# 1.0 INTRODUCTION

## 1.1 Definition and Functions of Surveying

Surveying can be defined as the science and art of determining relative positions of points above, on or beneath the surface of the earth, or establishing such points (Brinker et al., 1977). Surveying, as can be seen from this definition, is involved with measurements. These measurements need not to be confined to land areas. A surveyor makes measurements over water and through space. Surveyors measure above and below the earth as well as on its surface (Buckner, 1978).

The definition says the surveying is both a science and an art. The science portion is essentially that which involves mathematics (particularly algebra and trigonometry), physics and physical sciences. The art of surveying is the part that involves skill, talent, judgment and logical thinking. Examples of the art of surveying would be surveyor's arrangement of field notes, planning field surveys, plotting and analyzing data, and making correct decisions (Buckner, 1978).

The last part of the definition given above points to the fact that surveyors are faced with two fundamental problems:

1) to determine relative positions between points
2) to establish points in a specified system

In other words, the aim and purpose of surveying is to determine the geometry. The geometry of objects, as known, includes: length, width, height, slope, location, elevation, direction, coordinates, area, volume, etc. of objects. In this sense surveying is nothing more than geometry applied at the surface of the earth. The objects on the surface of the earth includes natural features like; valleys, mountains, hills, slopes, ridges, rivers, lakes, coast lines, etc. and artificial or man-made features like; roads, highways, freeways, streets, buildings, street furniture, bridges, ports, stations, parking areas, and so on.

An example of the first of these problems is measuring the distance and bearing between two marks already set in the ground. But, if only one marker exists and the surveyor wishes to establish a second one at a specified bearing and distance, this is an example of the second problem.

The definition of surveying above is rather simplified. The functions of modern-day surveyors are many and varied; collection of digital and intelligent data with attributes, analyzing the data, evaluate the errors, displaying and plotting desired information, querying required information etc.

As mentioned earlier, the main objective of surveying and engineering measurements is to determine position of arbitrary points. This includes (Moffitt et al., 1987):

- Planimetric coordinates in a given coordinate system
- Elevations relative to a given datum, usually relative to mean sea level
- Determine directions and/or length of lines; setting our construction works
- Establishing property boundary lines; developing data banks of land use and natural resource information which aid in managing natural resources
- Mapping the earth, preparing navigational charts
- Configuration of the ground; determining size, shape, gravity and magnetic fields of the earth
- Area enclosed by straight and/or curved boundaries

## 1.2 General Classes of Surveying

Plane surveying - a survey in which the surface of the earth is considered a plane. In other words, the horizontal datum is assumed to be a horizontal plane which approximates the true shape of the earth over the survey area.

Geodetic surveying - a survey in which the shape and size of the earth are considered. In other words, the horizontal datum is assumed to be a curved geometric surface which very closely approximates the true shape of the earth.

## 1.3 Specific Types of Surveys

Property or Cadastral Surveys - establish property corners, boundary lines, and areas of land parcels.

Control Surveys - establish horizontal and vertical positions of arbitrary points to establish a reference network or framework for other types of surveys. High accuracy geodetic methods are employed.

Topographic Surveys - establish the configuration of the ground and construct topographic maps which show natural and man-made features.

Photogrammetric Surveys - determine positions of points from measurements made on photographs, most commonly used for topographic maps.

Construction Surveys or Engineering Surveys - establish points and elevations for the location and layout of projects such as houses, bridges, utilities, etc.

Route Surveys - used for location, layout, and construction of long linear projects such as roads, power lines, etc.

Hydrographic Surveys - used to chart and map the bottoms and shorelines of bodies of water.

Surveying plays an important role in many branches of engineering; surveys are required prior to, during, and after planning and constructing buildings, highways, railroads, bridges, tunnels, canals, dams, drainage works, water supply and sewerage systems, pipelines, land subdivisions, etc. in civil engineering, geology, architecture and many other disciplines. Surveying is one of the very first work of an engineer in the above fields needs after his or her graduation.

Because of its wide applications and developments in digital techniques and artificial satellites, a large amount of research has been devoted to surveying profession lately.

In the past, land related information was maintained mostly in registers, on papers, films, etc. For making such information understandable and presentable, the original data has to be classified and reduced in volume causing local details to be lost and making the retrieval of the data expensive and difficult. This decade has witnessed the transition from conventional line mapping to digital mapping, primarily after the introduction of high speed computers and other digital equipment such as plotters, workstations and computer-aided plotters. Digital compilation and storage of maps make retrieval, display and updating of such digital information superior to conventional mapping.

Similar advancements have occurred in the storage, handling and management of large databases. It is now possible to supply land related information in a shorter time but more accurately, economically and efficiently by utilizing better trained personnel and better structured organizations.

The developments presented above have resulted in the establishment of Land Information System (LIS), or in broader concept, Geographic Information System (GIS). Any LIS/GIS system consists of the following three major components, i.e.,

a) A national geodetic control network
b) Topographic base maps
c) Cadastral framework

These elements may be thought of as the basic Infrastructure of a Land Information System.

The one and the only invariant parameter of a land related information system is spatial location. A reliable national control network provides the most appropriate geographic reference for all mapping, cadastral registration, land surveys, LIS, etc.

The second essential component in the establishment of a LIS is the digital topographic base maps. The type and scale of a base map product vary depending on the different land related management functions. This shows the need for base map products to be tailored to the type and complexity of the information to be displayed. In fact, land information begins with an up-to-date representation of what exists on the ground.

The next level in the conceptual model of the LIS is the cadastral framework. The cadastral fabric is based on the parcel as its basic unit. This is an indispensable part of a land management system. The defined land parcels or real property boundaries provide the integration base for social, economic and demographic information. The cadastral fabric can be conceptually viewed as having no scale, due to generally point to point coordinate nature of the data. Development of this fabric of land parcels, each with its own unique identifier, provides the method for linkage with other elements of the LIS, directly through the geographical locations of parcels and unique parcel identifiers.

## 1.4 Nature of Measurements

The surveying activities consist of two parts ;

1) Field work; to carry out measurements such as distances, angles, elevations, signals, etc.
2) Office work; to carry out computations and analysis.

It is well known fact that anything measured is inexact. That is, the exact or true value, though it may exist, can never be determined by humans or machines, no matter how refined the techniques are. It is, therefore, of utmost importance that the measurements are reliable. There are a large number of factors effecting measurements. As a result, there will be uncertainty and errors in the measurements. That is the main reason why the true value of the measured quantity cannot be obtained. Instead, the best estimation for the subject quantity is sought. The reliable measurement is the one that is free of systematic errors & blunders and has small random errors.

Accepting the fact that the measurements are inexact is not excuse for any sloppy work, because a level of accuracy should be achieved which is consistent with that needed according to specifications and as dictated by economy and available instrumentation.

Survey measurements are generally made in “three elements of space”. This means that surveyors are involved with measuring three dimensional (3-D) space rather than just on plane surfaces. However, traditionally, positions are divided into two components

1) Horizontal coordinates
2) Elevation.

Horizontal coordinates are defined within a coordinate system belonging to a plane projection surface. They are given as Cartesian coordinates (see section 7……) or as distance and direction. Elevations are defined below vertical reference surfaces such as Mean Sea Level (i.e., geoid).

## 1.5 Terms from Measurement Science

<u>Error</u> - unavoidable discrepancy of a measurement (or observation) from the true value of the quantity being measured.

<u>Mistake</u> - avoidable discrepancy of a measurement (or observation) from the true value of the quantity being measured. Caused by misunderstanding, carelessness, inattention, poor judgment, flawed procedure, etc.

<u>Natural errors</u> - caused by variations in natural phenomena such as temperature, wind, gravity, magnetism, etc.

<u>Instrumental errors</u> - caused by imperfections and maladjustments of the instruments.

ex.: imperfect spacing of gradations on scales

Personal errors - arise from human fallibility in the senses of sight, touch, and hearing.

ex.: misreading a scale due to poor vision

Systematic errors - errors which conform to mathematical and physical laws such that their effects may be computed and then corrected. These errors are sometimes called cumulative errors because they usually accumulate during a series of measurements. Systematic errors accumulate since their size and signs are usually constant.

Random errors - errors which conform to the laws of probability such that the size and sign of the errors are purely matters of chance. These errors are sometimes called compensating errors because their signs have equal chance of being positive (+) or negative (-) at each measurement and they will tend to cancel one another over a series of measurements.

Precision - the degree of repeatability among various measurements of the same quantity.

Accuracy - the absolute nearness of a measurement to the true value of the quantity being measured.

## 1.6 Basic Definitions and Terminology

Before proceeding further, it is intended to provide very basic definitions commonly used in surveying and mapping. These terminologies will be used throughout the notes in subsequent sections.

Horizontal Line is the one perpendicular to the vertical line at the same point.

Horizontal plane is the one perpendicular to the vertical line at that point.

Horizontal distance is the length between two given points projected onto a horizontal plane.

Horizontal angle is the angle Between two vertical planes Measured in a horizontal plane.

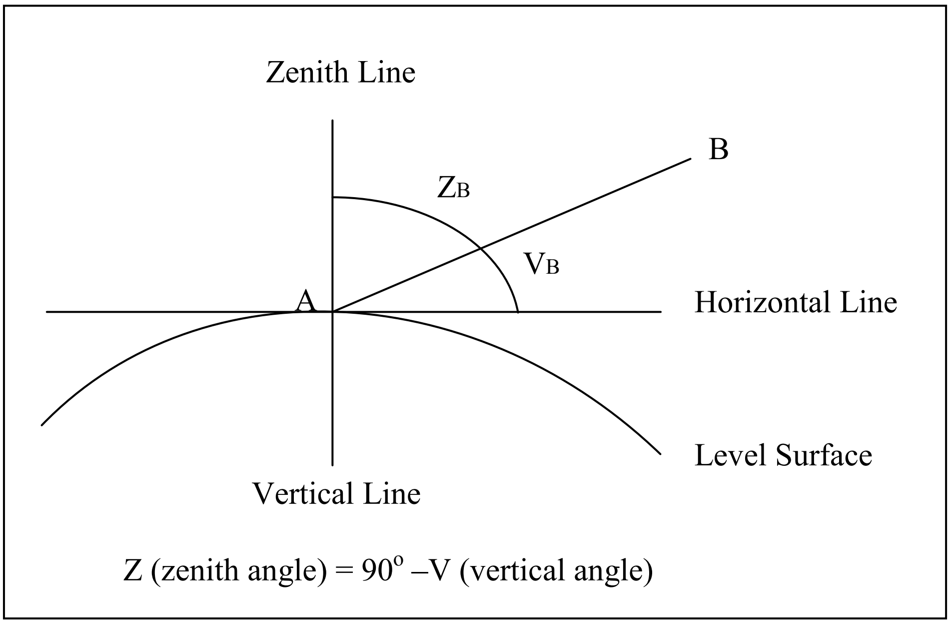
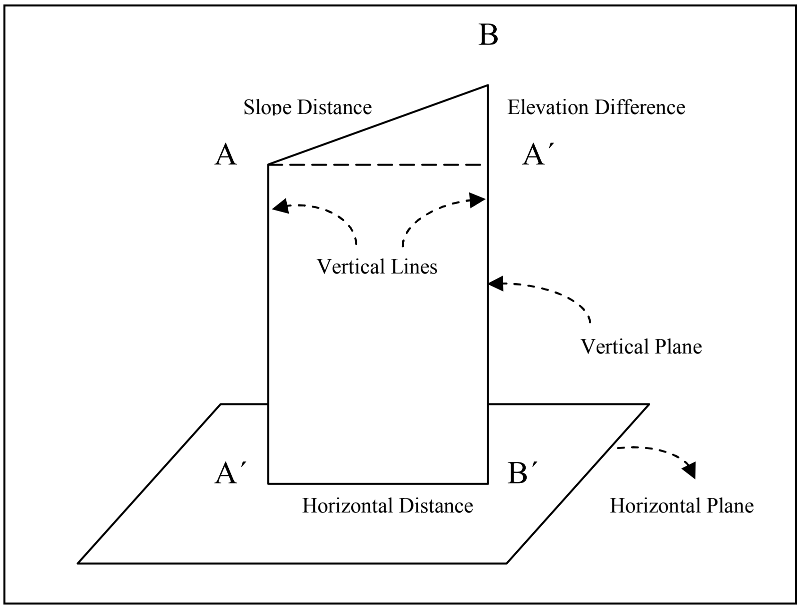



Figure 1.1 Vertical and horizontal line on level surface

Vertical Line at any point on the earth's surface is the line that follows the direction of gravity at that point.

Vertical Plane at a point is any plane that contains the vertical line at the same point.

Vertical angle (v) is an angle in vertical plane measured from a horizontal plane. It is also known as an elevation or inclination angle.



Zenith angle (z) is also an angle measured down from the upward direction. Thus, the relation between these two angles is v+z=90°.

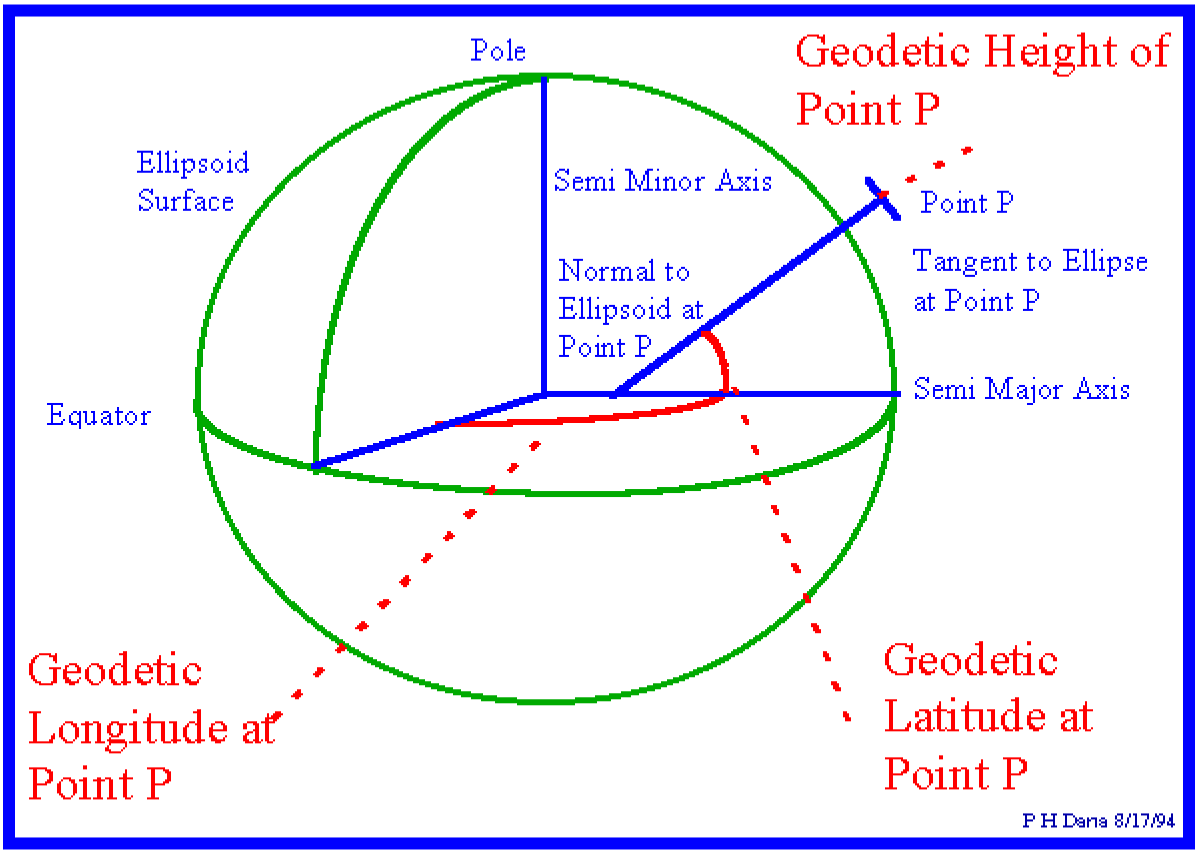
Elevation of a point is its vertical distance (measured along the vertical line) above or below a given reference level surface.

Slope distance (S) - the straight line distance between two points.

Level Surface is an equipotential surface. Tangents at every point of level surface is perpendicular to the vertical line.

Shape of the earth and ellipsoid of revolution: Measurements are made on the surface of the earth. As we know, the earth is not a plane but a round figure approximated by spheroid or ellipsoid. In fact, the actual figure of the earth is a complex one cannot be represented by any geometric figures. For this reason, in practice, there are approximations of the earth starting from a plane, spheroid, rotational ellipsoid, 3-D ellipsoid and geoid. The first 4 approximations are simple geometrical figures, but the latter one is a physical level surface coinciding with the mean sea level extended under continents. Geoid is the best approximation to the shape of the earth, but its use is limited since it cannot be expressed in equations of closed forms, making any computations on it almost impossible.

Figure 1.3 Shape of the earth



Selecting above the approximations will depend on the area of survey and precision required. For regular engineering works, the earth is taken as plane which simplifies computations extensively. For large areas, in general, rotational ellipsoids are used. Turkey uses International Ellipsoid with the parameters: a=6378388m, f=I/297.

Latitude of a point is the angular distance measured along the meridian from the equator to the zenith of that point.

Level line – a line that is perpendicular to the direction of gravity at all points.

Datum - quantity or set of quantities which serves as a reference or base for other quantities.

Horizontal datum - a reference surface with an established location and an established orientation. This surface is used as the reference for all horizontal measurements and is considered to approximate the earth's surface.

Vertical datum - a reference level surface to which elevations and vertical measurements are related. This surface is usually, but not always, related to mean sea level.

## 1.7 Units of Angular Measurement

The system most commonly used in the measurement of distance and angle is the “Systeme Internationale”, abbreviated to SI. The basic units of prime interests are:

Length in meters (m)

From which we have:

1m = 10 dm = $10^2$cm = $10^3$ millimeters (mm)
1m = $10^{-3}$ kilometers (km)

1 inch = 2.54 cm
1 foot = 30.48 cm

Both miles, namely nautical and statue, for distances are commonly used in countries like USA and England. They are equivalent to,

1 Nautical Mile = 1852.0 m
1 Statue Mile = 1609.3 m

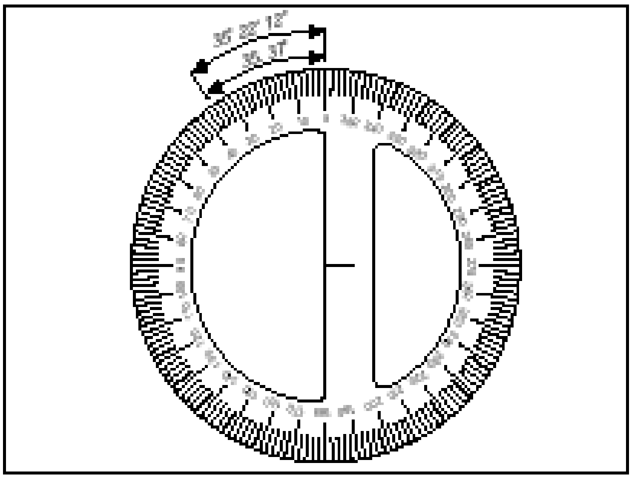
Similarly for areas we have:

1 $m^2$ = 1 000 000 $mm^2$
1 ha = 10 000 $m^2$
1 $km^2$ = 100 ha

and for volumes, $m^3$ and $mm^3$

There are three systems used for plane angles, namely the sexagesimal, the centesimal and radiants.

The most common angular units being employed in the United States is the Sexagesimal System. This system uses angular notation in increments of 60 by dividing the circle into 360 degrees; degrees into 60 minutes; and minutes into 60 seconds. Each unit has a corresponding symbol: degrees are indicated by °; and seconds by ` ;



Therefore;

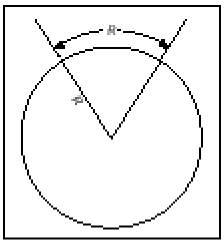
1 circle = 360° = 21,600′ = 1,296,000½
1° = 60′ = 3600½
1′ = 60½

Usually angles are expressed in Degrees, Minutes, and Seconds as applicable, but can be expressed in any combination. For example, 35.37° 2122.2′ 127332½, 34° 81′ 72½ , and 35° 22′ 12½ all represent the same magnitude of angle. However, in the last form, which is the preferred notation, notice that minutes and seconds equal to or greater than 60 are carried over to the next larger unit and that degrees and minutes do not have decimals. Decimal seconds are acceptable.

For performing certain mathematical operations with angles, it is sometimes easier to convert to decimal degrees first, perform the necessary mat h, then convert back to degrees, minutes, and seconds.

| | Degrees -Minutes -Seconds | Decimal Degrees |
|---|---|---|
| 10 | 23° 12′18″ | |
| 11 | | 42.885° |
| 12 | | 63.545° |
| 13 | 87° 58′48″ | |

The primary unit of angular measurement in the metric system is the radian. A radian is defined as the angle between radius lines from either end of an arc of radius length.



The circumference of a circle is twice the radius length times π, or C =2πr.

Therefore, 1 circle = 2π radians.
Since 1 circle = 360° = 2πrad.,
then 1 rad. = 360°/2π = 57.29578...°

1 rad = 57.29578...° = 63.6619972gon

The use of radians and the value of 57.29578° will be mentioned again when dealing with circular and spiral curves.

Another unit is the grad or gon. A grad is defined as 1/400 of a circle. The grad is widely used in much of the world as part of the metric system, even though the radian is the primary unit.

1 gon = 100 cgon (centigon)
1 cgon= 100 mgon (million)