

Chapter Two

· Measurements and Computations

WHAT IS MEASUREMENTS

- ♣ The word measurement is derived from the Greek word "**metron**," which means a **limited proportion**
- ♣ In science, measurement is **the process** of estimating or determining the magnitude of a quantity
- ♣ The term measurement can also be refers to a **specific result obtained** from a quantity

Measurements and Computations

- The purpose of this section is to discuss the different types of surveying measurements, identify error sources, and describe procedures to minimize errors.
- Measuring distances and angles from a known reference are fundamental surveying operations.
- The true value of a measurement is determined by taking the mean value of a series of repeated measurements.

Types of measurements in surveying

a. Horizontal Distances and Angles

- A linear measurement on the horizontal plane determines the **horizontal distance** between two points.
- **Horizontal angles** are measured on the horizontal plane and establish the azimuth of each survey measurement.
- An azimuth is a horizontal angle measured clockwise from a defined reference (typically geodetic north).
- Horizontal distance and angle measurements are then **used to calculate the position of a point** on the horizontal plane.
- However, the **true horizontal distance is actually curved like the Earth's surface**.

b. Vertical Distances and Angles

- **Vertical distances** are measured along the vertical axis **to determine the difference in height (or elevation)** between points.
- Vertical angles are measured in the vertical plane either above or below the horizontal plane of the instrument.
- Zenith angles, used as a reference for measuring vertical angles, are defined as 0° directly overhead and 90° at the horizontal plane.

c. Slope Distance

- The slope distance is the **shortest distance from the instrument to the target.**

- This distance is the hypotenuse of the horizontal and vertical distances.
- The horizontal and vertical distances can be calculated if the slope distance and vertical angle is known.

Note : Above all types of measurements have computation methods/instruments.

Significant Figures

Finding the significance in a number and its importance in measurements

- Significant figures are the **number of figures believed to be correct**
- Two types of numbers: ***exact*** and ***inexact***.
 - ✓ *Exact numbers are obtained by counting or by definitions –hundred cents in a dollar/5 students in the class.*
 - ✓ **All measured numbers are *inexact*.**
- In reading the number the **last digit quoted is a best estimate.**

Conventionally, the last figure is estimated to a tenth of the smallest division.

▪ **The last figure written is always an estimate**

RULES OF SIGNIFICANT FIGURES

- Nonzero digits are always significant
38.57 (four) 283 (three)
- Zeroes are sometimes significant and sometimes not
 - Zeroes at the beginning: never

Rounding up or down?

- 5 or above goes up
– 37.45 → 37.5 (3 S.F.)

$-123.7089 \rightarrow 123.71 (5 \text{ S.F.}); 124 (3 \text{ S.F.})$

· < 5 goes down

$-37.45 \rightarrow 37 (2 \text{ S.F.})$

$-123.7089 \rightarrow 123.7 (4 \text{ S.F.})$

significant 0.052 (two)

–Zeroes between: *always 6.08 (three)*

–Zeroes at the end after decimal: *always 39.0 (three)*

–Zeroes at the end with no decimal point may or may not: 23 400 km (three, four, five)

Theory of errors

♠ Surveying is concerned with measurements of quantity whose exact or true value may not be determined.

♠ It can be stated unconditionally that

1. no measurement is exact,
2. every measurement contains errors,
3. the true value of a measurement is never

known, and thus

4. the exact sizes of the errors present are always unknown.

*****The true value of a quantity is, a value which is, absolutely free from all types of errors*****

The true value cannot be determined because some errors always creep in the measured quantities

- ♠ *The surveyor must have the skill and judgment to make very accurate measurement*
- ♠ *As better equipment is developed, environmental conditions improve, and observer ability increases, observations will approach their true values more closely, but they can never be exact*

Errors and mistake

- ♠ Error is the difference, after blunders have been eliminated, between a measured or calculated value of a quantity and the true value of that quantity.
- ♠ *A blunder, also called a mistake, is an unpredictable, human mistake. Although a small blunder may remain undetected and have the same effect as an error, it is not an error.*
- ♠ Mistakes occur in measurements due to carelessness, inattention, fatigue, miss-communication, inexperience or poor judgment of

the surveyor.

For example, recording 79.36 or 73.69 instead of 73.96

Examples (mistakes)

- ❖ Transposing two numbers
- ❖ Neglecting to level an instrument
- ❖ Not placing the sighting point over the correct point
- ❖ Misplacing the decimal point
- ❖ Not sighting the point that corresponds to the point name or number put in the data collector.

Mistakes are detected and eliminated by using proper procedures, such as:

- ❖ Checking each recorded and calculated value
- ❖ Making independent and redundant measure check observations and measurements
- ❖ Making redundant measurements that allow closure computation of sections of the entire survey
- ❖ Calculating repeatedly

Sources of errors

- ♠ As discussed above, errors stem from three sources, which are classified as **instrumental, natural, and personal**:

a. **Instrumental errors:** *are caused by imperfections in instrument construction or adjustment.*

Examples of instrument error are:

- ❖ **Imperfect linear or angular scales**
- ❖ **Misalignment of various part of the instrument**
- ❖ **Optical distortions causing “what you see is not exactly what you are supposed to see”**

For example, the divisions on a theodolite or total station instrument may not be spaced uniformly.

Another example, if the tape used in measuring the distance is actually 29.95m long where as the nominal length is 30m, the instrumental error occurs because of the imperfect tape.

- ♠ *Most instrumental errors are eliminated by using proper procedures, such as*
 - ♠ *observing angles in direct and reverse modes,*
 - ♠ *balancing foresights and back sights and*
 - ♠ *repeating measurements.*
- ♠ *Since not all instrument errors can be eliminated by procedures, instruments must be periodically checked, tested and adjusted (or calibrated.)*
Instruments must be on a maintenance schedule to prevent inaccurate measurements.
- b. **Natural errors:** *are caused by changes in natural phenomena, such as temperatures, winds, humidity, refraction, and magnetic field.*

Examples of natural errors are:

- ❖ A steel tape whose length varies with changes in temperature.
- ❖ Sun spots activity and its impact on the ionosphere, hence on GPS surveying.

For example if a tape has been calibrated at 20°C, but the field temperature is 30°C there will be a natural error due to temperature variation.

♠ *Natural errors are mostly systematic and should be corrected or modeled in the adjustment.*

♠ *Some natural errors such as the effect of curvature and refraction in leveling can be eliminated by balancing backsight and foresight*

c. **Personal error:** occur due to human limitations,

such as sense of sight and touch.

-----Personal errors can be characterized as either systematic or random.

-----Personal systematic errors are caused by an observer tendency to react the same way under the same conditions (inconsistency). When there is no such tendency, the personal errors are considered to be random.

An example of a personal error is an error in the measured value of a horizontal angle, caused by the inability to hold a range pole perfectly in the direction of the plumb line.

Types of errors

In surveying, errors can be broadly classified into

the following two types.

1. Systematic or cumulative errors

2. Accidental or random errors

1. Systematic /cumulative error

♠ *A systematic error is an error that will always have the same magnitude and the same algebraic sign under the same conditions.*

♠ *In most cases, systematic errors are caused by*

physical and natural conditions that vary in accordance with fixed mathematical or physical laws.

- ♠ Systematic errors follow some well-defined mathematical or physical law or system.
- ♠ The magnitude and the sign of the systematic errors can be determined and a suitable correction can be applied to the measured quantity.
- ♠ So, systematic errors can be corrected or eliminated

. Random/accidental errors

- ♠ These are the errors that remain after all mistakes and systematic errors have been removed from the measured values.
- ♠ Random errors are random in nature and occur beyond the control of the surveyor.
- ♠ They usually do not follow any physical law and therefore must be dealt with according to the mathematical laws of probability.
- ♠ It is impossible to avoid random errors in measurements entirely
- ♠ Theoretically, an accidental error has an equal chance of being negative or positive. Thus, errors of this type tend to be compensating.

Nature of error

- Positive and negative errors equal chance to occur
- Small errors have most probability to occur.
- Large errors has small chance occurs

Accidental errors occur due to:

- imperfection in the instruments
- human limitation or
- Change in atmospheric conditions

Accuracy and Precision

A. *Accuracy* refers to the degree of perfection obtained in measurements.

♠ It denotes how close a given measurement is to the true value of the quantity.

♠ Accuracy is the degree of conformity of a given measurement with a standard value.

B. *Precision* is the degree of refinement with which a given quantity is measured.

♠ In other words, it is the closeness of one measurement to another.

♠ If a quantity is measured several times and the values obtained are very close to each other, the precision is said to be high.

• Precision is the extent to which a given set of measurements agree with their mean.

- The goal of any survey should be to produce accurate and precise observations. Often measurements with greater accuracy and precision requirements employ multiple