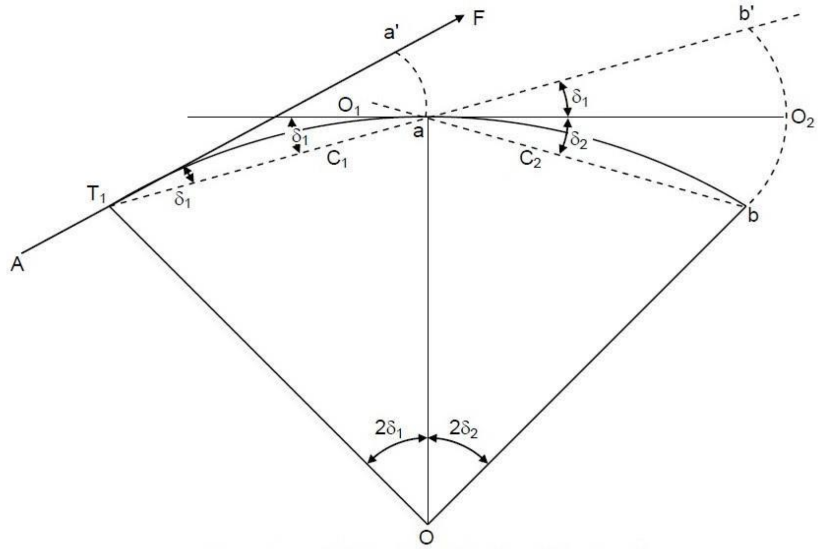
In general $O_x=\sqrt{R^2+x^2}-R$

OffsetsfromtheChordProduced

The method has the advantage that not all the land between the tangents points T_1 and T_2 need beaccessible. However to have reasonable accuracy the length of the chord chosen should notexceed R/20. The method has a drawback that error in locating is carried forward to other points.This method is based on the premise that for small chords, the chord length is small andapproximatelyequal to thearclength.

For setting out the curve, it is divided into a number of chords normally 20 to 30 m in length. Forthe continuous chainage required along the curve, the two sub-chords are taken, one at thebeginning and the other at the end of the curve. The first sub-chord length is such that a fullnumberofchainageisobtainedonthecurvenear T_1andthesecond sub-chordlengthnearT_2.

Fromthepropertyofacircle,iftheangle<FT_1a=ð$_1$



Offsets from the Chord Produced

Theangleatthecentre<T_1Oa

=2ð$_1$

C_1=chordT_1a≈arc T_1a

=2ð$_1$R

Or ð$_1$ = $\frac{C1}{2R}$

Thefirst offsetO_1=C_1ð$_1$

$O_1 = C_1 \frac{C_1}{2R} = \frac{C_1^2}{2R}$

ThefirstchordC_1iscalledthesub-chord.Thelengthofthesub-chordissoadjustedthatthechordlengthwhenaddedtothechainageofT_1makesthechainageof point*a*asfullchain.

SubsequentchordlengthsC_2,C_3,C_4.......... arefullchains.T_1aisthenproducedtob′suchthata fullchainab′=C_2,afullchain.

Thesecondoffset

O_2=C_2(ð$_1$+ð$_2$)

$=C_2(\frac{C_1}{2R}+\frac{C_2}{2R})$

$=\frac{C_2}{2R}(C_1+C_2)$

Similarly $O_3=\frac{C_3}{2R}(C_2+C_3)$

The lastoffset $O_n=\frac{C_n}{2R}(C_{n-1}+C_n)$

where C_{n-1} is a full chain and C_n is the last sub-chord which is normally less than one chain length.

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Angular Method

Following are some of the angular method used to set out a simple circular curve:

(a) Tape and theodolite method

(b) Two theodolite method

(c) Tachometric method

(d) Total station Method

Tape and Theodolite Method

In this method, a tape is used for making linear measurements and a theodolite is used for making angular measurements. The curve can be set out by the following procedures :

Rankine's Method

The method is known as Rankine's method of tangential angle or the deflection angle method. The method is accurate and is used in railways and highways.

Let T_1ab be a part of a circular curve with T_1, the initial tangent point. Thus, T_1a is the first sub-chord which is normally less than one chain length. From the property of a circle

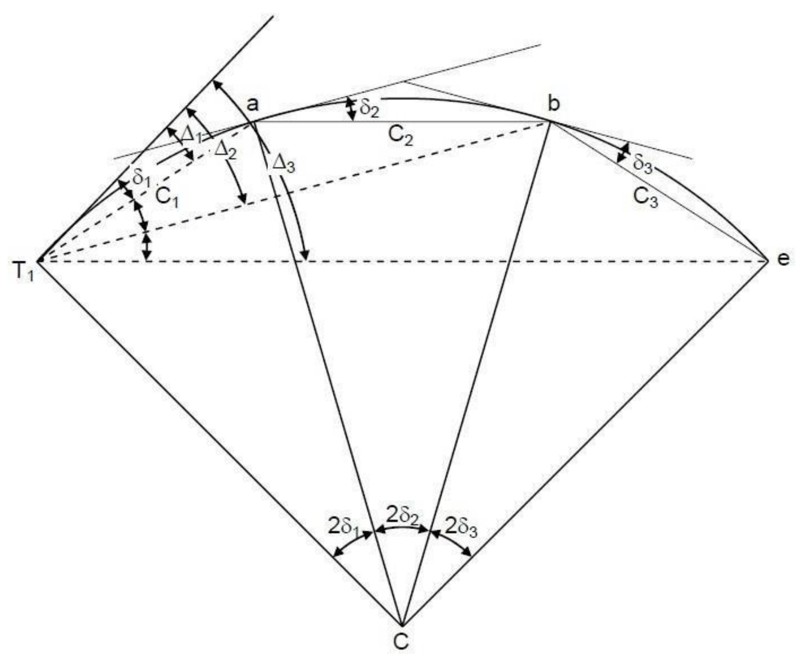
$C_1 = 2\delta_1 R$

$\delta_1 = \frac{C_1}{2R}$ radian

$= \frac{C_1}{2R}\frac{180^0}{\pi}$

$= \frac{C_1}{2R}\frac{180 \times 60}{\pi}$ minutes

$= 1718.87 \frac{C_1}{R}$ minutes



Rankine's Method

Therefore to locate the point $a$withthehelpofatheodolitean dtape,theinstrumentisset atT_1andthe lineof sightisputatanangleofδ$_1$=$\Delta_1$ascomputedabove.Thenwiththe helpofa tapeandrangingrod,thetapeisputalongthelineofsightanddistanceC_1isthenmeasuredto locatepoint$a$alongthelineofsight.

Similarly,

$ð_2=1718.87\frac{C_2}{R}$minutes

SincethetheodoliteremainsatT_1,$b$issightedfromT_1bymeasuring$ð_1+ð_2=\Delta_2$fromthe tangentline.Thepoint$b$islocatedwiththehelpofatapeandrangingrod.Thetapewiththeranging rodissoadjustedthatthetapemeasures$ab=C_2$andtherangingrodliesalongtheline ofsightTb_1

Similarly,

$\Delta_3=ð_1+ð_2+ð_3=\Delta_2+ð_3$

$\Delta_n=ð_1+ð_2+ð_3+\ldots\ldots\ldots+ð_n=\Delta_{n-1}+ð_n$

Inpractice,C_1isthefirstsub-chordand$C_n$thelastsub-chord.

$C_2=C_3=\cdots=C_{n-1}$arefullchainlengths.Asacheckthedeflectionangle$\Delta_n$forthelastpoint $T_2$is equal to $\frac{\Delta}{2}$where$\Delta$is theangleofintersection.

Field ProblemsinSettingOuttheCircularCurves

Thefollowingaresome ofthefieldproblemsinsettingoutthecircularcurves.

(a) Pointofcurveinaccessible.

(b) Pointoftangencyinaccessible.

(c) Pointofintersectioninaccessible.

(d) Curvetangentialtothreelines.

(e) Bothpointofcommencementandpointofintersectioninaccessible

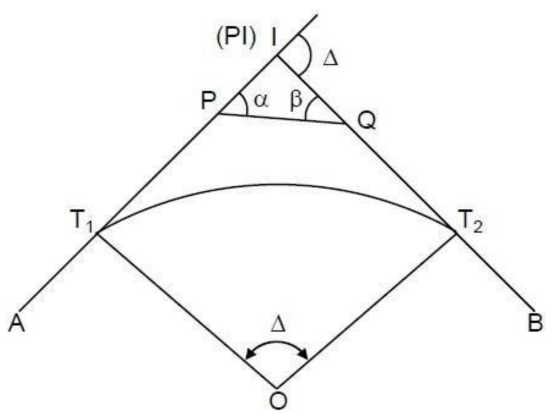
Pointofintersectioninaccessible

IfthepointofintersectionP.I.isinaccessiblethentosetoutacurve,thefollowingprocedureisfollowed:FirstlocatepointsPandQon IT_1 and IT_2 respectively,thenmeasureanglesαandβ withthetheodoliteandlength*PQ*withatape.

Then $\frac{IP}{\sin\beta} = \frac{PQ}{\sin\Delta}$

Or $IP = \frac{PQ\sin\beta}{\sin\Delta}$

Similarly



Point of Intersection Inaccessible

$$IQ = \frac{PQ\sin}{\alpha\sin\Delta}$$

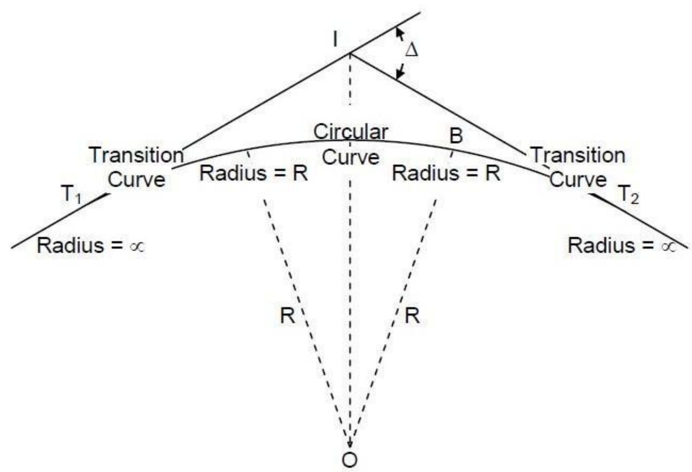
Calculate$PT_1 = IT_1 - IP$$QT_2 =$

$IT_2 - IQ$

Thus,T_1andT_2canbelocatedfrom$P$and$Q$respectivelyandthecurvecanbeplottedfromT_1.

TRANSITIONCURVE

A transition or easement curve is a curve of a varying radius introduced between a straight and acircular curve, or between branches of a compound curve or reverse curve. The introduction of atransition curve between the straight and the circular arc, as indicated in Figure below, permitsthe gradual elevation of the outer edge or gradual introduction of *cant or super-elevation* (raisingthe outer edge over the inner). At the same time, it also permits gradual change of direction fromstraightto thecircularcurveandvice-versa.



Transition Curve

On a straight track, its two edges are at thesame level. On a circular arc the outer edgeis elevated depending on the radius of thecurve and the speed to the vehiclesexpected, to avoid over turning of thevehicles due to centrifugal force acting onthem while moving on circular path. Also,there is an abrupt change in direction whenthe alignment changes from straight tocircular curve and vice-versa.

Inrailways,suchacurveisprovidedonboth sidesofacircularcurvetominimise super-elevation.Excessivesuper-elevationmaycausewearandtearoftherailsectionanddiscomfortto passengers.

AdvantagesofaTransitionCurve

The introduction of a transition curve between a straight and a circular curve has the followingadvantages:

(a) The chances of overturning of the vehicles and the derailment of trains are reducedconsiderably.

(b) Itprovides comforttothepassengersonvehicleswhilenegotiatingacurve.

(c) Thesuper-elevationisintroduced graduallyin proportiontotherateofchangeofcurvature.

(d) Itpermitshigherspeedsatcurves.

(e) Itreducesthewearon therunninggears

CharacteristicsofaTransitionCurve

(a) Itshouldbetangentialtothestraight.

(b) Itshouldmeetthecircularcurvetangentially.

(c) Itscurvatureshouldbezeroattheoriginontangent.

(d) Itscurvatureshouldbeequaltothatofthecircularcurveatthejunction withthecircularcurve.

(e) The rate of change of curvature from zero to the radius of the circular curve should be thesameas that ofincreaseofcantorsuper-elevation.

(f) Thelengthofthetransitioncurveshouldbesuchthatfullcantorsuper-elevationisattainedatthejunction with thecircularcurve.

A **map series** is a group of topographic or thematic charts or maps usually having the same scale and cartographic specifications, and with each sheet appropriately identified by its publisher as belonging to the same series.

Map series occur when an area is to be covered by a map that, due to its scale, must be spread over several sheets. Nevertheless, the individual sheets of a map series can also be used quite independently, as they generally have full map surround details and legends. If a publisher produces several map series at different scales, for instance 1:25,000, 1:50,000 and 1:100,000, then these series are called **scale series**.

According to 2007/2/EC European directive, national mapping agencies of European Union countries must have publicly available services for searching, viewing and downloading their official map series.[2] Maps produced by some of them are available under a free license that allows re-use, such as a Creative Commons license

The concept of a map series

In everyday use, individual maps and atlases are sometimes described as being part of a "map series". However, that is not a correct use of the technical language of cartography, in which the term *map series* refers exclusively to the phenomenon described here, namely a map published over several sheets. The scope of a map series can range from as few as two sheets to at least tens of thousands of sheets.

Obsolete maps, especially of the 19th century, are often named *Topographic Atlases*, because their small-sized sheets were also bound into atlases. An example of such a map series is the Topographic Atlas of the Kingdom of Hanover and the Duchy of Brunswick.

A map series is not to be confused with a map collection, which is a map storage site and its contents, usually forming part of a library, archive, museum, or held at the premises of a map publisher or public authority.

Extract of the 1:25,000 Swiss National Map showing Lake Lucerne on nine different sheets

It is technically very difficult, and it would be highly impractical, to print, e.g., the National Map of Switzerland on a single sheet at a scale of 1:25,000 (that particular map would be about 9 metres (30 ft) high and 14 metres (46 ft) wide). For that reason, map series are issued and preserved in loose-leaf form. In extreme cases, a map series can include thousands of sheets. Probably the greatest map series ever created is the 1:25,000 topographic map of the Soviet Union, with about 300,000 sheets, completed in 1987.

Occasionally, smaller map series will be compiled by the buyer into a bound volume, without thereby incorporating into the bound work the otherwise typical features of an atlas.

The sheets of a map series can also be glued by the buyer to their neighboring sheets, especially as a wall decoration. So, for example, the National Map of Switzerland (1:100,000), which consists of 22 sheets, can be seen as a wall decoration in the Federal Palace of Switzerland and in the Swiss National Library.

Map series are divided into particular systems of single sheets named and numbered according to common principles. Thus, the characteristics of a particular sheet in a map series apply equally to all the other sheets of the map series. So, for example, all sheets normally have the same cartographic projections, geodetic datums, scale, and a uniform content and cartographic design.

Sheet network designs

Theoretically, almost any sheet network design can be used. In practice, variants of the mercator projection are the most widely used today, frequently in conjunction with the UTM coordinate system.

Organization

All sheets of a map series are created in the same way. Thus, they bear all of the common map series titles, have the same author and copyright notices, use the same map legend and, with the exception of any possible edge sheets, are usually printed on paper of a uniform size. An individual sheet's title and number identifies and locates that sheet's place in the map series.

Nature of the sheet divisions

The sheets are divided from each other either square to the map grid, or along the meridians and parallels. In the first case, the sheets will all be the same size. In the second case, the sheet size will decrease towards the north (for a northern hemisphere map) or the south (for a southern hemisphere map).

Regardless of the selected type of division, there is a convention that four sheets of a particular scale map are used to depict the same area as one sheet of the next smaller scale map series produced by the same publisher.

Numbering and naming systems

To determine whether a specific map sheet forms part of a map series, it is often sufficient simply to search for a map sheet number. These numbers are usually printed prominently on the map sheet, and facilitate the identification of connecting sheets, either directly, or indirectly with the aid of a sheet index.

The following numbering systems are the main ones used:

40	5	8
	32	15

Consecutively in order of appearance: The sheets are numbered consecutively as each is published. Thus, it is not possible to determine the sheets neighboring a particular sheet without a current sheet index. Nor is it always possible to indicate on a sheet's map surround the numbers of adjacent sheets, as the date of publication of forthcoming sheets (and therefore their place in the numbering system) may not yet be known. This system is therefore suitable only for small maps, or those in an irregular sheet division (as in tourist maps published by the private sector), and is seldom now used for modern official map series. Example: *Geological Atlas of Switzerland* (1:25,000).

36	37	38
42	43	44

Continuous row by row, or column by column: The numbering starts at top left with the northwestern most sheet, then rises on the same row towards the right (east) to jump from there to the left (westernmost) sheet of the next lower (southern) row, etc. In some countries, this system is applied not row by row, but column by column. The disadvantage of both options is that in each case two of the four sheets adjacent to each sheet are not directly identifiable from the numbers. To address this problem, the neighboring sheet numbers are usually printed on the map surround of each sheet. Example: *Belgique* (1:50,000).

1211	1212	1213
1231	1232	1233

According to zones and columns: These numbers run row by row from the left (west) to the right (east). In contrast with the previous numbering system, the number of the left hand sheet in the next lower (southern) row will jump to a specific higher value (e.g. 20, 100). All sheets in any particular column will therefore bear one or more identical digit(s). Such numbering systems often use four-digit numbers, and make note of the jump in value in a simple way to facilitate identification of neighboring sheets. Example: *National Map of Switzerland* (1:25,000).

3648	3748	3848
3647	3747	3847

By longitude and latitude: The sheets are arranged by integer numbers, denoting geographical longitude and latitude (the reverse order is not common). The geographical location of the map sheets in this system can be directly localized. Unlike the previous system, each adjacent lower (southern) row bears lower numbers, and the final digit for each of the sheets in a particular row is always the same. At least in Central Europe, the numbers used in this system are made up of four digits. Example: *General map of Central Europe* (1:300,000).

M-35-V	M-35-VI	M-36-I
M-35-XI	M-35-XII	M-36-VII

According to subdivisions of the International Map of the World: The sheet numbers of the *International Map of the World* 1:1,000,000 are augmented in the next smaller scale by a suffix (e.g. capital letters). Sheet numbers of each further smaller scale will bear a different system of suffixes (e.g., Roman numerals, small letters, etc.). These numbers can become very complex, but at the same time allow "the experts" to gain at least a rough location of the map sheet on the globe. Example: *Soviet General Staff map* (1:200,000).

The name of a sheet, regardless of the chosen sheet dividing and numbering system, depends almost entirely upon the largest town depicted on the sheet. Since the publication in the 18th century of the important French *Carte de Cassini* 1:86,400, nearly all sheets of map series globally have been not only numbered, but also given an individual sheet name. The current practice is that only sheets depicting very remote areas with a shortage of toponyms (e.g. in northern Canada) are published without their own sheet names.

Current map series

See also: Topographic map § Publishers of national topographic map series

Most nations of any significant size now have several topographic map series of coordinated scales (scale series). Examples of such series are the German Topographic maps of 1:25.000 scale (TK25) to 1:1,000,000 scale (TK1000). In Germany, the federal States have responsibility for the production and updating of the map series up to and including 1:100,000 scale, and for larger scales the responsibility rests with the Federal Office of Land Surveying. The small scale map series are edited by the Federal Agency for Cartography and Geodesy.

In most European countries, the largest scale topographic map series is a 1:25.000 scale series. Notable exceptions are Austria (1:50,000) and Finland (1:20,000).

Many non-European states limit the largest scale of their map series, usually to 1:50,000 scale, frequently due to the large size of the country covered (and hence for financial reasons). A noted exception is the quadrangle series of the United States in 1:24,000 scale.

A high-profile has been gained worldwide by map series published as a collaborative effort by several countries, especially the International Map of the World (1:1,000,000) (IMW) and the World Map / *Karta Mira* (1:2.500, 000). The IMW was developed from 1913. Although many sheets of the IMW were published, the series as a whole was never finished. The Karta Mira was published from 1963. Although it is complete, it has not been revised since the 1980s. Both map series also served as a basis for thematic mapping.

BASICS OF MAPS AND SCALES

What is Scale?

You must have seen maps with a scale bar indicating equal divisions, each marked with readings in kilometres or miles. These divisions are used to find out the ground distance on the map. In other words, a map scale provides the relationship between the map and the whole or a part of the earth's surface shown on it. We can also express this relationship as a ratio of distances between two points on the map and the corresponding distance between the same two points on the ground.

There are at least three ways in which this relationship can be expressed.
These are:
1. Statement of Scale
2. Representative Fraction (R. F.)
3. Graphical Scale

Each of these methods of scale has advantages and limitations. But before taking up these issues, let us understand that the scale is normally expressed in one or the other system of measurement. You must have read and/or used kilometer, meter, centimeter etc. to measure the linear distances between two points on the ground. You might have also heard of miles, furlongs, yards, feet, etc. These are two different systems of Measurement of the distances used in different countries of the world. Whereas the former system is referred to as the Metric System of Measurement and presently used in India and many other countries of the world, the latter system is known as the English System of Measurement and is prevalent in both the United States and the United Kingdom. India also used this system for measuring/showing linear distances before 1957.

METHODS OF SCALE

As mentioned above, the scale of the map may be expressed using one or a combination of more than one methods of scale. Let us see how these methods are used and what are their advantages and limitations.

1. Statement of Scale: The scale of a map may be indicated in the form of a written statement. For example, if on a map a written statement appears stating 1 cm represents 10 km, it means that on that map a distance of 1 cm is representing 10 km of the corresponding ground distance. It may also be expressed in any other system of measurement, i.e. 1 inch represents 10 miles. It is the simplest of the three methods.
However, it may be noted that the people who are familiar with one system may not understand the statement of scale given in another system of measurement. Another limitation of this method is that if the map is reduced or enlarged, the scale will become redundant and a new scale is to be worked out.
2. Graphical or Bar Scale: The second type of scale shows map distances and the corresponding ground distances using a line bar with primary and secondary divisions marked on it. This is referred to as the graphical scale or bar scale (Fig. 2.1). It may be noted that the scale readings as shown on the bar scale in Figure 2.1 reads only in kilometers and metres. In yet another bar scale the readings may be shown in miles and furlongs. Hence, like the statement of scale method, this method also finds restricted use for only those who can understand it. However, unlike the statement of the scale method, the graphical scale stands valid even when the map is reduced or enlarged. This is the unique advantage of the graphical method of the map scale.

3. Representative Fraction (R. F.): The third type of scale is R.F. It shows the relationship between the map distance and the corresponding ground distance in units of length. The use of units to express the scale makes it the most versatile method. R. F. is generally shown in fraction because it shows how much the real world is reduced to fit on the map. For example, a fraction of 1 : 24,000 shows that one unit of length on the map represents 24,000 of the same units on the ground i.e. one mm, one cm or one inchon the map representing 24,000 mm, 24,000 cm and 24,000 inches, respectively of the ground. It may, however, be noted that while converting the fraction of units into Metric or English systems, units in centimetre or inch are normally used by convention. This quality of expressing scale in units in R. F. makes it a universally acceptable and usable method. Let us take R. F. of 1 : 36,000 to elaborate the universal nature of R. F.

If the given scale is 1: 36,000, a person acquainted with the Metric System will read the given units by converting them into cm, i.e. the distance of 1 unit on the map as 1 cm and the distance of 36,000 units on the ground distance as 36,000 cm. These values may subsequently be converted into a statement of scale, i.e. 1 cm represents 360 metres. (by dividing values in denominator by the number of centimetres in a metre, i.e. 100). Yet another user of the map familiar with the English system of measurement will understand the map scale by converting it into a statement of scale convenient to him/her and read the map scale as 1 inch represents 1,000 yards. The said statement of scale will be obtained by dividing 36,000 units in the denominator by 36 (number of inches in a yard).

CONVERSION OF SCALE

If you have carefully read the advantages and limitations of the different methods of scale, then it will not be difficult for you to convert the Statement of Scale into Representative Fraction and vice-versa.

Statement of Scale into R. F.

Problem Convert the given Statement of Scale of 1 inch represents 4 miles into R. F.
Solution The given Statement of Scale may be converted into R. F. using the following steps.

1 inch represents 4 miles or 1 inch represents 4 × 63,360 inches (1 mile = 63,360 inches) or 1 inch represents 253,440 inches
NOTE: We can now replace the character “inches” into “units”
And read it as:
1 unit represents 253,440 Units
Answer R. F. 1 : 253, 440

R. F. into Statement of Scale

Problem Convert R. F. 1 : 253, 440 into Statement of Scale (In Metric System)
Solution The given R. F. of 1 : 253, 440 may be converted into Statement of Scale using the following steps :

1 : 253, 440 means that 1 unit on the map represents 253, 440 units on the ground.
or 1 cm represents 253, 440/100,000 (1 km = 100,000 cm)
or 1 cm represents 2.5344 km

After rounding of up to 2 decimals, the answer will be:
Answer 1 cm represents 2.53 km

Photogrammetric Surveying: It is the branch of surveying in which maps are prepared from photographs taken from ground or air stations. Photographs are also being used for interpretation of geology, classification of soils, crops, etc. The art, science, and technology of obtaining reliable information about physical objects and the environment through process of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and phenomenon. Originally photogrammetry was considered as the science of analysing only photographs.

Advantages and Disadvantages: Some advantages of photogrammetry over conventional surveying and mapping methods are: It provides a permanent photographic record of conditions that existed at the time the aerial photographs were taken. Since this record has metric characteristics, it is not only a pictorial record but also an accurate measurable record. If information has to be re-surveyed or re-evaluated, it is not necessary to perform expensive field work. The same photographs can be measured again and new information can be compiled in a very timely fashion. Missing information, such as inadequate offsets for cross sections, can be remedied easily. It can provide a large mapped area so alternate line studies can be made with the same data source can be performed more efficiently and economically then other conventional methods. It provides a broad view of the project area, identifying both topographic and cultural features. It can be used in locations that are difficult, unsafe, or impossible to access. Photogrammetry is an ideal surveying method for toxic areas where field work may compromise the safety of the surveying crew. An extremely important advantage of photogrammetry is that road surveys can be done without closing lanes, disturbing traffic or endangering the field crew. Once a road is photographed, measurement of road features, including elevation data, is done in the office, not in the field. Intervisibility between points and unnecessary surveys to extend control to a remote area of a project are not required. The coordinates of every point in the mapping area can be determined with no extra effort or cost. The aerial photographs can be used to convey or describe information to the public, State and Federal agencies, and other divisions within the Department of Transportation. Some disadvantages are: Weather conditions (winds, clouds, haze etc.) affect the aerial photography process and the quality of the images. Seasonal conditions affect the aerial photographs, i.e., snow cover will obliterate the targets and give a false ground impression. Therefore, there is only a short time normally November through March, that is ideal for general purpose aerial photography. A cleared construction site or a highway that is not obstructed by trees, is less subjected to this restriction. These types of projects can be flown and photographed during most of the year. Hidden grounds caused by man-made objects, such as an overpass and a roof, cannot be mapped with photogrammetry. Hidden ground problems can be caused by tree canopy, dense vegetation, or by rugged terrain with sharp slopes. The information hidden from the camera must be mapped with other surveying methods. The accuracy of the mapping contours and cross sections depends on flight height and the accuracy of the field survey.

Classification of Photogrammetry: Photogrammetry is divided into different categories according to the types of photographs or sensing system used or the manner of their use as given below:

I. On the basis of orientation of camera axis:

a. Terrestrial or ground photogrammetry When the photographs are obtained from the ground station with camera axis horizontal or nearly horizontal

b. Aerial photogrammetry If the photographs are obtained from an airborne vehicle. The photographs are called vertical if the camera axis is truly vertical or if the tilt of the camera axis is less than 3^o . If tilt is more than (often given intentionally), the photographs are called oblique photographs.

II. On the basis of sensor system used: Following names are popularly used to indicate type of sensor system used:

Radargrammetry: Radar sensor

- X-ray photogrammetry: X-ray sensor
- Hologrammetry: Holographs
- Cine photogrammetry: motion pictures
- Infrared or colour photogrammetry: infrared or colour photographs
- III. On the basis of principle of recreating geometry: When single photographs are used with the stereoscopic effect, if any, it is called Monoscopic Photogrammetry. If two overlapping photographs are used to generate three dimensional view to create relief model, it is called Stereo Photogrammetry. It is the most popular and widely used form of photogrammetry.

IV. On the basis of procedure involved for reducing the data from photographs: Three types of photogrammetry are possible under this classification:

a. Instrumental or Analogue photogrammetry: It involves photogrammetric instruments to carry out tasks.

b. Semi-analytical or analytical: Analytical photogrammetry solves problems by establishing mathematical relationship between coordinates on photographic image and real world objects. Semi-analytical approach is hybrid approach using instrumental as well analytical principles.

c. Digital Photogrammetry or softcopy photogrammetry: It uses digital image processing principle and analytical photogrammetry tools to carry out photogrammetric operation on digital imagery.

V. On the basis of platforms on which the sensor is mounted: If the sensing system is space borne, it is called Space Photogrammetry, Satellite Photogrammetry or Extra-terrestrial Photogrammetry. Out of various types of the photogrammetry, the most commonly used forms are Stereo Photogrammetry utilizing a pair of vertical aerial photographs (stereo pair) or terrestrial photogrammetry using a terrestrial stereo pair.

Application of Photographic Survey: Photogrammetry has been used in several areas. The following description gives an overview of various applications areas of photogrammetry

a. Geology: Structural geology, investigation of water resources, analysis of thermal patterns on earth's surface, geomorphological studies including investigations of shore features.

- Stratigraphic studies
- General geologic applications
- Study of luminescence phenomenon
- Recording and analysis of catastrophic events
- Earthquakes, floods, and eruption.

b. Forestry: Timber inventories, cover maps, acreage studies

c. Agriculture: Soil type, soil conservation, crop planting, crop disease, crop-acreage.

d. Design and construction: Data needed for site and route studies specifically for alternate schemes for photogrammetry. Used in design and construction of dams, bridges, transmission lines.

e. Planning of cities and highways: New highway locations, detailed design of construction contracts, planning of civic improvements.

f. Cadastre: Cadastral problems such as determination of land lines for assessment of taxes. Large scale cadastral maps are prepared for reapportionment of land.

g. Environmental Studies:

H. Land-use studies.

I. Urban area mapping.

j. Exploration: To identify and zero down to areas for various exploratory jobs such as oil or mineral exploration.

k. Military intelligence: Reconnaissance for deployment of forces, planning manoeuvres, assessing effects of operation, initiating problems related to topography, terrain conditions or works.

l. Medicine and surgery: Stereoscopic measurements on human body, X-ray photogrammetry in location of foreign material in body and location and examinations of fractures and grooves, biostereometrics.

m. Mountains and hilly areas can be surveyed easily.

n. Miscellaneous Classification of Photographs: The following paragraphs give details of classification of photographs used in different applications

A. On the basis of the alignment of optical axis Vertical: If optical axis of the camera is held in a vertical or nearly vertical position.

- Tilted: An unintentional and unavoidable inclination of the optical axis from vertical
- Produces a tilted photograph. Oblique: Photograph taken with the optical axis intentionally inclined to the vertical.
- Following are different types of oblique photographs:

i. High oblique: Oblique this contains the apparent horizon of the earth.

ii. Low oblique: Apparent horizon does not appear.

iii. Trimetrogon: Combination of a vertical and two oblique photographs in which the central photo is vertical and side ones are oblique. Mainly used for reconnaissance.

iv. Convergent: A pair of low oblique taken in sequence along a flight line in such a manner that both the photographs cover essentially the same area with their axes tilted at a fixed inclination from the vertical in opposite directions in the direction of flight line so that the forward exposure of the first station forms a stereo-pair with the backward exposure of the next station.

Introductory definitions of Aerial Photogrammetry:

i. Vertical photograph: A photograph taken with the optical axis coinciding with direction of gravity.

ii. Tilted or near vertical : Photograph taken with optical axis unintentionally tilted from vertical by a small amount (usually < 3°)

iii. Focal length (f): Distance from front nodal point to the plane of the photograph (from near nodal point to image plane).

iv. Exposure station (point L) : Position of frontal nodal point at the instant of exposure (L)

v. Flying height (H): Elevation of exposure station above sea level or above selected datum.

vi. Principal point: The point where the perpendicular dropped from the front nodal point meets/strikes the plane of photograph.

vii. Principal Line: The trace (intersection) of the principal plane upon the photograph; also, the line on the photograph which passes through the principal point and the nadir point (and the "isocenter").

viii. Tilt: The angle formed between the optical axis of the camera and the plumb line.

ix. Isocentre: The point where the bisector of angle of tilt meets the plane of photograph.

x. Ground Nadir: The point on the ground that is vertically beneath (directly below) the perspective center of the camera lens.

xi. Nadir Point or Photographic Nadir: The point on the photograph which corresponds to the ground nadir. The point at which a vertical line (plumb line) from the perspective center to the ground nadir intersects the photograph.

xii. Photograph Perpendicular: The perpendicular from the interior perspective center (real nodal point) to the plane of the photograph.

xiii. Photograph Center: The point on the photograph that is located at the intersection of the fiducial axes. (The photograph center is sometimes called the "center of collimation.") In a perfectly adjusted camera, the photograph center and the principal point are identical (i.e., unless camera calibration indicates otherwise, the principal point is generally assume d to coincide with the photography center).

xiv. Scale: The ratio of a distance on a photograph or map to its corresponding distance on the ground. Although photographic scale varies from point to point (due to relief and/or tilt), it is usually taken as f/H' . . . where f = focal length and H' = height of camera above mean ground elevation. Scale may be expressed as a ratio (1:24,000), a fraction (1/24,000), or equivalence (1 in. = 2,000 ft.).

xv. Relief Displacement: If a ground object is below (above) the elevation of the ground nadir, its image will be displaced radially inward (outward) with respect to the nadir point. Relief displacements may be measured accurately from the photography center if two conditions are met:

(1) The photography is truly vertical (i.e., the nadir and principal points coincide), and (2) the camera is in perfect adjustment (i.e., the principal point and photograph center coincide).

xvi. Overlap: The amount by which one photograph covers the same area as covered by another (customarily expressed as a percentage). The overlap between aerial photographs in the same flight line is called "end lap," and the overlap between photographs in adjacent, parallel flight lines is called "side lap."

xvii. Parallax Difference: The difference in the absolute stereoscopic parallaxes of two points imaged on a pair of photographs. Customarily used to determine the elevation difference between the two objects.

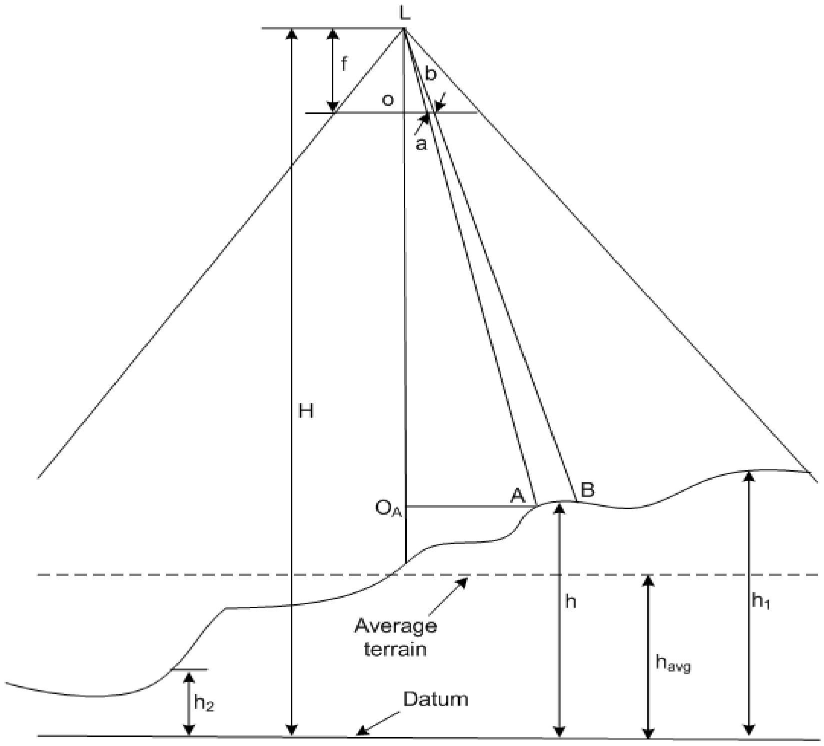
xviii. Azimuth: The horizontal angle measured clockwise about the ground nadir from a reference plane (usually the ground-survey north meridian) to the principal plane. (The azimuth of a photograph is the ground-survey direction of tilt, while swing is the direction of tilt with respect to the photograph axes).

Scale of a Vertical Photograph / Scale of Photograph:

CASE-I:

Due to perspective geometry of photographs, the scale of photograph varies as a function of **focal length, flying height, and the reduced level of terrain** over a certain reference datum. In the figure given below, for a vertical photograph**,**

L = Exposure station
f = Focal length
H = Flying height above datum
h = the height of ground point **A** above datum.
Point **A** is imaged as a in the photograph. From the construction and using similar triangles **Loa** and **LOAA**, we can write the following relations:



Determination of Scale of photograph

Scale of photograph can be determined by various methods such as:
By using known full length and altimeter reading, the datum scale can be found.
Any scale can be determined if havg known. havg can be obtained from a topographic map.
By comparing length of the line on the photo with the corresponding ground length. To arrive at fairly representative scale for entire photo, get several lines in different area and the average of various scales can be adopted.

$$\frac{\text{Photo Scale}}{\text{Map Scale}} = \frac{\text{Photo Distance}}{\text{Map Distance}}$$

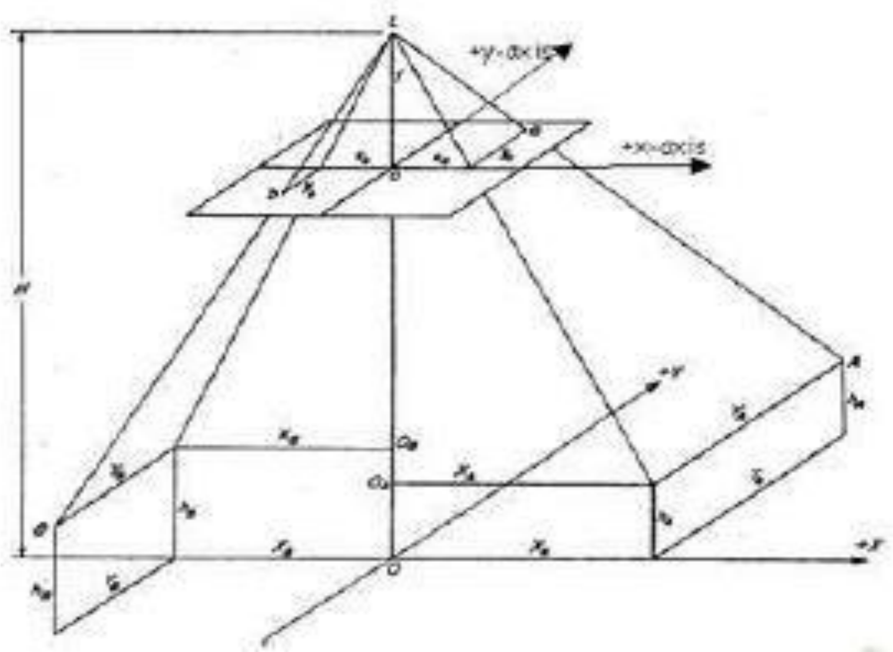
$$\text{Scale} = \frac{ao}{AO_A} = \frac{f}{H-h_A}$$

$$\text{Datum Scale} = S_d = \frac{f}{H}$$

$$\text{Average Scale} = S_{avg} = \frac{f}{H-h_{avg}}$$

CASE-II:

In the figure given below, *X* and *Y* are ground co-ordinates with respect to a set of axes whose directions are parallel with the photographic axes and whose origin is directly below the exposure station, x and y indicate x and y photo coordinates with respect to the photo coordinate system with origin at o axes as shown. Using similar triangles, we can write the following relations:



$$\frac{Lo}{LO_A} = \frac{x_a}{X_A} = \frac{y_a}{Y_A} = \frac{f}{H - h_A}$$

$$\frac{Lo}{LO_B} = \frac{x_b}{X_B} = \frac{y_b}{Y_A} = \frac{f}{H - h_B}$$

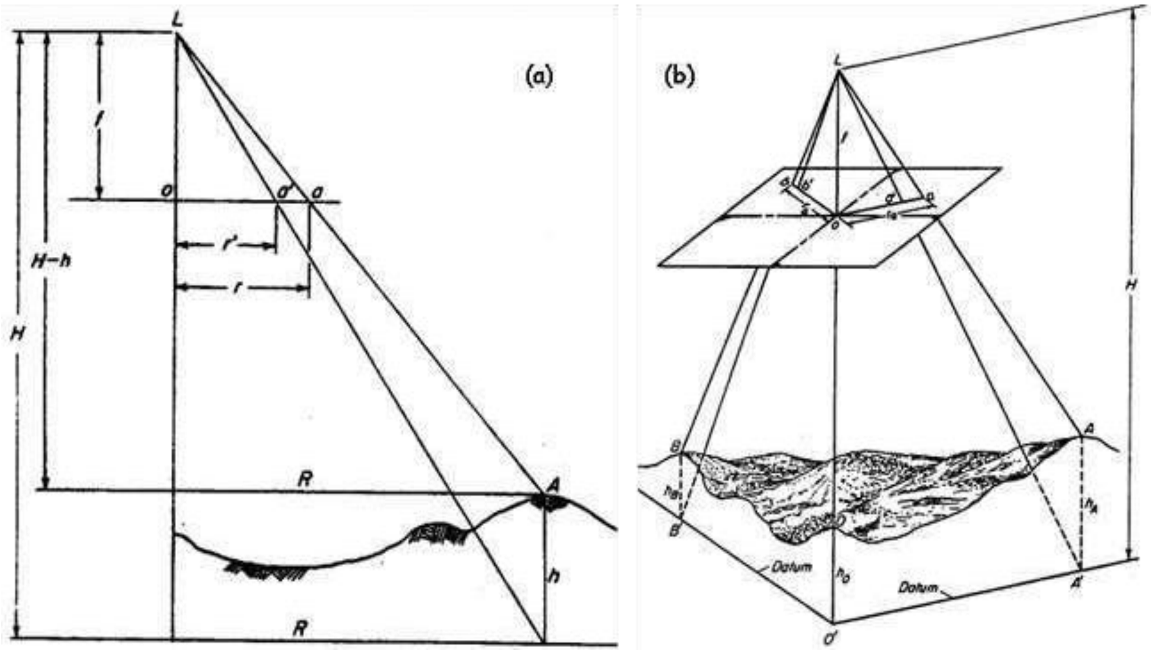
$$X = \frac{H - h}{f}.x$$

$$Y = \frac{H - h}{f}.y$$

Relief displacement on Vertical photographs:

Relief displacement is the radial distance between where an object appears in an image to where it actually should be according to a Planimetric coordinate system. The images of ground positions are shifted or displaced due to terrain relief, in the central projection of an aerial photograph. If a photograph is truly vertical, the displacement of images is in a direction radial from the photograph centre. This displacement is called the radial displacement due to relief. Radial displacement due to relief is also responsible for scale differences within any one photograph, and for this reason a photograph is not an accurate map. Relief displacement is caused by differences in relative elevation of objects photographed. All objects that extend above or below a datum plane have their photographic images displaced to a greater or lesser extent. This displacement occurs always along the line which connects the photo point and thenadir and is, therefore termed “radial line displacement”. Or this displacement is always radial with respect to principal point. It increases with increasing height of the feature and the distance from nadir.

In figure, **L** is the perspective center of the camera system. **A** is the point on ground at an elevation of **h** with respect to the datum. **a** is the image of ground point on photograph. **a'** is the location of projected point **A'** on the datum. These figures indicate that although point A is vertically above point B, their images are not coinciding and are displaced on photographic plane due to relief.



•The displacement of the point a on the photograph from its true position, due to height, is called the height or relief displacement or relief distortion (RD). This distortion is due to the perspective geometry.

•It can also be noticed form these figures that the relief displacement is radial from nadir point. In case of vertical photographs, the nadir point and the principal point coincide. Hence, in this case relief displacement can be considered to be radial from the principal point also. The following derivation using figure 4(a) provides the magnitude of relief distortion

$$\frac{f}{H-h} = \frac{r}{R}$$

$$\frac{f}{H} = \frac{r'}{R}$$

$$r = \frac{Rf}{Hh} \ and \ r' = \frac{Rf}{H}$$

$$R = \frac{r(H-h)}{f} \quad and \quad R = \frac{r'H}{f}$$

$$\text{Relif Distortion} = d = r - r' = \frac{Rf}{H-h} - \frac{Rf}{H} = \frac{Rfh}{H(H-h)}$$

$$d = r - r' = \frac{rh}{H} = \frac{r'h}{H-h}$$

Number of Photographs:

CASE-I: The number of photographs required is calculated by dividing the total area tobe photographed by net area covered by a single photograph.

So,

$$\text{Number of Photographs (N)} = \frac{A}{a}$$

Let,

A = Total area to be photographed

l = Length of the photograph in the direction of flight

w = Width of the photograph normal to the direction

of flightL = Actual ground length covered by each

photograph

W = Actual ground width covered by each

photographa = Net ground area covered by

each photograph

CASE-II: If the rectangular dimensions (length and width) of ground are given, the numbers of photographs required are computed by calculating the number of strips and the number of photographs required in each strip and multiplying two.

Remote sensing:

History:

 Indian remote sensing program was initiated in 1970, following the successful demonstration flights of Bhaskara-1 and Bhaskara-2 satellites launched in 1979 and 1981, India began to develop the indigenous Indian Remote Sensing (IRS) satellite program to support the national economy in the areas of agriculture, water resources, forestry and ecology, geology, water sheds, marine fisheries and coastal management and launched first IRS sat in 1989.

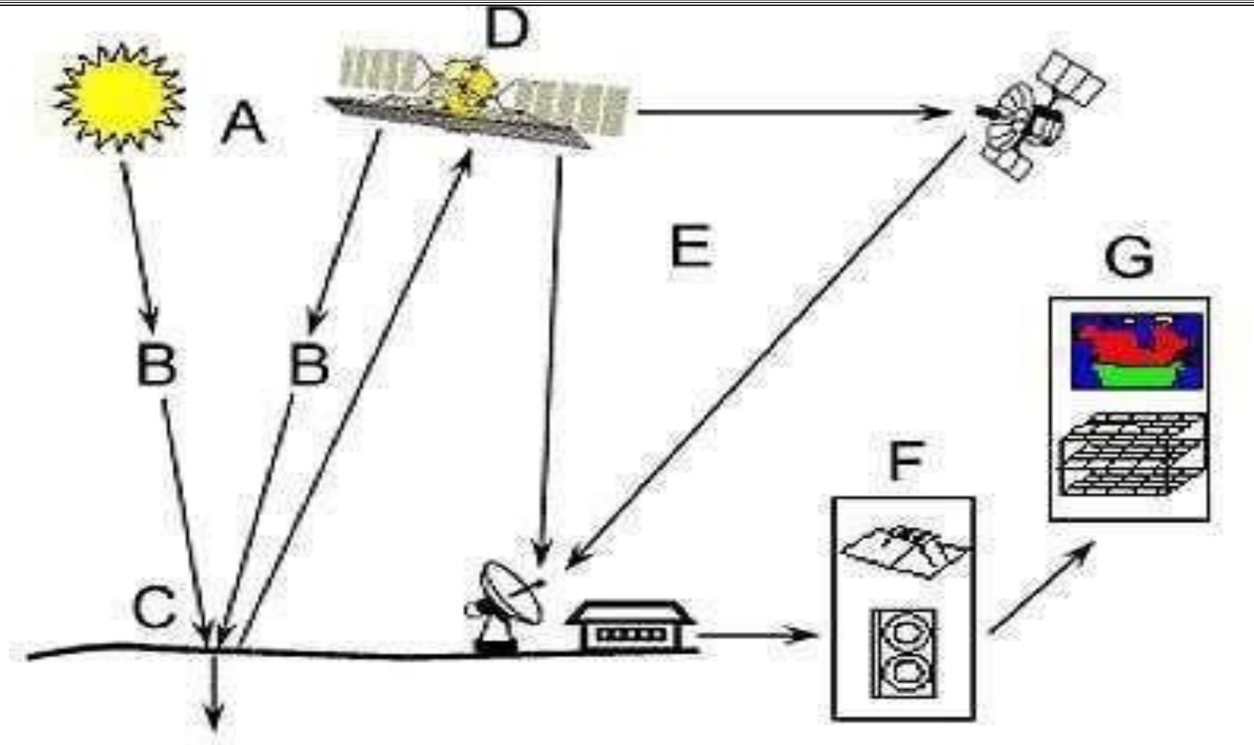
 India established the National Natural Resources Management System (NNRMS) for which the Department of Space (DOS) is the nodal agency, providing operational remote sensing data services.

 With the advent of high-resolution satellites new applications in the areas of urban sprawl, infrastructure planning and other large scale applications for mapping have been initiated.

 The IRS system is the largest constellation of remote sensing satellites for civilian use in operation today in the world, with 10 operational satellites. All these are placed in polar sun synchronous orbit and provide data in a variety of spatial, spectral and temporal resolutions.

Remote sensing is science of
❑ acquiring,
❑ processing, and
❑ interpreting

Images and related data that are obtained from ground-based, air-or space-borne instruments that record the interaction between matter (target) and electromagnetic radiation.



Advantages

 It is relatively Inexpensive. The cost of software and data (which often represents a one-off cost) is less expensive than sending teams of surveyors out into the field.

 Current (within reason). One particular problem that the developing world faces is that data is old or out of date. Satellite imagery can be acquired for free from the last decade and contemporary data can be acquired fairly inexpensively.

 Provides data about large areas.

 Provides data about inaccessible areas - or even if they're not inaccessible, then at least you don't have to go there.

 Rapid production of maps possible.

 Easy to manipulate (relatively!) with computers and derive information for map production.

 Rapid collection of data – much more efficient that ground survey.

Disadvantages

 There will be doubtful and uncertainties of classification related to pixel size. A full field check will be necessary to resolve ground use in these areas.

 Datasets from multiple sources are sometimes difficult to geo reference. Using images and maps that are drawn in different scales and projections can lead to difficulty combining them.

 The sensor performs a sweep and as such can create errors. i.e., only some of the image is directly below the sensor and so pixels toward the edge of the image may be distorted.

 Objects in the image can be confused or mis-classified. For example, shadows may look like metalled roads.

 To get any level of detailed, current data and to buy specialist RS software can be expensive.

 In some active sensing systems (such as lidar) the sensor and source are moving relative to each other distortions can creep to the image. This is a form of Doppler effect (the visual equivalent of a police siren changing pitch as it moves closer or further away
from you).

 the interpretation of imagery requires a certain skill level

 needs cross verification with ground (field) survey data

 Data from multiple sources may create confusion

 Objects can be misclassified or confused

 Distortions may occur in an image due to the relative motion of sensor and source.

Types of remote sensing:

I. Based on Source of Light:

a. Passive remote sensing:

 It generally consists of an array of small sensors or detectors, which records the amount of electro-magnetic radiation reflected and/or emitted from the Earth's surface. Thus, passive remote sensing relies on naturally reflected or emitted energy of the imaged surface. Most remote sensing instruments fail into this category, obtaining pictures of visible, near-infrared and thermal infrared energy.

❑ It can acquire the data only in presence of solar light.

❑ High initial and maintenance cost.

b. Active remote sensing:

 This type of a system propagates its own electro-magnetic radiation and measures the intensity of the return signal. Thus, active remote sensing means that the sensor provides its own illumination and measures what comes back. Remote sensing technologies that use this type of system include lidar (laser) and radar.

❑ It can acquire the data in all-weather condition.

❑ High initial and maintenance cost.

II. Based on Platform:

❑ **Ground-based platforms:** ground, vehicles and/or towers => up to 50 m

❑ **Airborne platforms:** airplanes, helicopters, high-altitude aircrafts, balloons => up to 50 km

❑ **Spaceborne**: rockets, satellites, shuttle => from about 100 km to 36000 km

Ideal Remote Sensing System:

The basic components of an ideal remote sensing system include:

i. A Uniform Energy Source which provides energy over all wavelengths, at a constant, known, high level of output

ii. A Non-interfering Atmosphere which will not modify either the energy transmitted from the source or emitted (or reflected) from the object in any manner.

iii. A Series of Unique Energy/Matter Interactions at the Earth's Surface which generate reflected and/or emitted signals that are selective with respect to wavelength and also unique to each object or earth surface feature type.

iv. A Super Sensor which is highly sensitive to all wavelengths. A super sensor would be simple, reliable, accurate, economical, and requires no power or space. This sensor yields data on the absolute brightness (or radiance) from a scene as a function of wavelength.

v. A Real-Time Data Handling System which generates the instance radiance versus wavelength response and processes into an interpretable format in real time. The data derived is unique to a particular terrain and hence provide insight into its physicalchemical- biological state.

vi. Multiple Data Users having knowledge in their respective disciplines and also in remote sensing data acquisition and analysis techniques. The information collected will be available to them faster and at less expense. This information will aid the users in various decision making processes and also further in implementing these decisions.

[**Components of an ideal remote sensing system**]

Characteristics of Real Remote Sensing Systems:

Real remote sensing systems employed in general operation and utility have many shortcomings when compared with an ideal system explained above.

i. **Energy Source:** The energy sources for real systems are usually non-uniform over various wavelengths and also vary with time and space. This has major effect on the passive remote sensing systems. The spectral distribution of reflected sunlight varies both temporally and spatially. Earth surface materials also emit energy to varying degrees of efficiency. A real remote sensing system needs calibration for source characteristics.

ii. **The Atmosphere:** The atmosphere modifies the spectral distribution and strength of the energy received or emitted (Fig. 8). The effect of atmospheric interaction varies with the wavelength associated, sensor used and the sensing application. Calibration is required to eliminate or compensate these atmospheric effects.

iii. **The Energy/Matter Interactions at the Earth's Surface:** Remote sensing is based on the principle that each and every material reflects or emits energy in a unique, known way. However, spectral signatures may be similar for different material types. This makes differentiation difficult. Also, the knowledge of most of the energy/matter interactions for earth surface features is either at elementary level or even completely unknown.

iv. **The Sensor:** Real sensors have fixed limits of spectral sensitivity i.e., they are not sensitive to all wavelengths. Also, they have limited spatial resolution (efficiency in recording spatial details). Selection of a sensor requires a trade-off between spatial resolution and spectral sensitivity. For example, while photographic systems have very good spatial resolution and poor spectral sensitivity, non-photographic systems have poor spatial resolution.

v. **The Data Handling System:** Human intervention is necessary for processing sensor data; even though machines are also included in data handling. This makes the idea of real time data handling almost impossible. The amount of data generated by the sensors far exceeds the data handling capacity.

vi. **The Multiple Data Users:** The success of any remote sensing mission lies on the user who ultimately transforms the data into information. This is possible only if the user understands the problem thoroughly and has a wide knowledge in the data generation. The user should know how to interpret the data generated and should know how best to use them.

Application remote sensing:

The applications of remote sensing summarized below:

 Agricultural: Agriculture plays an important role in economies of countries. The production of food is important to everyone and producing food in a cost-effective manner is the goal of every farmer and an agricultural agency. The satellites has an ability to image individual fields, regions and counties on a frequent revisit cycle.

Customers can receive field-based information including **crop identification, crop area determination and crop condition monitoring (**health and viability). Satellite data are employed in precision agriculture to manage and monitor farming practices at different levels. The data can be used to farm optimization and spatially-enable management of technical operations. The images can help determine the location and extent of crop stress and then can be used to develop and implement a spot treatment plan that optimizes the use of agricultural chemicals. The major agricultural applications of remote sensing include the following: Vegetation, crop type classification, crop condition assessment (crop monitoring, damage assessment), crop yield estimation, soil, mapping of soil characteristics, mapping of soil type, soil erosion, soil moisture, mapping of soil management practices, compliance monitoring (farming practices)

 Forest mapping: One of the basic applications is forest cover typing and species identification. Forest cover typing can consist of reconnaissance mapping over a large area, while species inventories are highly detailed measurements of stand contents and characteristics (tree type, height, density). Using remote sensing data we can identify and delineate various forest types that would be difficult and time consuming using traditional ground surveys. Data is available at various scales and resolutions to satisfy local or regional demands. Requirements for reconnaissance mapping depend on the scale of study.

 Land cover mapping: is one of the most important and typical applications of remote sensing data. Land cover corresponds to the physical condition of the ground surface, for example, forest, grassland, concrete pavement etc., while land use reflects human activities such as the use of the land, for example, industrial zones, residential zones, agricultural fields etc Initially the land cover classification system should be established, which is usually defined as levels and classes. The level and class should be designed in consideration of the purpose of use (national, regional or local), the spatial and spectral resolution of the remote sensing data, user's request and so on.

 Assessment and monitoring of vegetation types and their status.

 Monitoring and planning of water resources and groundwater exploration.

 Geographic information

 Urban planning.

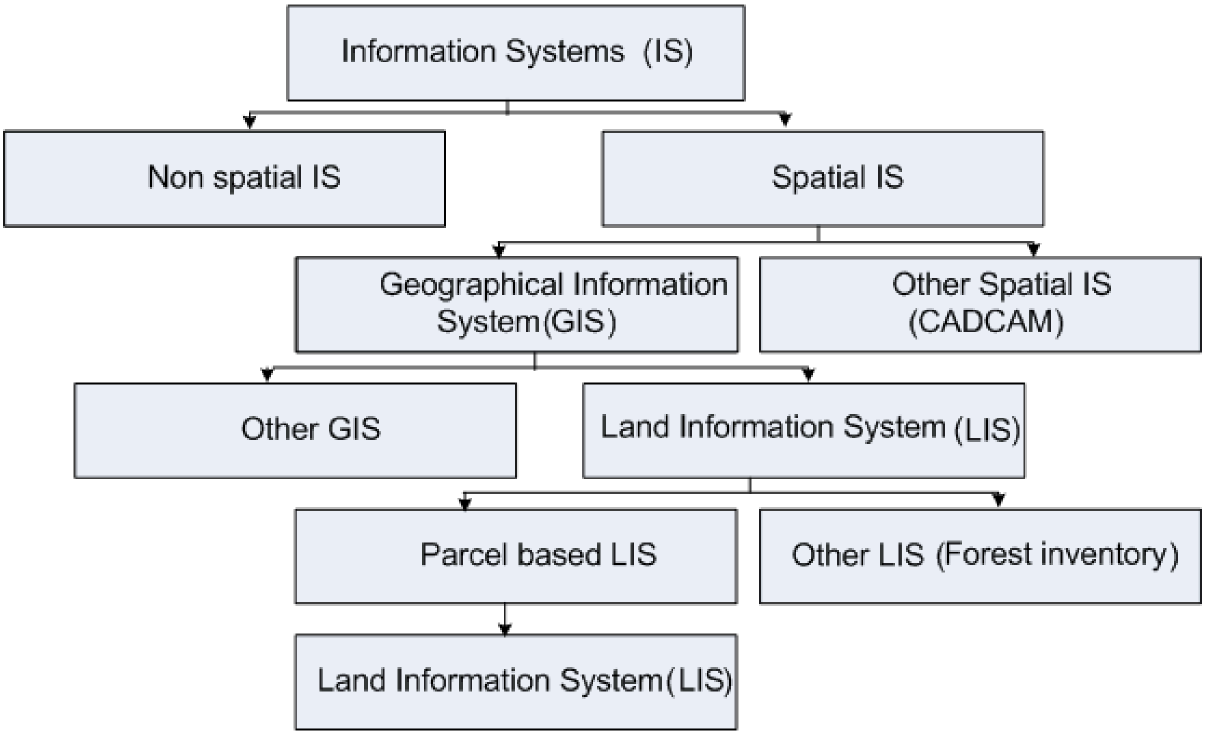
 Weather and agricultural forecasts and assessment of environment and natural disasters
.

 Laser film writing and printing.

 Satellite imagery can provide the visible boundaries of soil types, while remote sensing provide for a shallow penetration of soils. Additional physical data can be obtained from spectral signatures for the soil surfaces.

 Remote sensing allows for classification of soils, which can be interpreted from the remote sensing images and the spectral signatures.

Geographical Information System (GIS)
Introduction:
A large variety of information systems are available for various applications. Figure given below describes different types of such systems. This module will focus on Geographical Information System (GIS), one of the important spatial information systems with a capability to handle spatial information (information distributed in space).



Definitions

❑❑A powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world.

❑❑A system for capturing, storing, checking, manipulating, analysing, and displaying data which are spatially referenced to earth.

❑❑An information technology which stores, analyses, and displays both spatial and nonspatial data.

❑❑An automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, manipulation and display of geographically located data.

❑❑An institutional entity, reflecting an organisational structure that integrates technology with a database, expertise, and continuing financial support over time. A decision support system involving the integration of spatially referenced data in a problem solving environment

❑❑An information system that is designed to work with data referenced by spatial or geographic co-ordinates. In other words, a GIS is both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data. In a sense, a GIS may be thought of as a higher-order map.

❑❑A system of hardware and software that links mapped objects with text information that describes them and provides tools for the storage, retrieval and manipulation of both types of data.

❑❑A system of computer hardware, software and procedures designed to support the capture, management, manipulation, analysis, and display of spatially referenced data for solving complex planning and management problems.

❑❑A system that contains spatially referenced data that can be analysed and converted to information for a specific set of purposes, or application. The key feature of a GIS is the analysis of data to produce new information.

Why GIS is required:

Use of GIS is advocated on account of following observations:

- Poorly maintained geospatial data
- Out of date maps and statistics
- Inaccurate data and information
- Absence of data retrieval service
- Absence of data sharing
- Digital format data is compact and large quantities can be maintained and retrieved at a greater speed and lesser cost
- Planning scenarios, decision models and interactive process are normal functions of GIS
- Ability to perform complex spatial analysis rapidly
- Ability to manipulate different types of data efficiently

Benefits of GIS

- Geospatial data better maintained in a standard format
- Revision and updating easier
- Geospatial data and information easier to search, analyze and represent
- Value added products can be generated
- Geospatial data can be shared and exchanged freely
- Productivity and efficiency of staff is improved
- Saving in time and money
- Better decisions making

Data Mode of GIS:

There are two fundamental ways of representing topological data which can be summarised as follows

❑❑Raster Form

❑❑Vector Form

Raster Form	Vector Form
• A representation of the world as a surface divided into a regular grid of cells. Raster models are useful for storing data that varies continuously, as in an aerial photograph, a satellite image, a surface of chemical concentrations, or an elevation surface. • Simple data structure • Divides the entire area into rectangular grid cells. • Overlaid is very simple. • The basic symbol is grid cell. • It gives high accuracy.	• A representation of the world using points, lines, and polygons. Vector models are useful for storing data that has discrete boundaries, such as country borders, land parcels, and streets. • More compact data structure • Divides the entire area into set of linesegments. • Overlaid is very difficult. • The basic symbols are points, lines &polygons. • It gives less accuracy.

Application of GIS:

1. GIS in Mapping: Mapping is a central function of Geographic Information System, which provides a visual interpretation of data. GIS store data in database and then represent it visually in a mapped format. People from different professions use map to communicate. It is not necessary to be a skilled cartographer to create maps. Google map, Bing map, Yahoo map are the best example for web based GIS mapping solution.

2. Telecom and Network services: GIS can be a great planning and decision making tool for telecom industries. **GDi GISDATA** enables wireless telecommunication organizations to incorporate geographic data in to the complex network design, planning, optimization, maintenance and activities. This technology allows telecom to enhance a variety of application like engineering application, customer relationship management and location based services.

3. Accident Analysis and Hot Spot Analysis: GIS can be used as a key tool to minimize accident hazard on roads, the existing road network has to be optimized and also the road safety measures have to be improved. This can be achieved by proper traffic management. By identifying the accident locations, remedial measures can be planned by the district administrations to minimize the accidents in different parts of the world. Rerouting design is also very convenient using GIS.

4. Urban Planning: GIS technology is used to analyze the urban growth and its direction of expansion, and to find suitable sites for further urban development. In order to identify the sites suitable for the urban growth, certain factors have to consider which is: land should have proper accessibility, land should be more or less flat, land should be vacant or having low usage value presently and it should have good supply of water.

5. Transportation Planning: GIS can be used in managing transportation and logistical problems. If transport department is planning for a new railway or a road route then this can be performed by adding environmental and **topographical data** into the GIS platform. This will easily output the best route for the transportation based on the criteria like flattest route, least damage to habitats and least disturbance from local people. GIS can also help in monitoring rail systems and road conditions.

6. Environmental Impact Analysis: EIA is an important policy initiative to conserve natural resources and environment. Many human activities produce potential adverse environmental effects which include the construction and operation of highways, rail roads, pipelines, airports, radioactive waste disposal and more. Environmental impact statements are usually required to contain specific information on the magnitude and characteristics of environmental impact. The EIA can be carried out efficiently by the help of GIS, by integrating various GIS layers, assessment of natural features can be performed.

7. Agricultural Applications: GIS can be used to create more effective and efficient farming techniques. It can also analyze soil data and to determine: what are the best crop to plant?, where they should go? how to maintain nutrition levels to best benefit crop to plant?. It is fully integrated and widely accepted for helping government agencies to manage programs that support farmers and protect the environment. This could increase food production in different parts of the world so the world food crisis could be avoided.

8. Disaster Management and Mitigation: Today a well-developed GIS systems are used to protect the environment. It has become an integrated, well developed and successful tool in disaster management and mitigation. GIS can help with risk management and analysis by displaying which areas are likely to be prone to natural or man-made disasters. When such disasters are identified, preventive measures can be developed.

9. Landslide Hazard Zonation using GIS: Landslide hazard zonation is the process of ranking different parts of an area according to the degrees of actual or potential hazard from landslides. The evaluation of landslide hazard is a complex task. It has become possible to efficiently collect, manipulate and integrate a variety of spatial data such as geological, structural, surface cover and slope characteristics of an area, which can be used for hazard zonation. The entire above said layer can well integrate using GIS and weighted analysis is also helpful to find Landslide prone area. By the help of GIS we can do risk assessment and can reduce the losses of life and property.

10. Determine land use/land cover changes: Land cover means the feature that is covering the barren surface .Land use means the area in the surface utilized for particular use. The role of GIS technology in land use and land cover applications is that we can determine land use/land cover changes in the different areas. Also it can detect and estimate the changes in the land use/ land cover pattern within time. It enables to find out sudden changes in land use and land cover either by natural forces or by other activities like deforestation.

11. Navigation (routing and scheduling): Web-based navigation maps encourage safe navigation in waterway. Ferry paths and shipping routes are identified for the better routing. ArcGIS supports safe navigation system and provides accurate topographic and hydrographic data. Recently DNR, s Coastal Resources Division began the task of locating, documenting, and cataloging these no historic wrecks with GIS. This division is providing public information that make citizens awareness of these vessel locations through web map. The web map will be regularly updated to keep the boating public informed of these coastal hazards to minimize risk of collision and injury.

12. Flood damage estimation: GIS helps to document the need for federal disaster relief funds, when appropriate and can be utilized by insurance agencies to assist in assessing monetary value of property loss. A local government need to map flooding risk areas for evaluate the flood potential level in the surrounding area. The damage can be well estimate and can be shown using digital maps.

13. Natural Resources Management: By the help of GIS technology the agricultural, water and forest resources can be well maintain and manage. Foresters can easily monitor forest condition. Agricultural land includes managing crop yield, monitoring crop rotation, and more. Water is one of the most essential constituents of the environment. GIS is used to analyze geographic distribution of water resources. They are interrelated, i.e. forest cover reduces the storm water runoff and tree canopy stores approximately 215,000 tons carbon. GIS is also used in afforestation.

14. GIS Solutions in Banking Sector: Today rapid development occurs in the banking sector. So it has become more market driven and market responsive. The success of this sector largely depends on the ability of a bank to provide customer and market driven services. GIS plays an important role providing planning, organizing and decision making.

15. Soil Mapping: Soil mapping provides resource information about an area. It helps in understanding soil suitability for various land use activities. It is essential for preventing environmental deterioration associated with misuse of land. GIS Helps to identify soil types in an area and to delineate soil boundaries. It is used for the identification and classification of soil. Soil map is widely used by the farmers in developed countries to retain soil nutrients and earn maximum yield.

16. GIS based Digital Taxation: In Local Governments, GIS is used to solve taxation problems. It is used to maximize the government income. For example, for engineering, building permits, city development and other municipal needs, GIS is used. Often the data collected and used by one agency or department can be used by another. Example Orhitec ltd can supply you with a system to manage property tax on a geographic basis that can work interactively with the municipal tax collection department. Using GIS we can develop a digital taxation system.

17. Land Information System: GIS based land acquisition management system will provide complete information about the land. Land acquisition managements is being used for the past 3 or 4 years only. It would help in assessment, payments for private land with owner details, tracking of land allotments and possessions identification and timely resolution of land acquisition related issues.

18. Surveying: Surveying is the measurement of location of objects on the earth’s surfaces. Land survey is measuring the distance and angles between different points on the earth surface. An increasing number of national and governments and regional organizations are using GNSS measurements. GNSS is used for topographic surveys where a centimeter level accuracy is provided. These data can be incorporated in the GIS system. GIS tools can be used to estimate area and also, digital maps can prepared.

19. Wetland Mapping: Wetlands contribute to a healthy environment and retain water during dry periods, thus keeping the water table high and relatively stable. During the flooding they act to reduce flood levels and to trap suspended solids and attached nutrients. GIS provide options for wetland mapping and design projects for wetland conservation quickly with the help of GIS. Integration with Remote Sensing data helps to complete wetland mapping on various scale. We can create a wetland digital data bank with spices information using GIS.

20. GIS Applications in Geology: Geologists use GIS in a various applications. The GIS is used to study geologic features, analyze soils and strata, assess seismic information, and or create three dimensional (3D) displays of geographic features. GIS can be also used to analyze rock information characteristics and identifying the best dam site location.

21. Detection of Coal Mine Fires: GIS technology is applied in the area of safe production of coal mine. Coal mine have developed an information management system, the administrators can monitor the safe production of coal mine and at the same time improve the abilities to make decisions. Fire happens frequently in coal mines. So it can assessed spontaneous combustion risk using GIS tools.(Kun Fang, GIS Network Analysis in Rescue of Coal Mine)

22. Assets Management and Maintenance: GIS helps organizations to gain efficiency even in the face of finite resources and the need to hold down the cost. Knowing the population at risk enables planners to determine where to allocate and locate resources more effectively. Operations and maintenance staff can deploy enterprise and mobile workforce. GIS build mobile applications that provide timely information in the field faster and more accurate work order processing.

23. GIS for Planning and Community Development: GIS helps us to better understand our world so we can meet global challenges. Today GIS technology is advancing rapidly, providing many new capabilities and innovations in planning. By applying known part of science and GIS to solve unknown part, that helps to enhance the quality of life and achieve a better future. Creating and applying GIS tools and knowledge allow us integrating geographic intelligence into how we think and behave.

24. GIS in Dairy Industry: Geographic Information System is used in a various application in the dairy industry, such as distribution of products, production rate, location of shops and their selling rate. These can be monitored by using GIS system. It can be also possible to understand the demand of milk and milk products in different region. GIS can prove to be effective tool for planning and decision making for any dairy industry. These advantages has added new vistas in the field of dairy farm and management.

25. Tourism Information System: GIS provides a valuable toolbox of techniques and technologies of wide applicability to the achievement of sustainable tourism development. This provide an ideal platform tools required to generate a better understanding, and can serve the needs of tourists. They will get all the information on click, measure distance, find hotels, restaurant and even navigate to their respective links. Information plays a vital role to tourists in planning their travel from one place to another, and success of tourism industry. This can bring many advantages for both tourist and tourism department.

26. Irrigation water management: Water availability for irrigation purposes for any area is vital for crop production in that region. It needs to be properly and efficiently managed for the proper utilization of water. To evaluate the irrigation performance, integrated use of satellite remote sensing and GIS assisted by ground information has been found to be efficient technique in spatial and time domain for identification of major crops and their conditions, and determination of their areal extent and yield. Irrigation requirements of crop were determined by considering the factors such as evapotranspiration, Net Irrigation Requirement, Field irrigation Requirement, Gross Irrigation Requirement, and month total volume of water required, by organizing them in GIS environment.

27. Fire equipment response distance analysis: GIS can be used to evaluate how far (as measured as via the street network) each portion of the street network is from a firehouse. This can be useful in evaluating the best location for a new firehouse or in determining how well the fire services cover particular areas for insurance ratings.(Himachal Pradesh, Development Report)

28. Worldwide Earthquake Information System: One of the most frightening and destructive phenomena of nature is the occurrence of an earthquake. There is a need to have knowledge regarding the trends in earthquake occurrence worldwide. A GIS based user interface system for querying on earthquake catalogue will be of great help to the earthquake engineers and seismologists in understanding the behavior pattern of earthquake in spatial and temporal domain. (A. M. Chandra, S. K. Ghosh Remote Sensing and Geographical Information System)

29. Volcanic Hazard Identification: Volcanic hazard to human life and environment include hot avalanches, hot particles gas clouds, lava flows and flooding. Potential volcanic hazard zone can be recognized by the characteristic historical records of volcanic activities, it can incorporate with GIS. Thus an impact assessment study on volcanic hazards deals with economic loss and loss of lives and property in densely populated areas. The GIS based platforms enables us to find out the damage and rapid response against volcanic activities may helps to reduce the effect in terms of wealth and health of people.

30. Energy Use Tracking and Planning: GIS is a valuable tool that helps in the planning organizing and subsequent growth in the energy and utilities industries. The effective management of energy systems is a complex challenge. GIS has enormous potential for planning, design and maintenance of facility. Also it provide improved services and that too cost effectively.

31. GIS for Fisheries and Ocean Industries: GIS tools add value and the capability to ocean data. ArcGis is used to determine the spatial data for a fisheries assessment and management system. It is extensively used in the ocean industry area and we get accurate information regarding various commercial activities. To enhance minimizing cost for the fishing industry. Also it can determine the location of illegal fishing operations.

32. Monitor Rangeland Resources: GIS is a valuable tool used to monitor the changes of rangeland resource and for evaluating its impact on environment, livestock and wild life. Accurate observation and measurements are to be made to find out the changes in the rangeland conditions. GIS is also used to monitoring ecological and seasonal rangeland conditions.

33. Reservoir Site Selection: GIS is used to find a suitable site for the dam. GIS tries to find best location that respect to natural hazards like earthquake and volcanic eruption. For the finding of dam site selection the factors include economic factors, social considerations, engineering factors and environmental problems. This all information are layered in the GIS.

34. Forest Fire Hazard Zone Mapping: Forest is one of the important element of the nature. It plays an important role in the local climate. Forest fires caused extensive damage to our communities and environmental resource base. GIS can effectively use for the forest fire hazard zone mapping and also for the loss estimation. GIS also help to capture real time monitoring of fire prone areas. This is achieved by the help of GNSS and satellite Remote Sensing.

35. Pest Control and Management: Pest control helps in the agricultural production. Increasing in the rate of pest and weeds can lead to decrease in the crop production. Therefore GIS plays an important role to map out infested areas. This leads in the development of weed and pest management plan.

36. Traffic Density Studies: GIS can effectively use for the management of traffic problems.

Today's population along with the road traffic is increasing exponentially. The advantage of GIS make it an attractive option to be used to face the emerging traffic problems. By creating an extensive database that has all the traffic information such as speed data, road geometry, traffic flow and other spatial data and processing this information will provide us the graphical bigger picture for the traffic management.

37. Deforestation: Nowadays forest area is decreasing every year, due to different activities. GIS is used to indicate the degree of deforestation and vital causes for the deforestation process.
GIS is used to monitor deforestation.

38. Space Utilization: GIS helps managers to organize and spatially visualize space and how it can best be used. Operational costs can be decreased by more efficiently using space including managing the moves of personal and assets as well as the storage materials. The 3D visualization in GIS platforms helps planers to create a feeling of experience like virtual walk inside the building and rooms before construction.

39. Desertification: Desertification is the land degradation due to climatic variations or human activities. GIS can provide the information of degraded land which can be managed by governmental agencies or by the communities themselves. GIS plays a vital role to reduce the desertification, the local governments are now widely depends on GIS for reducing desertification. With location based GIS analysis we can find where or which area is suitable for planting new vegetation and which area for the pipeline construction.

40. Disaster and Business Continuity Planning: Viewing building and locations assets along with emergency information such as weather patterns, and disaster zones, can provide organizations the required information to make better decision. GIS provide holistic understanding of facility status and performance, and brings together department, business systems, and data source for a comprehensive view into and throughout the organization.
(Faisal I. Al-Shukri, GIS Utilization in Facility Management)

41. GIS for Business: GIS is also used for managing business information based on its location. GIS can keep a track of where the customers are located, site business, target marketing campaigns, and optimize sales territories and model retail spending patterns. Such an added advantage is provided by the GIS to enhance in making companies more competitive and successful. (Sita Mishra, GIS in Indian Retail Industry-A Strategic Tool)

42. Utilities: The GIS is used for different type of utilities like electricity, telecom and cooking gas on a daily basis and utilities to help them in mapping, in inventory systems, track maintenance, monitor regulatory compliance or model distribution analysis, transformer analysis and load analysis.(Gulzara Mamazhakypova)

43. Lease Property and Management: Revenue can be increased, operations and maintenance cost can be reduced when GIS is used to help manage space. Real estate and property managers can see and make queries about space including its availability, size and special constraints for the most cost effective use.

44. Development of Public Infrastructure Facilities: GIS has many uses and advantages in the field of facility management. GIS can be used by facility managers for space management, visualization and planning, emergency and disaster planning and response. It can be used throughout the life cycle of a facility from deciding where to build to space planning. Also it provides facilitate better planning and analysis.(Gulzara Mamazhakypova)

45. GIS for Drainage Problems in Tea Plantation Areas: Drainage problem in tea plantation differ widely because of its varied nature of physical conditions. Tea crop requires moisture at adequate levels all times of its growth. Any variation either excess or lack has a direct impact on the tea yield. This become greatly influenced the productivity of tea. Required some hydraulic design to solve this problem such as design of drains, checking the adequacy of the river and classification of water logged areas etc. GIS helps to reduce the water logging by establishing well developed plans.

46. Collection of Information about Geographic Features: GIS is not simply a computer system used for making maps. A map is simply the most common way of reporting information from a GIS database. So these systems are not only for creating maps but also most importantly the collection of information about the geographic features such as building, roads, pipes, streams, ponds and many more that are located in your community.

47. GIS for Public Health: GIS provides the cost effective tool for evaluating interventions and policies potentially affecting health outcomes. GIS analysis, environmental health data is also helpful in explaining disease patterns of relationships with social, institutional, technological and natural environment. It can be understand the complex spatial temporal relationship between environmental pollution and disease, and identifying exposures to environmental hazards. GIS can significantly add value to environmental and public health data.(The application of GIS in environmental health sciences: opportunities and limitations.)

48. Location Identification: This technique is used to find a location for a new retail outlet. It helps to find out what exists at a particular location. A location can be described in many ways, using, for instance, name of place, post code, or geographic reference such as longitude or latitude or X/Y.

49. Knowledge Based System for Defense Purpose: Regular analysis of terrain is essential for today's fast paced battlefield. Conventional method of studying paper topographical maps is being replaced by use of maps in digital form to get terrain information. It is increasingly being used to derive terrain information from digital images. Which help to the selection of suitable sites for various military uses more accurate and faster. The uses of GIS provide information regarding the terrain features which can be useful for planning today's war strategies.

50. Pipeline Route Selection: Pipeline route planning and selection is usually a complex task. GIS technology is faster, better and more efficient in this complex task. Accurate pipeline route selection brings about risk and cost reduction as well as better decision making process. GIS least cost path analysis have been effectively used to determine suitable oil and gas pipeline routes. An optimal route will minimize reduce economic loss and negative socio-environmental impacts.

51. Producing Mailing Labels for abutter Notification: Zoning board of appeals hearings or proposed action by a town or city require notifying abutting property owners. A GIS application for producing abutter mailing labels enables you to identify abutting property owners are in different ways. Once the properties are identified this kind of GIS applications can produce mailing labels and be integrated with a word processing "mail merge ."

52. Site Suitability for Waste Treatment Plant: There is an increasing amount of waste due to the over population growth. This has negative impact on the environment. With the help of GIS we can integrate various aspect layers in GIS and can identify which place is suitable for waste treatment plant. This process will reduce the time and it is cost effective. Also it enhances the accuracy. It provides a GIS analyst to identify a list of suitable dumping sites for further investigations. It also provides a digital bank for future monitoring program of the site.

53. Geologic Mapping: GIS is an effective tool in geological mapping. It becomes easy for surveyors to create 3D maps of any area with precise and desired scaling. The results provide accurate measurements, which helps in several field where geological map is required. This is cost effective and offers more accurate data, there by easing the scaling process when studying geologic mapping.

54. Environment: The GIS is used every day to help protect the environment. The environmental professional uses GIS to produce maps, inventory species, measure environmental impact, or trace pollutants. The environmental applications for GIS are almost endless. It can be used to monitor the environment and analyze changes.(by S Farog Mostafa)

55. Infrastructure Development: Advancement and availability of technology has set a new mark for professionals in the infrastructure development area. Now more and more professionals are seeking help of these technologically smart and improved information systems like GIS for infrastructure development. Each and every phase of infrastructure life cycle is greatly affected and enhanced by the enrollment of GIS.

56. Coastal Development and Management: The coastal zone represents varied and highly productive ecosystem such as mangrove, coral reefs, see grasses and sand dunes. GIS could be generating data required for macro and micro level planning of coastal zone management. GIS could be used in creating baseline inventory of mapping and monitoring coastal resources, selecting sites for brackish water aquaculture, studying coastal land forms.

57. Crime Analysis: GIS is a necessary tool for crime mapping in law enforcement agencies worldwide. Crime mapping is a key component of crime analysis. Satellite images can display important information about criminal activities. The efficiency and the speed of the GIS analysis will increase the capabilities of crime fighting.

58. River Crossing Site Selection for Bridges: The important geotechnical consideration is the stability of slope leading down to and up from the water crossing. It is advisable to collect historical data on erosion and sedimentation. On the basis of these information asses the amount of river channel contraction, degree of curvature of river bend, nature of bed and bank materials including the flood flow and the flow depth, all these can be done in GIS within estimated time and accurately. This information has been often used for river crossing site selection for bridges.

59. Land Use Changes Associated with Open Cast Strip Mining: Mining is the back bone of the developing economy of any country. Mapping, monitoring and controlling the impact caused by the mining activities is necessary so as to understand the character and magnitude of these hazardous events in an area. The data required to understand the impact of mining from the environment is coming from different discipline, which need integration in order to arrive hazard map zonation.

60. Economic Development: GIS technology is a valuable tool used for the economic development. It helps in site selection, suitability analysis, and for finding the right sites to locate new business and grow existing ones. Within economic development, GIS is used to support the emerging trend of economic gardening, a new way to foster local and regional economic growth by existing small business in the community.(By Ahmed Abukhater,GIS for Planning and Community Development: Solving Global Challenges)

61. School Student Walking Distance Analysis: If your community buses students to school, but only if they lived beyond a certain distance from their school, this can be used to determine what addresses are eligible for busing.

62. Locating Underground Pipes and Cables: Pipe line and cable location is essential for leak detection. It can be used to understand your water network, conducting repairs and adjustments, locating leaks known distance for correlating etc. Pipelines are continually monitored, check for leak detection and avoid the problem of geo hazards.

63. Coastal Vegetation Mapping and Conservation: Coastal vegetation like Mangroves are the protectors of coast from natural hazards like tsunami , so that the conservation of these vegetation are highly important. GIS enable us to map which are having higher density of vegetation and which area need more vegetated? Integration of these details to coastal zone mapping helps to identify the area prone to coastal erosion and we can plant more vegetation to reduce coastal erosion.

64. Regional Planning: Every day, planners use Geographic Information System (GIS) technology to research, develop, implement, and monitor the progress of their plans. GIS provides planners, surveyors, and engineers with the tools they need to design and map their neighborhoods and cities. Planners have the technical expertise, political savvy, and fiscal understanding to transform a vision of tomorrow into a strategic action plan for today, and they use GIS to facilitate the decision-making process. (ESRI, GIS Solutions for Urban and Regional Planning)

65. GIS for Land Administration: In a number of countries, the separate functions of land administration are being drawn together through the creation of digital cadastral databases, with these database they can reuse land for suitable needs ,digital taxation and even utilities are also easily handle using these database.

66. Snow Cover Mapping and Runoff Prediction: Systematic, periodical and precise snow cover mapping supported by GIS technology, and the organization of the results in a snow cover information system forms the basis for a wide range of applications. On the practical side, these applications are related to the monitoring of seasonal and yearly alterations of the snow cover under the presently existing climatic conditions, to simulate and forecast runoff, to map the regional distribution of the water equivalent, and to document the recession process of the snow cover during the melting period in its relation to geological features.

67. GIS for Wildlife Management: Man made destruction such as habitat loss, pollution, invasive species introduction, and climate change, are all threats to wildlife health and biodiversity. GIS technology is an effective tool for managing, analyzing, and visualizing wildlife data to target areas where international management practices are needed and to monitor their effectiveness. GIS helps wildlife management professionals examine and envision.

Electronic Distance Measuring (EDM):

EDMIs were first introduced in 1950's by Geodimeter Inc. Early instruments were large, heavy, complicated and expensive. Improvements in electronics have given lighter, simpler, and less expensive instruments. EDM can be manufactured for use with theodolites (both digital and optical) or as an independent unit. These can be mounted on standard units or theodolites or can also be tribrach mounted.

The electronic methods depend on the value of velocity of Electromagnetic radiation (EMR), which itself is dependent upon measurement of distance and time. Hence, there is no inherent improvement in absolute accuracy by these methods. The advantage is mainly functional - precise linear measurement can now be used for longer base lines, field operations can be simplified and trilateration can replace or augment triangulation.

Principle of EDM:

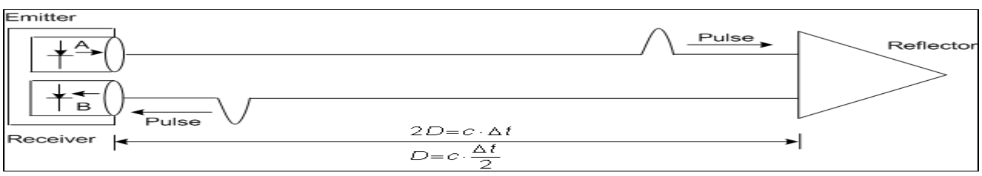
The general principle involves sending a modulated Electro-magnetic (EM) beam from one transmitter at the master station to a reflector at the remote station and receiving it back at the master station. The instrument measures slope distance between transmitter and receiver by modulating the continuous carrier wave at different frequencies, and then measuring the phase difference at the master station between the outgoing and the incoming signals. This establishes the following relationship for a double distance (2D):

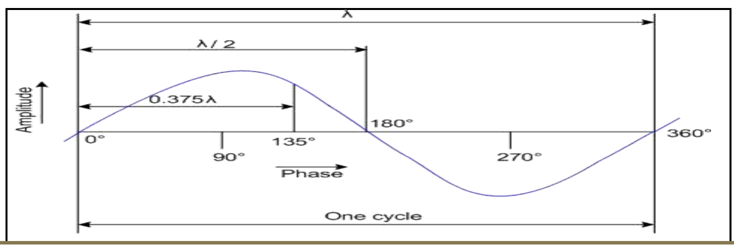
$$2D = m\lambda + \frac{\phi}{2\pi}\lambda + k$$

There are basically two methods of measurement:

I. Pulse techniques:

All such measurements incorporate a very precise measurement of time usually expressed in units of nanoseconds (1x10-9 s), which a EM wave takes to travel from one station to another. In this method, a short, intensive pulse radiation is transmitted to a reflector target, which is immediately transmitted back to the receiver. As shown in Figure given below, the distance (D) is computed as the velocity of light (V) multiplied by half the time (Δt/2) the pulse took to travel back to the receiver (D = V x Δt/2).





Classification on the basis of range
EDMs are also available as:

High range radio wave equipment for ranges up to 100 km

Medium range microwave equipment with frequency modulation for ranges up to 25 km
Short range electro-optical equipment using amplitude modulated infra-red or visible light for ranges up to 5 km

Total Station:
This is an electronic instrument. In this instrument, all the parameters required to be observed during surveying can be obtained. The value of observation gets displayed in a viewing panel. The precision of this type of instrument varies in the order of 0.1" to 10". Total station surveying - defined as the use of electronic survey equipment used to perform horizontal and vertical measurements in reference to a grid system. It is also a form of an electronic theodolite combined with an electronic distance measuring device (EDM).

These instruments can record horizontal and vertical angles together with slope distance and can be considered as combined EDM plus electronic theodolite. The microprocessor in TS can perform various mathematical operations such as averaging, multiple angle and distance measurements, horizontal and vertical distances, X, Y, Z coordinates, distance between observed points and corrections for atmospheric and instrumental corrections.

Due to the versatility and the lower cost of electronic components, future field instruments will be more like total stations that measure angle and distance simultaneously having:

o all capabilities of theodolites

o electronic recording of horizontal and vertical angles

o Storage capabilities of all relevant measurements (spatial and non-spatial attribute data) for manipulation with computer.

Nowadays surveying systems are available which can be use in an integrated manner with Global Positioning System (GPS). Hence, future theodolites/total stations may have integrated GPS receivers as part of the measurement unit.

Advantages of Total Station:

Relatively quick collection of information

surveys can be performed at one set-up location.

Easy to perform distance and horizontal measurements with simultaneous calculation of project coordinates (Northings, Eastings, and Elevations).

Layout of construction site quickly and efficiently.

Digital design data from CAD programs can be uploaded to data collector.

Daily survey information can also be quickly downloaded into CAD which eliminates data manipulation time required using conventional survey techniques.

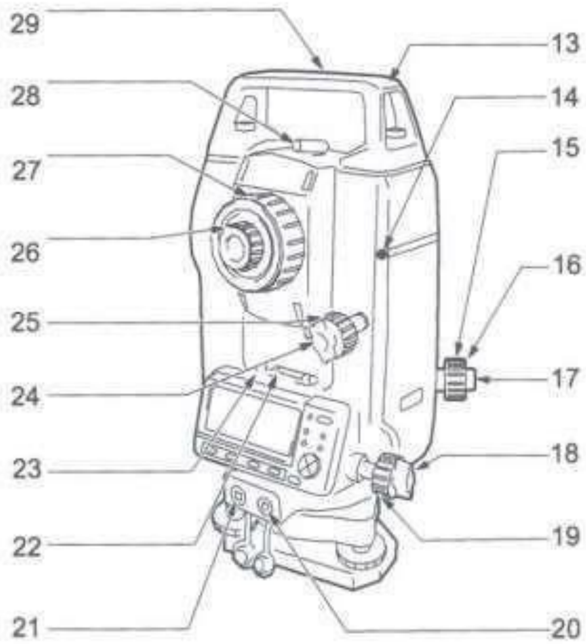
Disadvantages of Total Station:

Vertical elevation accuracy not as accurate as using conventional survey level and rod technique.

Horizontal coordinates are calculated on a rectangular grid system. However, the real world should be based on a spheroid and rectangular coordinates must be transformed to geographic coordinates if projects are large scale.

Examples: highways, large buildings, etc.

As with any computer-based application “Garbage in equals Garbage out”. However, in the case of inaccurate construction surveys “Garbage in equals lawsuits and contractors claims for extras.”



13 Tubular compass slot
14 Beam detector for wireless keyboard (Not included on SET610/610S)
15 Optical plummet focussing ring
16 Optical plummet reticle cover
17 Optical plummet eyepiece
18 Horizontal clamp
19 Horizontal fine motion screw
20 Data input/output connector (Beside the operation panel on SET610/610S)
21 External power source connector (Not included on SET610/610S)
22 Plate level
23 Plate level adjusting screw
24 Vertical clamp
25 Vertical fine motion screw
26 Telescope eyepiece
27 Telescope focussing ring
28 Peep sight
29 Instrument center mark

Field techniques with TS:

Various field operations in TS are in the form of wide variety of programs integrated with microprocessor and implemented with the help of data collector. All these programs need that the instrument station and at least one reference station be identified so that all subsequent stations can be identified in terms of (X, Y, Z). Typical programs include the following functions:

❑ Point location
❑ Slope reduction
❑ Missing line measurement (MLM)
❑ Resection
❑ Azimuth calculation
❑ Remote distance and elevation measurement
❑ Offset measurements
❑ Layout or setting out operation
❑ Area computation

FUNCTIONS PERFORMED BY TOTAL STATIONS

Total Stations, with their microprocessors, can perform a variety of functions and computations, depending on how they are programmed. The capabilities vary with different instruments, but some standard computations include:
Averaging multiple angle and distance measurements.

Correcting electronically measured distances from prism constant, atmospheric pressure, and temperature.

Making curvature and refraction corrections to elevations determine by trigonometric levelling.

Reducing slope distances to their horizontal and vertical components.

Calculating point elevations from the vertical distance components (supplemented with keyboard input of instrument and reflector heights).

Computing coordinates of survey points from horizontal angle and horizontal distance.

- Averages multiple angle measurements.
- Averages multiple distance measurements.
- Computes horizontal and vertical distances.
- Corrections for temp, pressure and humidity.
- Computes inverses, polars, resections.
- Computes X, Y and Z coordinates.

Applications of Total Station

There are many other facilities available, the total station can be used for the following purposes.

Detail survey i.e., data collection.

Control Survey (Traverse).

Height measurement (Remove elevation measurement- REM).

Fixing of missing pillars (or) Setting out (or) Stake out.

Resection.

Area calculations, etc.

Remote distance measurement (RDM) or Missing line measurement (MLM).

Global Positioning System:

History:

The GPS project was launched in the United States in 1973 to overcome the limitations of previous navigation systems,[11] integrating ideas from several predecessors, including a number of classified engineering design studies from the 1960s. The U.S. Department of Defense developed the system, which originally used 24 satellites. It was initially developed for use by the United States military and became fully operational in 1995. Civilian use was allowed from the 1980s. Roger L. Easton of the Naval Research Laboratory, Ivan A. Getting of The Aerospace Corporation, and Bradford Parkinson of the Applied Physics Laboratory are credited with inventing it.

The design of GPS is based partly on similar ground-based radio-navigation systems, such as LORAN and the Decca Navigator, developed in the early 1940s.

Introduction:

Official name of GPS is Navigational Satellite Timing And Ranging Global Positioning System (NAVSTAR GPS)

Global Positioning Systems (GPS) is a form of Global Navigation Satellite System (GNSS)

GPS is funded and controlled by the U. S. Department of Defense (DOD). While there are many thousands of civil users of GPS world-wide, the system was designed for and is operated by the U. S. military.

The GPS receivers convert the satellite's signals into position, velocity, and time estimates for navigation, positioning, or geodesy.

Four GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock.

GPS units are becoming smaller and less expensive, there are an expanding number of applications for GPS. In transportation applications, GPS assists pilots and drivers in pinpointing their locations and avoiding collisions.

GPS can provide accurate positioning 24 hours a day, anywhere in the world.

Uncorrected positions determined from GPS satellite signals produce accuracies in the range of 50 to 100 meters. When using a technique called differential correction, users can get positions accurate to within 5 meters or less.

Billions and billions of dollars have been invested in creating this technology for military uses. However, over the past several years, GPS has proven to be a useful tool in non-military mapping applications as well.

The Term GPS stands for Global Positioning System. The GPS is used to locate alocation with the help of Latitude and Departure. with the help of GPS it’s possible to locate a point very precisely. GPS consist Of two main ends, the one is the Locating Sattelites and the other is the Receiver. Most of the people now a days are familier with GPS due to the huge use of Smart Phones.

Advantages

It helps to survey with many times greater Precision.

It helps to complete a Survey with lesser time and thus helps to cut down the Completion Period.

It Reduces the Difficulty of taking manual measurements to great extent.

With GPS there is a very less chances of error. And this error may come only due to the Instrument malfunction.

Disadvantages

The main Disadvantage is that, it requires high initial investments.

To conduct such High End Survey works and to operate such Electronic Equipments much skilled persons are required.

Application of GPS:

Some of these applications are:

Establishment of high precision zero order Geodetic National Survey Control Network of GPS stations.

Strengthening, densification and readjustment of existing Primary Control Networks using GPS stations.

Connecting remote islands to mainland Geodetic Control Networks.

Determination of a precise geoid using GPS data.

Earth rotation and Polar Motion Studies from GPS data.

Estimating gravity anomalies using GPS.

Marine Geodesy: positioning of oceanic stations, buoys etc.

Earthquake monitoring: Crustal movements of the order of few cm/year can be monitored using GPS method, thus making GPS most suitable for monitoring continental drifts, seism tectonic movement, etc.

Vertical Control Network : High accuracy of few mm in heights achievable with GPS at much less cost and time compared to levelling to make GPS method most suitable for establishing lower accuracy vertical control networks.

Geophysical positioning, mineral exploration and mining.

Survey control for topographical and cadastral surveys.

Ground control for photogrammetric control surveys and mapping.

Offshore positioning: Shipping, offshore platforms, fishing boats etc.
Instantaneous time transfer over trans-continental distances with accuracies of few nano seconds.

Space craft tracking: Vector separation between GPS satellites and any other satellites can be monitored by GPS, e.g., pinpointing the location of LANDSAT etc.

General aircraft navigation, approach to runways, navigation/positioning in remote areas like deserts, dense jungles, shaded areas of microwave, precise sea navigation, approach to harbours etc. It is expected that in 1990s most civilian aircrafts, ships, boats will be fitted with GPS equipment's and even hikers, boat and car owners, truck drivers will be using it extensively.,

Military ; Improved weapon delivery accuracies i.e. for missiles etc., for ranging in artillery, navigation for Army, Navy, Airforce - thus affecting ultimate saving of upto 1billion dollars annually on navigation in U.S.A. Scientific applications, like studies related to the ionosphere and troposphere, glaciology, etc.