Practical Geography

for Advanced Secondary Schools

Student's Book

Form Five and Six

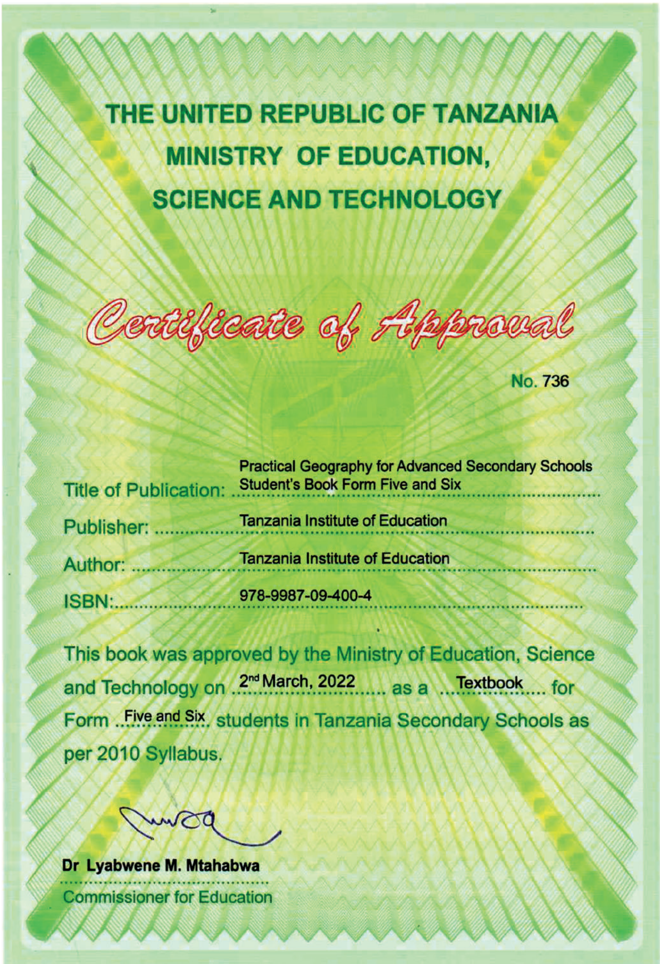
Tanzania Institute of Education

Practical Geography

for Advanced Secondary Schools

Student's Book

Form Five and Six



THE UNITED REPUBLIC OF TANZANIA
MINISTRY OF EDUCATION,
SCIENCE AND TECHNOLOGY

Certificate of Approval

No. 736

Title of Publication: Practical Geography for Advanced Secondary Schools Student's Book Form Five and Six

Publisher: Tanzania Institute of Education

Author: Tanzania Institute of Education

ISBN: 978-9987-09-400-4

This book was approved by the Ministry of Education, Science and Technology on 2nd March, 2022 as a Textbook for Form Five and Six students in Tanzania Secondary Schools as per 2010 Syllabus.

Dr Lyabwene M. Mtahabwa
Commissioner for Education

Tanzania Institute of Education

Published 2022

ISBN: 978-9987-09-400-4

Tanzania Institute of Education
P.O. Box 35094
Dar es Salaam

Mobile numbers: +255 735 041 168/+255 735 041 170
Email: director.general@tie.go.tz
Web: www.tie.go.tz

Table of Contents

Acronyms and abbreviations

Gb	Giga bite
GIS	Geographic Information System
GWh	Giga Watt per hour
JNIA	Julius Nyerere International Airport
KIA	Kilimanjaro International Airport
LEO	Low Earth Orbiting
TMA	Tanzania Meteorological Authority
TANESCO	Tanzania Electric Supply Company
TPDC	Tanzania Petroleum Development Cooperation
TN	

Acknowledgements

The Tanzania Institute of Education (TIE) would like to acknowledge the contributions of all the organisations and individuals who participated in designing and developing this textbook. In particular, TIE wishes to thank the University of Dar es salaam (UDSM) and the University of Dodoma (UDOM), School Quality Assurance (SQA) Department, teachers' colleges and secondary schools. Besides, the following individuals are acknowledged:

Writers:	Dr Fredy S. Mswima (UDOM), Ms Beatrice S. Rulenguka (TIE) & Ms Neema A. Kashindye (TIE)
Editors:	Dr Julius Mngumi (DUCE), Mr Anton Nzali (UDOM), Dr Festo J. Ndumbaro (UDSM), Dr Barnabas M. Msongaleli (UDOM), Dr Julius E. Frank (OUT - Language), Mr Frank Mahuve (UDOM), Mr Daniel A. Mwalutolo (UDSM), Mr Michael N. Sichundwe (Tusiime Secondary School), Mr Iddi A. Moh'd (Kiembe Samaki Islamic Secondary School)
Designer:	Mr Anton Asukile
Photographer:	Mr Chrisant A. Ignas (TIE)
Illustrators:	Mr Fikiri A. Msimbe, Ms Rehema Maganga and Mr Godlove Kyando (TIE)
Coordinator:	Ms Neema A. Kashindye

TIE is also appreciative for the participation of secondary school teachers and students in the trial phase of the manuscript. Likewise, the Institute would like to thank the Ministry of Education, Science and Technology for facilitating the writing and printing of this textbook.

Dr Aneth A. Komba
Director General
Tanzania Institute of Education

Preface

This textbook, *Practical Geography for Secondary Schools*, is written specifically for Form Five and Six students in the United Republic of Tanzania. It is written in accordance with the 2010 Geography Syllabus for Advanced Level Secondary Education, Form V-VI issued by then, Ministry of Education and Vocational Training.

The book consists of five chapters, namely Application of statistics in geography, Field research techniques, Simple survey and mapping, Maps and map interpretation, and Photograph interpretation. Each chapter contains illustrations, activities and exercises. You are encouraged to do all the activities and exercises as well as other assignments that your teacher will provide. Doing so, will enable you to develop the intended competencies.

Tanzania Institute of Education

Chapter One

Application of statistics in geography

Introduction

Statistics is a useful field in our daily life. Statistical information is used by different people in understanding the nature of the world and its dynamics. In this chapter, you will learn about concepts and types of statistics, role of statistics, statistical data and variables. You will also learn about methods of data collection, analysis and organization. Additionally, you will learn about sources of data, presentation methods and interpretation. The competencies acquired from this chapter will enable you to find solutions to the day-to-day geographically related issues and make informed decision on statistical geographical related events and phenomena for personal and community development.

Conceptualising statistics

Statistics deals with scientific methods of collecting, organising, analysing, presenting, interpreting numerical information and making conclusions on the basis of the associated analyses. It is concerned with collecting, organising, summarising and analysing multitude of numerical data so as to understand the essential features and relationship of data. In other words, the term statistics denotes the study and practice of collecting, analysing and presenting data that have geographical and real world dimension such as census and demography. Statistics provides a basis for decision making when testing hypothesis that are formulated through the scientific methods in geography. Statistics aims at drawing some insights from *population* based on measurements taken from a *sample*. A population is a group of individuals, objects or units from which we intend to know something.

A sample is a collection of representative members of the population from which the statistical measurements are taken. It is the subject of the population from which statistical data will be calculated. For example, if one is interested in examining statistical information such as the effect of class-size on advanced level students' performance in Geography, he or she will choose representatives (sample) among the students. It is therefore from this sample, data will be collected, analysed and interpreted. The obtained information can be generalised to the entire population.

Types of statistics

Statistics is basically divided into two major types namely: descriptive and inferential statistics. Descriptive statistics is concerned with describing and summarising the entire population or sampled data with the aim of bringing out the important facts about data. Mean, median, mode, range, standard deviation and percentages are some examples of descriptive statistics. Inferential statistics is concerned with studying the sample of the population for the sake of drawing conclusions based on the analysis of data. Inferential statistics though not covered in this book includes probability distributions and statistical hypothesis testing. The essence of inferential statistics is to make inferences about a population based on the information obtained from the sample.

Role of statistics

Practically, statistics plays a wide role in simplifying complex mass of data and present them in a comprehensive way so that they can easily be understood and interpreted. Large raw data can be summarised into percentages, modes and means hence become understood easily compared to raw mass of data. Moreover, statistical representation of data in form of histograms, bar charts or pie charts enables one to understand the information easily. Statistics present data in a comprehensive and definite form. Statistics enables drawing of sound numerical conclusions that are more convincing as opposed to conclusions stated verbally. For example, it sounds clear and appealing to say 70% of the candidates sat for NECTA 2021 passed as opposed to general conclusion that most of the candidates sat for NECTA in 2021 passed.

Additionally, statistics present, interpret and predict conditions. Statistics present conditions by using for example, pie charts, histograms or bar charts of the studied phenomenon which can be easily understood. Some statistical conditions for presenting data allow the predictions of the future phenomenon thus giving clues to finding ways to offset them or reduce their occurrence in future. Again, it provides easy way of classifying numerical data. That is, the method of classification in statistics often provides clear features of a variable that is under investigation. For example, statistical methods provide an appropriate method of classifying two or more data by bringing out the maximum, minimum and standard deviation of the various categories.

Moreover, statistics is useful in evaluation. For example, it is easy to evaluate the Tanzania development vision of 2025 with statistics. It is also useful in budgeting at both family and national level. For example, free basic education in Tanzania is provided to the known number of students. Statistics is the basis of projection of different geographical events such as climate and outputs of agriculture. It acts as an evaluative tool in different fields, such as demography, education and business. Statistics is used to evaluate the effectiveness of the policies under implementation to understand to what extent the expected results will be achieved or not. For example, in the free basic education policy, statistics is normally applied in monitoring the proper utilization of funds, human resource, construction and maintenance of learning facilities among others according to the demand. Statistics helps to project the future trends and the impact of a particular social or geographical phenomena. With the use of probability statistics, we can accurately project the outcome of natural and cultural phenomena. For instance, basing on the existing situations in the climatic factors, it is possible to spell out what will happen after a considerable span of time, and how the society and environment in particular will suffer. Statistics is a basis for policy formulation. Statistical facts and evidence are usually among the international and national policy foundations. For instance, the daily reports on the number of Covid-19 infected people worldwide, pressurise nations to formulate local policies and to agree with the international policies such as vaccination. Furthermore, demographic data may indicate the rate at which the population of a country is growing and statistically get clues in policy formulation for resources distribution to cater for the needs. Lastly, it provides an easy way of comparing data. Statistical analyses make it possible to compare the relevant analysed data from two or more different studied areas or time. Volumes of data from two or more sites can be compared basing on descriptive statistics such as mean, median and mode of their distributions.

Statistical data and variables

The word data is derived from Latin word *datum* meaning 'something given'. Data can be of numeric, text, graphic, art, image or symbol that researchers obtain from the subjects, respondents or participants of the study. It is a raw or unprocessed information about certain phenomenon or event. The raw data needs to be processed by subjecting it to some statistical analysis in order to obtain useful information for decision making. The data that has been processed in a context and assigned to give their meaning is referred to as information (Figure 1.1). Largely, statistics deals with quantitative data which exist in numeral and to some extent integrate the qualitative data. Data can be obtained from weather and climate, demography, transport and communication, as well as agricultural production. When one does any sort of inquiry or research, he or she will collect data of different kinds. In fact, data can be seen as the essential raw material of any kind of research. Data can be managed by using information technology in the form of bytes stored in electronic memory (database).

Information = Data + Context + Meaning

Figure 1.1: *Schematic representation of data and information*

An individual piece of data in a data set is called a score or observation whereas a quantity to which any of a set of values such as (scores or observations) is assigned is called variable. For example, the quantities height, weight or age are variables, while the values assigned to them are data. Data can be collected from the respondents or subjects by using different methods such as survey, focus group discussion, document review and interview. Data may also be collected through any other method, depending on the needs of the research.

Nature of data

Data may be classified in four categories namely: Discrete, continuous, individual and grouped data. Discrete data is a numerical type of data that can only be given in whole, concrete numbers with specific and fixed data values determined by counting. Examples of discrete data include; number of people, computers, animals, houses and eggs.

Continuous data include complex numbers and varying data values that are measured over a specific interval or within a range. Values in these data set often carry fraction or decimal points. Examples of continuous data include; eight, wind speed, temperature, altitude and distance.

For example temperature of 23.15° C in a range 0° C to 30° C or an altitude of 483. 23 m in a range 0 to 1000 m. Individual data are data through which an exact value is given for each individual item in a sample. For example, population of Tanzania, and number of students at Mjimwema secondary school which may be 200 students are types of individual data. Grouped data are data by which no exact figure is quoted but several values fall within certain classes or groups. For example, grouping people according to their age ranging from 1-5, 6-10, 11-15, 16-20 to 85 and above.

Classification of statistical data

Data are classified into three main categories on the basis of sorting or distribution; unit of measurement; and methods and sources. Basing on sorting or distribution data is classified into ungrouped and grouped data. Ungrouped data (raw data) is concerned with raw facts that have been collected from the experiment or study and usually not sorted into categories. For example; 10, 15, 20, 25 and 30 vehicles. Furthermore, when expressing number of houses, people, employee and eggs we use whole numbers and we normally list them. Grouped data (array data) refers to a set of raw numerical facts that has been sorted or distributed into categories. For example; Tsh 10 001- 20 000, 20 001-30 000 and 30 001 - 40 000 or heights of people in centimetres 151-160, 161- 170, 171 - 180 and 181-190.

On the basis of unit of measurements, there are two types of data namely, categorical (qualitative) and numerical (quantitative). Categorical data are measures that normally describe the characteristics of the studied subject and can be in the form of text, graphics, art, image or symbol. Categorical data are further grouped into nominal and ordinal data. Nominal data are labeled or named data without quantitative measure and often without logical sequence. For example, marital status, occupation, common elements of weather and Yes/No responses. Likewise, ordinal data are labeled or named data without quantitative measure but with logical sequence. For example, satisfaction, opinion or feelings. Numerical data, are measures expressed in numbers. Numerical data are further grouped into discrete and continuous data. Numerical data corresponds to interval and ratio data.

On the basis of methods and sources, data can either be primary or secondary. Primary data refers to the first-hand raw facts from an experiment or field. They are original and freshly gathered from the source. Primary data have several uses or advantages including: originality and independence which increase validity and enhance reliability of the data. They are used in both quantitative and qualitative studies. These are the only data which can explore from the hidden information through appropriate approaches. The data can also be transformed to secondary data after analysis. Primary data however, are likely to be influenced by expenses and time consumed in collecting them. They are generally difficult to collect due to their complexity and high demand of commitment. Unlike the primary data, secondary data means second-hand data in published or unpublished form that was earlier collected by some one else and often passed through statistical analysis and usage. Secondary data can be obtained from public or private offices and searched from websites and internet sources. Secondary data have a number of merits to researchers such as: easy manageability; time saving and low cost of accessing them. In addition, some are readily available in analysed form; useful in updating the existing data and demand less field work. However, the applicability of secondary data are limited in terms of lack of means to validate them; demand expertise; and less accuracy and reliability compared to primary data. Table 1.1 indicates the differences between primary and secondary data.

Table 1.1: *Distinction between primary and secondary data*

S/N	Description	Primary data	Secondary data
1.	Source	Original sources	Secondary sources
2.	Methods of collection	Observation, questionnaires, interview, focus group discussion, and measurements	Review of documents such as books, journals, magazines, research publications and websites sources
3.	Statistical process	Not done	Done

S/N	Description	Primary data	Secondary data
4.	Originality of data	Original or first hand	Not original or second hand
5.	Use of data	For specific purpose data are compiled	For the purpose it was established
6.	Methods of data collection	Given	Not necessarily given
7.	Time consumed	More	Less
8.	Cost and accuracy	Accurate and expensive	May not be accurate but cheap

Types of variables

A variable is any characteristic, number or quantity of a person, object or phenomenon that can be measured or counted. A variable may also be called a data item that varies in magnitude. There are different ways in which statistical variables are described depending on the way they are studied. Variables are grouped basing on the scale of measurement, study designs and association. Basing on the scale of measurement variables are described as numerical and categorical; while in the study design they are described as active and attribute variables; and in causal relationships they are dependent and independent variables (Figure 1.2).

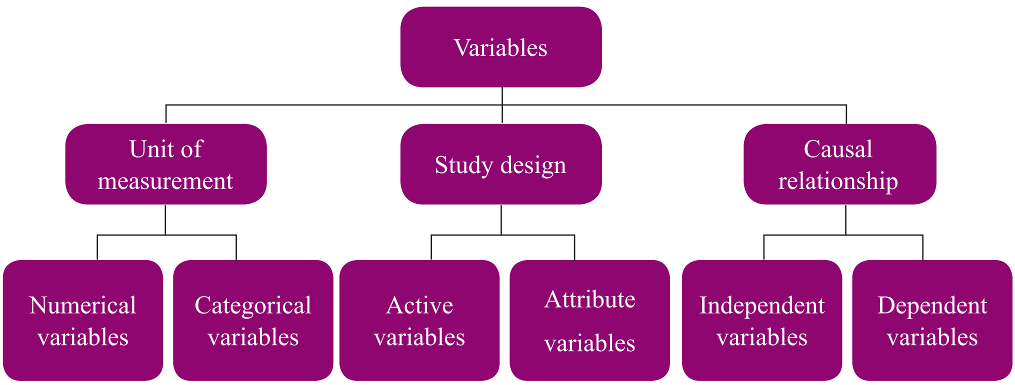


Figure 1.2: *Schematic representation of variables and respective classification criteria*

Numerical variables are variables that can be described as either continuous or discrete variables. The measurements for these variables are numbers. Continuous variable refers to quantitative variable which take any value in measurements normally within some ranges. They can be expressed in decimal places or fractions, Example of continuous variables are; height, time, age and temperature. Discrete variables are quantitative variables, which take isolated values in measurements. In other words, they are variables which cannot be expressed in form of a fraction or decimal places. Examples of discrete variables include the number of registered cars, houses and children which are all measured as whole number.

Categorical variables categorical variables are qualitative in nature as they are represented by non-numeric values. They normally take a form of text, image or symbol. Based on the nature of data, categorical variables are classified as ordinal or nominal variable. Ordinal variables deal with the value that can be logically ordered or ranked higher or lower than another without establishing a numeric difference. Examples of ordinal categorical variables include academic grade such as A, B and C; and clothing size such as small, medium, large and extra-large. Nominal variable deals with values and the classification of variables in which the logical sequencing of variables is not applicable.

Active and attribute variables differ with regard to manipulation. Active variables are those that can be manipulated, changed or controlled. Active variables are independent variables. While attribute variables are variable that cannot be manipulated, changed or controlled, and that reflect the characteristics of the study population. For example age, weight, height, income and level of education.

Independent and dependent variables

Independent variables are not usually affected or influenced with external factor for change. For example, someone's age cannot be influenced to change by either eating or better health services. *Dependent variables* are easily affected or influenced by external factors for change. For example, temperature, amount of rainfall, body weight and academic performance are all likely to be affected or influenced by external factors. Generally, a *dependent* variable depends on the independent variable. The statistical measure that indicates the extent to which two or more variables are related is known as *correlation*. Correlation is concerned with quantifying the degree and direction to which two variables are related. It can be positive, negative or zero relationship. Though in correlation it is observed that change in one variable may result to a change on another still such a change on the latter does not often imply causation. Sometimes there may be an unknown factor that affects both variables in the same way. A relevant example of correlation is good market price of agricultural produce which may result into the increased production of crop since farmers enjoy good prices. Similarly, a relatively large Geography class may be associated with poor performance of the students.

Relationship between variables

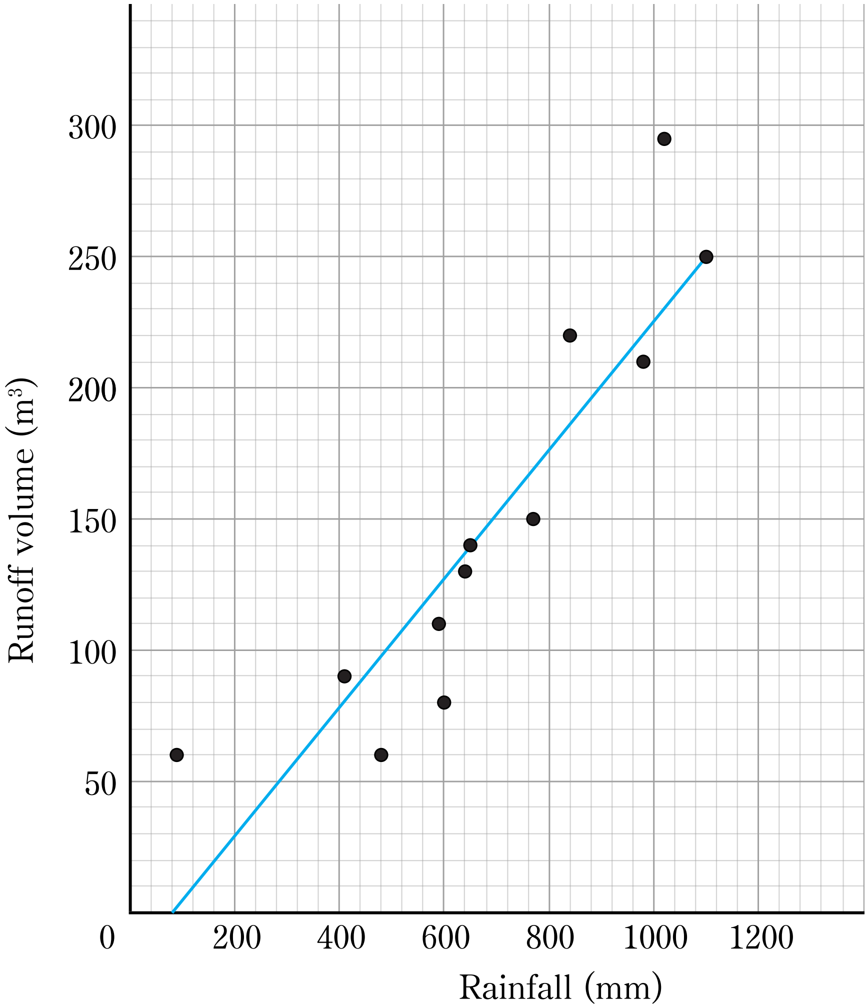
Variables are related in three different ways namely positive, negative and no relationship as subsequently described as follows.

(i) *Positive relationship.*

This is the relationship which exists when an increase in independent variable results to an increase in dependent variable and a decrease in independent variable results to a decrease in dependent variable. For example, enrolment of form five students at Mtakuja High School increased with time for four consecutive years (2012-2015) as shown in Table 1.2 and Figure 1.3.

Table 1.2: *Annual rainfall and runoff generated in the hypothetical catchments*

Rainfall (mm)	90	410	480	600	590	640	650	770	840	980	1020	1100
Runoff (m^3)	60	90	60	80	110	130	140	150	220	210	295	250



Scale: Horizontal scale: 1 cm to 200 mm; Vertical scale: 1 cm to 50 m^3

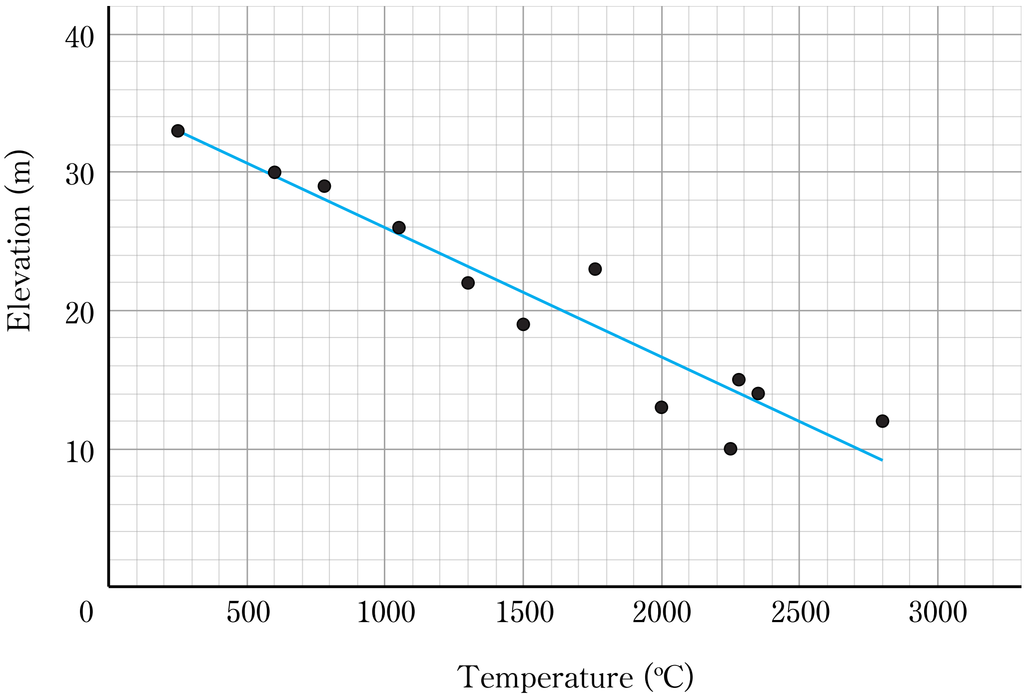
Figure 1.3: *Positive relationship*

(ii) *Negative relationship*

This is a relationship where the variables are negatively or inversely related that is, when independent variables increase, the dependent variables decreased. For example, crop production decreases with time for five consecutive years as shown in Table 1.3 and Figure.1.4.

Table 1.3: *Temperature recorded on a hypothetical land with varying elevation*

Elevation (m)	250	600	780	1050	1300	1500	1760	2000	2250	2280	2350	2800
Temperature (°C)	33	30	29	26	22	19	23	13	10	15	14	12



Scale: Horizontal scale: 1cm to 500 m; Vertical scale: 1cm to 5 °C

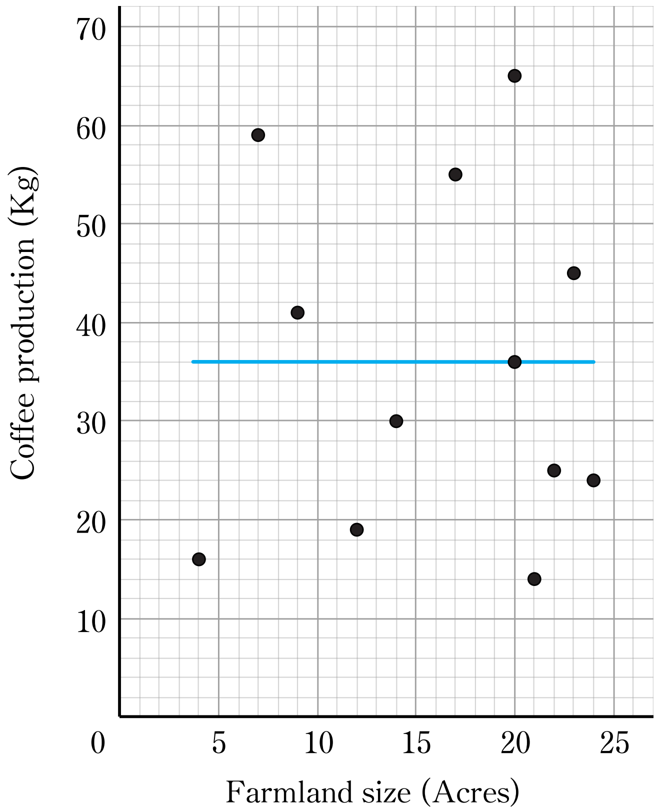
Figure 1.4: *Negative relationship*

(iii) *No relationship*

This occurs, when there is no direct relationship between variables. As such, change in one variable does not cause any change to the other. For example, the number of students who scored division one in a certain school for five consecutive years as shown in Table 1.4 and Figure 1.5.

Table 1.4: *Coffee production on farmlands of different sizes.*

Farmland size (Acres)	12	9	14	7	17	4	20	20	21	22	24	23
Coffee production (Kg)	19	41	30	59	55	16	36	65	14	25	24	45



Scale: Horizontal Scale: 1cm to 5 acres; Vertical Scale: 1cm to 10 Kg

Figure 1.5: *No relationship*

Activity 1.1

1. (i) In groups of five students, survey your school premises including offices and library and identify five types of data commonly recorded at the school.

   (ii) Describe the uses of the identified types of data within the school.

2. Using the test scores for your class from the school notice board where monthly tests results are posted for six months, identify the independent and dependent variables.

Exercise 1.1

1. Distinguish between the following statistical terms:
   (a) Data and information
   (b) Data and variables
   (c) Discrete and continuous data
2. Explain at least four uses of data in our daily life.
3. Describe the criteria used to classify data.
4. What are the types of variables?
5. Both primary and secondary sources of data are of paramount importance. Elaborate on this statement.

6. State at least two differences between the following types of data:
   (a) Categorical and numerical
   (b) Single and grouped
   (c) Discrete and continuous

Statistical measures

The common important statistical measures that are used to summarise and describe data are: measures of central tendency, measure of dispersion and measures of asymmetry (skewness). Measures of central tendency and measures of dispersion are also called summary statistics. The measures of central tendency computed from the entire population are called *parameters* whereas the measures obtained from the sample are called *statistics*. Parameter is a descriptive property of the population while statistics is a descriptive property of a sample (Figure 1.6). Regardless of the similarity of procedures adopted in obtaining parameters and statistics, they are often expressed by different symbols. For example, the mean for population is symbolised with a Greek letter μ (pronounced as mew) while that of a sample is symbolised by Latin letter $\bar{x}$ (*x* bar). Still the difference is also maintained in expressing measure of dispersion. For example, standard deviation which is one of the parameters of dispersion when addressing a population is abbreviated by a Greek letter σ (pronounced as sigma) while when addressing with a sample standard deviation as one of the sample statistic is expressed by small letter "s". Measure of central tendency and measure of dispersion enable a geographer to summarise the data in a frequency distribution with a single number and make interpretation of the obtained statistical information.

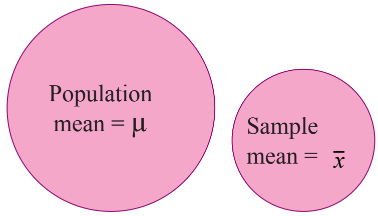


Figure 1.6: *Illustration of mean for a population and sample*

Measures of central tendency

In frequency distributions, the tabulated values show a distinctive tendency to cluster or to group around a typical central value. The characteristics of the data to concentrate the values around a central part of distributions is termed as *central tendency* of the data. In other words, central tendency is the *average*. An average is a single value within a range of the data that is used to represent the entire values in a series. Both central tendency and average are concerned with central values. Based on these concepts measure of central tendency (average) is a single value that is used to describe a set of data by identifying the central position within the given set of data. It is the value tends to lie centrally within the set of data arranged according to the magnitude that is in ascending order. Measure of central tendency enables one to compare two or more distributions pertaining to the same period of time or within the same distribution over time. For example, the average consumption of tea in two different geographical areas for two years, say 2003 and 2004, can be obtained by means of an average.

The most commonly used measures of central tendency are ***mean, mode*** and ***median***. All measures of central tendency are useful, however, in different conditions some have become more appropriate than others. It is thus, important to understand a good measure of central tendency. Often a good measure possesses some main characteristics such as easy to understand; simple to compute; based on all observations; uniquely defined; has possibility of further algebraic treatment; Possesses sampling stability and not unduly affected by extreme values. Simple statistical measures of central tendency can be calculated by various formula using both individual and grouped data as indicated in the subsequent subsections:

(a) *Mean*

This is sometimes referred to as arithmetic mean. It should, be noted that mean is not a synonym of average. Instead measures of central tendency and averages are used interchangeably. Mean is the most popular measure of central tendency and may be defined as the value which we get by dividing the total of the value of various given items in a series by the total number of items. Mean is often used in reporting the weather and climate specifically for elements like temperature and rainfall. For instance, in Tanzania, we have been frequently hearing the reports and information related to the changes in mean annual temperatures and rainfall from sources such as the Tanzania Meteorological Authority (TMA). Thus, mean can be used to compute the central values of different variables and explain its importance on the phenomena in question. For example, the mean agricultural and livestock produce/yield. Mean is categorised into arithmetic mean, geometric mean, harmonic mean and quadratic mean. In this book, only arithmetic mean has been covered.

(i) *The mean of ungrouped data*

This is obtained by diving the sum of value or scores in the range of individual data by the number of observations. It is the sum of all values in the set divided by the number of observations.

Procedures

The following are procedures for calculating mean of ungrouped data.

1. Find the sum of all data values or observation
2. Divide by the total number of observation

Sample mean $\bar{x}$

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

Population mean μ

$$\mu = \frac{\sum_{i=1}^{N} x_i}{N}$$

Where;

n = number of data values in the sample population

N = number of data values in the population

Σ = means summation of

xi = score or observations

Using the notation $\sum_{i=1}^{n} x_i$ we can write:

$$\sum_{i=1}^{n} x_i = x_1 + x_2 ... + x_n$$

Example:

1. Study the data given in the Table 1.5 showing passengers transported by the TAZARA in ‘000 thousands from 2010 to 2016

Table 1.5: *Passengers transported by the TAZARA in ‘000 thousands from 2010 to 2016*

Year	2010	2011	2012	2013	2014	2015	2016
Passengers in ‘000 thousands	758	414	678	654	287	327	440

Source: Ministry of Works, Transport and Communication (2016)

Compute the sample mean

Solution:

$$\bar{x} = \frac{\sum_{i=1}^{N} x_1}{n}$$

$$\bar{x} = \frac{758 + 414 + 678 + 654 + 287 + 327 + 440}{7} = \frac{3\,558}{7}$$

$$\bar{x} = 508.2857 \approx 508$$

Therefore, this means that on average; the passengers transported by TAZARA per year were 508 000.

For data set with frequencies

The mean of ungrouped data with frequencies (Table 1.6) can be calculated by using similar procedures.

Table 1.6: *Scores of a given sample*

x_i	Frequency (f)
1	3
2	4
3	6
4	2
5	5

Procedures

The following are procedures for calculating mean of ungrouped data with frequence

(i) Multiply the data (x) against the respective (f) to get (fx).

(ii) Sum the product (fx)

(iii) Divide by the total frequency ($\sum f$)

Example, use data in Table 1.7 for street “A” to calculate the mean of ungrouped data

Table 1.7: *Score for a given sample*

x	f	fx
1	3	3
2	4	8
3	6	18
4	2	8
5	5	25
	$\sum f = 20$	$\sum fx = 62$

Solution

A formula for calculating mean for frequency table is $\bar{x} = \frac{\Sigma fx}{\Sigma f}$.

Where;

f = frequency

x = score

$\sum f = 62, \sum f = 20$

$$\bar{x} = \frac{62}{20}$$

$= 3.1$

Therefore the central value for the score of a given sample is 3.1

Mean of grouped data

This is useful when someone has a big range of data which are supposed to be grouped into classes to facilitate further calculations. Mean in the grouped data can be computed by using two methods namely; assumed mean method and direct method (shortcut method).

Example:

Find the mean of the following population data for town "K".

Table 1.8: *Data for town "K"*

Class interval	Frequency (*f*)
0-2	2
3-5	5
6-8	6
9-11	2
12-14	2
15-17	4
18-20	6

Procedures

(i) Arrange the data in class interval. For example, 0 - 2, 3 - 5, 6 - 8, 9 - 11, 12 - 14, 15 - 17, 18 - 20.

(ii) Find the midpoint/classmark of each of the class interval (x).

(iii) Draw a table with required columns for class interval, frequency (f), midpoint x_i and fx_i.

Table 1.9: *Data for town "K"*

Class interval	Frequency (*f*)	Mid-point (x_i)	fx_i
0-2	2	1	2
3-5	5	4	20
6-8	6	7	42
9-11	2	10	20
12-14	2	13	26
15-17	4	16	64
18-20	6	19	114
TOTAL	$\sum f = 27$		$\sum fx_i = 288$

(iii) Calculate the mean of grouped data

Mean is given by

$$\bar{x} = \frac{\sum_{i=1}^{n} fx_i}{\sum f}$$

$\sum fx_i = 288, \ \sum f = 27$

$$\bar{x} = \frac{288}{27}$$

$= 10.6666$

Therefore, the central value for the score of a given sample is 10.67

Calculating mean by assumed mean method

When the values or scores under observation are extremely large and in fractions, the use of the direct method becomes inconvenient. As a result the use of the assumed mean method can be done. Assumed mean method is also known as the assumed mean method. The method uses the concept of the arbitrary mean or assumed mean.

Example:

Find the mean of school Y students' scores in Geography using the mean by assumed mean method.

Table 1.10: *School Y students' scores in Geography*

Scores	*f*
0-10	4
10-20	8
20-30	11
30-40	15
40-50	12
50-60	6
60-70	2

Procedures

(i) Find the midpoint/class mark of each class interval (x);

(ii) Assume one value as mean. In the table, the largest f is on intervals 30-40, which also happens to be almost in the centre of the distribution, 35 is taken as assumed mean;

(iii) Subtract the arbitrary mean from each value of mid-point and the resultant value is shown in column d;

(iv) Multiply each d by respective frequencies (f) to get (fd);

(v) Find the algebraic sum of the $\sum fd$ and divide this sum by $\sum f$

(vi) Sometime $\sum fd$ will be positive and sometimes negative;

(vii) Multiply this value by class mark. This gives the correction factor to be applied to the Assumed Mean; and

(viii) The assumed Mean + the correction factor = the Actual Mean. Correction factor is computed by $\sum f$.

Table 1.11: *School Y students' scores in Geography*

Scores	Mid-point	*f*	*d*	*fd*
0-10	5	4	-30	-120
10-20	15	8	-20	-160
20-30	25	11	-10	-110
30-40	35	15	0	0
40-50	45	12	10	120
50-60	55	6	20	120
60-70	65	2	30	60
		$\sum f = 58$		$\sum fd = -90$

The formula for calculation of the mean by the assumed mean method is given below:

$$\bar{x} = A + \frac{\sum fd}{\sum f}$$

Where:

A = arbitrary or assumed mean

f = frequency

d = deviation from the arbitrary or assumed mean

$\sum f$ = number of data values in the population

Assumed mean (A) = 35, the correction factor for the difference between the actual mean and the assumed mean ($\sum fd$) = -90 and $\sum f$ = 58.

$$\bar{x} = 35 + \frac{(-90)}{58}$$

= 35 + (-1.55)

= 33.45

Therefore, the central scores for the school Y students in Geography is 33.45

Calculating mean by direct method

The same data in Table 1.12 can be used to calculate mean by direct method. For example; use data for school "Y" to calculate mean for grouped data by direct method.

Table 1.12: *School Y students' scores in Geography*

Scores	Mid-point	*(f)*	fx_1
0-10	5	4	20
10-20	15	8	120
20-30	25	11	275
30-40	35	15	525
40-50	45	12	540
50-60	55	6	330
60-70	65	2	130
		$\sum f = 58$	$\sum fx_i = 1940$

$$\bar{x} = \frac{\Sigma fx_i}{\Sigma f}$$

$$= \frac{1940}{58}$$

= 33.45

Therefore, the central score of the school Y students in Geography is 33.45

Advantages and disadvantages of mean

The use of mean in analysing and summarising data has both advantages and disadvantages. Some of the advantages are in cases of small data set it is fast and easy to calculate; it includes all values in the distribution; it is useful for statistical summarisation of data; and it is used for making comparison in statistical data. It is also widely understood compared to other averages and suited to further statistical analysis. Some of the disadvantages are: the mean is highly distorted by *outliers*. Outliers refer to the extremely high or low values in the observation. It is also impossible to locate the mean by inspection as in the case of mode and median. Value of mean will be effective only if the frequency is normally distributed. Otherwise in case of skewness the results become ineffective.

(b) *Median*

The median is value of the middle item. This is a middle item for a set of data that has been arranged in order of magnitude or the point below and above 50 % of the scores in distribution (the mid-point in a distribution). There are for grouped data and un-grouped data.

Median for individual data

Procedures

The following are procedures to be observed in calculating the median for un-grouped data.

(i) Arrange data in ascending or descending order.

(ii) If the total number of items is in odd, add 1 to the total number of observations (n) then divide by 2 to acquire the position of median.

(iii) The value of the median for un-grouped data is given by the expressions below:

$$\text{Median} = \text{Value of the} \left(\frac{n+1}{2}\right)^{th}$$

term in a ranked data set.

Note: the expression is purposely for finding the position of the mid value.

Examples

1. Study the data in Table 1.13: which shows production of cashew nut '000 tonnes in Tanzania from 2012 to 2016, and find the median.

Table 1.13: *Production of cashew-nut in Tanzania*

Year	2012	2013	2014	2015	2016
Cashew nut production in tonnes	160	128	130	198	155

Solution

The values of production are arranged in ascending order = 128, 130, 155, 160, 198

$n = 5$, then

The $\left(\frac{n+1}{2}\right)^{th}$ value $= \frac{5+1}{2} = 3$ this means the mid value is on the 3rd position of the data set

That is the median is 155 ('000) tonnes which mean the mid value of production throughout five years of cashew-nut production.

When the total of the range (values) is even, median is obtained by adding the two central values and divide by 2.

Example:

Study the data in Table 1.14 showing the total monthly rainfall recorded in Tanzania in the year 2016 and find the median.

Table 1.14: *Total monthly rainfall recorded in Tanzania in the year 2016*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly total rainfall (mm)	191.8	131.2	14.0	213.6	41.1	9.2	2.2	8.3	14.1	27.8	64.6	66.6

Source: *Tanzania Meteorological Agency (2016)*

Solution

Arrange the value of temperature in ascending order:

That is 2.2, 8.3, 9.2, 14.0, 14.1, 27.8, 41.1, 64.6, 66.6, 131.2,191.8, 213.6

The position of the mid value is given by the expression $\left(\frac{n+1}{2}\right)^{th}$ value $= \frac{12+1}{2}$ $= 6.5$ this means the position of the mid value is at 6.5 position. In this case mid value is obtained by finding the mean of the 6th and 7th (the two middle) values in the data set. The 6th value is 27.8 and the 7th is 41.1 =

$$\frac{27.8+41.1}{2} = \frac{68.9}{2} = 34.45 \approx 34.5 \text{ mm}$$

Therefore, the median value for rainfall is 34.5 mm which is the mid value of the rainfall in twelve months.

Median for grouped data

Use the given data in Table 1.15 which show the distribution of students' scores for school "Y" in Tanzania to calculate median of grouped data.

The following are the procedures for calculating the median for grouped data.

(i) Construct the cumulative frequency distribution.

(ii) Decide the class that contain the median. Median class is the first class with the value of cumulative frequency equal to or at least $\frac{n}{2}$.

(iii) Find the median by using the following formula

$$\text{Medium} = L_m + \left(\frac{\frac{n}{2} - cf}{f_m}\right)i$$

Where;

n = the total frequency

cf = the cumulative frequency before median class

f_m = the frequency of the median class

i = the class interval or class width

L_m = the lower boundary of the median class

Note: Lower boundary of each class is calculated by subtracting half of the gap value from the class lower limit. For example, 10 - 0.5 = 9.5. 0.5 is used because the gap value is 1.

Table 1.15: *Distribution of students' scores for school "Y" in Tanzania*

Class interval	Frequency (f)	Cumulative (cf)
0 – 4	2	2
5 – 9	6	8
10 – 14	10	18
15 – 19	8	26
20 – 24	4	30

$$\text{Median} = 9.5 + \left(\frac{\frac{30}{2} - 8}{10}\right)5$$

$$= 9.5 + \left(\frac{15 - 8}{10}\right)5$$

$$= 9.5 + \left(\frac{7}{10}\right)5$$

$$= 9.5 + 3.5$$

$$= 13$$

Therefore, the mid value for the score is 13.

Advantages and disadvantages of median

The major advantages from the use of median in statistical geography are: it is easy to understand because of considering half way point of the data set under observation. Therefore, it is suitable for distributions with extreme values. The median is not distorted by the extreme value(s) in distribution; and relevant in skewed data distribution. However, median has some limitations such as unsuitability for further mathematical treatment or advanced statistical processing; not based on all values under observation; compared to mean, median is highly affected by the fluctuation of sampling. Furthermore, it is not reliable in testing geographical hypothesis, particularly in advanced levels of the field of Geography.

(c) ***Mode***

Mode is the most frequent score in a distribution. The mode of a set of data is the observation which occurs most frequently. It is also defined as a point of maximum frequency density in continuous data. It is presented by the highest column (s) in the histogram. In some data set, the mode may not exist, and if it does, there may be two or more modes. The occurring mode can be either uni-modal, bimodal or multi-modal. Mode is one of the useful averages in the field of climatology as it can be used in the classification of weather patterns in various geographical areas. In case of Tanzania, many areas receive rainfall per season called uni-modal areas while the rest of areas receive two seasonal rainfall called bimodal areas. Some of the areas that receive bimodal rainfall include Dar es Salaam, Musoma, Morogoro, Tanga, Kagera and some parts of Mwanza region. There are also areas that receive three seasonal rainfall per year, such a pattern is called trimodal.

Mode for the ungrouped data

Uni-modal occurs when there is one (1) mode value in a distribution. For example; 4, 5, 6, 6, 7, 8, 9, 10, 10, 10.

Mode is 10. Because; it has occurred three times.

Bimodal is when set of data has two modes, for example, 1, 2, 3, 3, 4, 4, 4, 5, 5, 6, 6, 6 11. The modes are 4 and 6. This is because; they have both occurred three times.

Multi-modal exist when data set has more than two modals, for example; 1, 3, 5, 8, 9, 2, 4, 8, 7, 20, 5, 6, 2, 1, 2, 3, 4, 5, 5, 6, 7, 8, 8, 9, 20, 2.

The modes are 2, 5 and 8. This is because; these numbers have more occurrences than others.

Mode for the grouped data

In grouped data, mode can be calculated by the following formula:

$$\text{Mode} = L_m + \left(\frac{t_1}{t_1 + t_2}\right) i$$

Where;

L_m = the lower limit of the modal class

t_1 = the frequency of the modal class minus frequency before the modal class. That is the difference between the frequency of modal class and frequency of premodal class.

t_2 = frequency of the modal class minus frequency after the modal class. That is the difference between frequency of modal class and frequency of post modal class.

i = class width or the size of the class interval.

Example:

Study the Table 1.16 and then find the mode.

Table 1.16: *Distribution of scores*

Class interval	Frequency
40 – 44	7
45 – 49	8
50 – 54	11
55 – 59	10
60 – 64	7

Solution

Given

$L_m = 49.5,$

$t_1 = (11 - 8)$

$= 3$

$t_2 = (11 - 10)$

$= 1$

$i = 5$

Using the formula for the mode:

$$\text{Mode} = 49.5 + \left(\frac{3}{3+1}\right)5$$

$$= 49.5 + \frac{3}{4} \times 5$$

$$= 49.5 + 3.75$$

$$= 53.25$$

Therefore, the maximum frequent denoted for the scores is 53.25

Estimating a mode from a histogram

Mode from the grouped data can be derived from the histogram. For example, using score distribution from Table 1.14, a mode can be determined from histogram.

Procedures

The following are procedures for estimating mode from histogram

(i) Draw a Histogram;

(ii) Identify the modal class represented by the tallest bar.

(iii) Draw the cross lines as shown in the diagram;

(iv) Draw a perpendicular doted line from the intersection of the two lines until it touches the horizontal axis as shown in Figure 1.7; and

(v) Read the mode at the intersection of the perpendicular line with the horizontal axis.

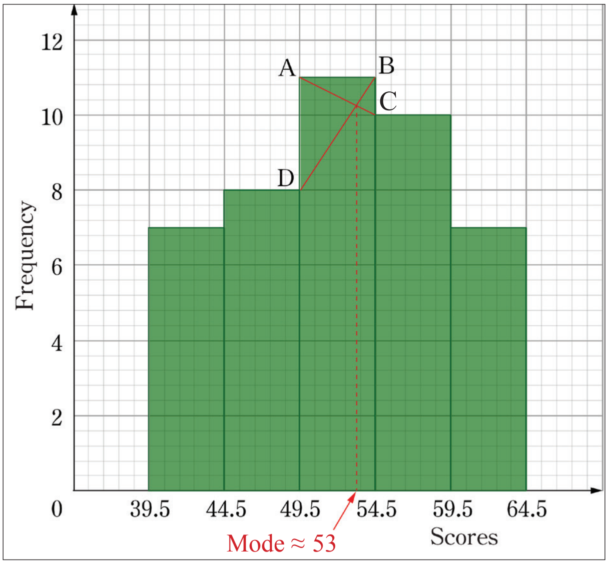


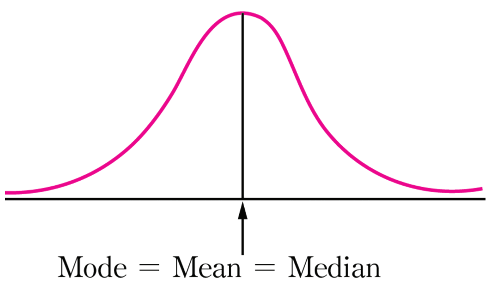
Figure 1.7: *Estimating a mode from a histogram*

Advantages and disadvantages of a mode

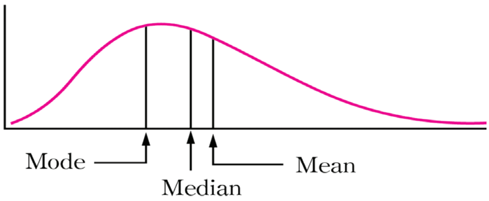
Mode is of paramount importance in geography. Some of its advantages are that: it is not affected by the occurrence of a few extreme values under the distributions; and it, determines various phenomena such as the magnitude of agricultural production or the trend of commodities. In addition, it is the only average to be opted for categorical data; easy to read and interpret in the given data; and easy to understand, calculate and interpret. However, mode is disapproved of the various limitations. It is not strictly defined in such a way that it is unstable with large samples; it is not based on all data values under observation; and it is not suitable for further mathematical treatment. Its existence when data are the same in some of the distributions discourages its use in analysis of data and its usefulness is less common in advanced statistical geography. Compared to mean, mode is severely affected by the fluctuation of sampling.

Relationship between different measures of central tendency

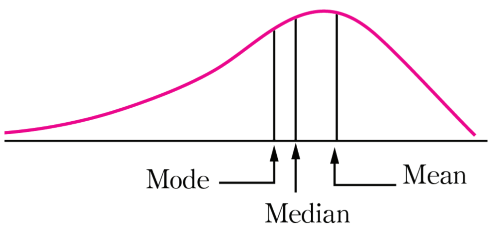
The various measures of central value give us one single figure that represents the entire data. But the average alone cannot adequately describe a set of observations, unless all observations are the same. Measures of central tendency often portray some relationships between them. The relationship is determined by the nature and pattern of distribution of scores in the sample or population. Normally, the relationship between mean, median and mode of a population generates symmetrical and skewed curves. When the population mean, population median and mode are all located at the centre, they result to a symmetrical bell-shaped curve called normal distribution curve in which the curve can be divided into two equal halves (one half is a mirror image of the other) as shown in Figure1.8 (a). In this case mean = median = mode. In case the distribution is skewed to the right, it is positive skewness in which the longer tail is on the right side, then mean > median > mode. Generally, income distribution is skewed to the right where a large number of families have relatively low income and only a small number of families have extremely high income. In this case the mean is pulled up by the extreme high incomes and the relation among these three measures is as shown in Figure1.8 (b): that is mean > median > mode.



(a) Normal distribution curve



(b) Positive skewed distribution curve



(c) Negative skewed distribution curve

Figure 1. 8: *Types of distribution curves*

When a distribution is skewed to the left negative skewness in which the tail is on the left, then mode> median> mean. In this case, the mean is pulled down below the median by extremely low values as shown in Figure1.8 (c).

The general limitations of measures of central tendency

On summarising data, various measures of central value give us one single figure that represents the entire data from sample or population being studied. It should be noted that the average alone could not adequately describe a set of observations, unless all the observations are the same. Mean, median and mode fall short of indicating the extent of dispersion or variability in distribution. Dispersion and variability are important because they enable us to understand the pattern of the data, which is limitedly explained by the measures of central tendency. In some cases, two or more distributions can have same central value yet there can be a wide discrepancy in the formation of distribution. In this ground, measures of dispersion become helpful for us in understanding more characteristics of a distribution.

Activity1.2

Collect your class midterm and terminal examination scores in Geography; for each group find the mean, median, and the mode.

Exercise 1.2

Answer all questions

1. Why average is called a measure of central tendency?
2. Average has its own peculiar characteristics. It is difficult to say which average is the best. Explain with examples.
3. What do you understand by “central tendency”?
4. Under which conditions is the median more suitable than other measures of central tendency?
5. Find the mean, median and mode of the following and data graphically, then comment on the obtained values of the calculated central tendency.

Class interval	0-10	10-20	20-30	30-40	40-50	50-60	60-70
Frequency	4	18	30	42	24	10	3

Measures of dispersion

The degree to which numerical data tend to spread about an average value is called dispersion or variation of data. The measure of dispersion is also known as measure of variation or spread. Two distributions can have identical means and medians, yet their difference can be identified by using measures of dispersion. For example, the distribution of these data A: 18, 20, 25, 35, 39 and B: 2, 3, 25, 30, 75.

The mean in both of these distributions is 27 and the median in both is 25. However, the distribution differs greatly. Just by observing the distribution in A, the scores are closer together and tend to cluster around the mean distribution while in B the scores are much more spread out. The difference of two or more distributions is termed by the statisticians as variability. Measures of dispersion show how spread out or dispersed the data are, something that cannot be achieved by the measures of central tendency. As a result, the central tendency becomes less appropriate for some analysis.

Moreover, consider a statement that by 2014 the mean annual salary for public servants in Tanzania was 200 billion. This claim falls short of hiding information on the fact that some workers earned far less than the mentioned amount and others earned more than 200 billion. Therefore, knowing the mean is insufficient to understand the entire distribution of workers' salaries. This limitation pave way to the need for applying other statistical measures that are capable of describing the spread or variability that exists within the distribution of a given data set. The commonly used measures of spread are range, mean deviation, variance and standard deviation.

(a) *Range*

Range is the difference between the smallest and the largest value in the distribution. The overall range represents the distance between the highest and lowest scores in the distribution.

Range for an individual data

Range can be calculated by subtracting the smallest value (S) from the largest value (L) in the distribution . Range is the difference between the maximum value and the minimum value of the data set. Range takes into consideration the extreme values in a data set.

Example:

Study the following distribution of data and calculate the range: 2, 3, 5, 7, 14, 15, 24, and 25.

Solution:

From the given data maximum value is 25 and the minimum value is 2.

The range = Maximum value (L) – minimum value (S) = 25 – 2 = 23

Therefore, the range = 23

(vi) The range for the grouped data

This is obtained by using the difference between mid-point of largest and smallest class interval. Consider the data in Table 1.17 and find the range.

Table 1. 17: *The distribution of scores*

Class interval	Frequency
15 – 19	2
10 – 14	1
5 – 9	1
0 – 4	2

Solution:

(a) Range = Highest upper class limit – Lowest upper class limit

$19 - 4 = 15$

Range = Highest lower class limit – Lowest lower class limit

$15 - 0 = 15$

(b) Range = Highest upper real limit – Lowest upper real limit

$19.5 - 4.5 = 15$

Range = Highest lower real limit – Lowest lower real limit

$14.5 - (-0.5) = 15$

$= 15$

Therefore $a = b$, the largest class interval is 15-19 and the smallest class interval is 0 - 4. Hence range is obtained first by computing the midpoint of the largest class interval and that of the smallest class interval as follows:

Midpoint of the largest class interval (L)

$= \frac{15+19}{2} = \frac{34}{2} = 17$

The midpoint of the smallest class interval (S) $= \frac{0+4}{2} = \frac{4}{2} = 2$

Thus, L – S = 17 – 2 = 15

Therefore, the Range = 15

Coefficient of range

Coefficient of range is the ratio of difference between the highest and lowest value of frequency to the sum of the highest and lowest value of frequency. It is a relative measure of the distribution based on the range of any given data set.

The coefficient of range is calculated by the formula: $\left(\frac{L-S}{L+S}\right)$. This is the relative measure.

Whereby;

L is the highest value in the frequency distribution

S is the lowest value in the frequency distribution.

In other words;

$$\text{The coefficient of range} = \frac{\text{Highest value in frequency} - \text{Lowest value in frequency}}{\text{Highest value in frequency} + \text{Lowest value in frequency}}$$

The coefficient of range is more appropriate for the purposes of comparison.

Example

Study Table 1.18 with two sets of data and calculate the coefficient of range separately.

Table 1.18: *Distribution of scores for two sets in class "H"*

Set 1	8	10	20	9	15	10	13	28
Set 2	30	35	42	50	32	49	39	33

Solution:

As shown in calculation, range of the two sets of data are the same:

Set 1 $28 - 8 = 20$

Set 2 $50 - 30 = 20$

Coefficient of range in Set 1 is:

$$\frac{28-8}{28+8} = 0.55$$

Coefficient of range in Set 2 is:

$$\frac{50-30}{50+30} = 0.25$$

The coefficient of range tells the degree of dispersion in a set of data. The larger the value, the higher the dispersion.

Advantages and disadvantages of the range

Range is opted because it is easy to calculate and understand. It also gives a quick estimate of variability in distribution. Regardless of the simplicity of obtaining range just by considering only two values of a set of data, it is important to many fields and individuals including statisticians, and geographers in many ways. It is used in circumstances which one intends to get a quick understanding of variability or a set of data. In case of small sample range is considered as a sufficient measure of the variability. For example, it is often used in quality control where a continuous check on the variability of raw materials or finished products is required. The range is also an appropriate measure in weather forecast. For example, in daily reports on weather forecast from Tanzania Meteorological Authority (TMA) we normally hear of maximum and minimum temperatures, rainfall, wind, and humidity and sunshine. Such statistical information may seem useless to some people but it is very important for others whose plans and activities need updates on weather so as to make appropriate decisions.

Range has some drawbacks. It is highly affected by the extreme values in a distribution, hence it cannot depict the nature of dispersion of items in a distribution. Range can mislead the interpretation of data if there were some errors during collection of raw data. It is also based on only two items, hence does not cover all the items in a distribution. The other weakness is its susceptibility to wide fluctuations from sample based on the same population. It fails to give any idea about the pattern of distribution; and in the case of open-ended distributions, it is impossible to compute range.

(b) ***Mean deviation (MD)***

The mean deviation is also known as the average deviation. Mean deviation denotes the amount by which individual value deviates from the mean in irrespective of sign (+ or −). The negative and positive signs are ignored during computation since the deviations are always equal irrespective of their signs. It is the average difference between various measurements and the mean.

Mean deviation for un grouped data

The formula for computing the mean deviation is given below.

$$\text{Mean deviation} = \frac{\Sigma\left|x_i - \bar{x}\right|}{n}$$

Where:

$\left|x_i - \bar{x}\right|$ = deviation of an item from the mean irrespective of positive and negative signs. It is the absolute difference between each value and the mean.

n = the total number of observations

Σ = summation

x = observation or values

Procedures

The following are procedures for calculating mean deviation

(i) Compute the mean of the given data set;

(ii) Find the individual deviation by subtracting the mean from each of the given data set as shown in the table below;

(iii) Sum the absolute deviation; and

(iv) Divide by the total number of observations or values.

Example:

Compute the mean deviation of the given data of a sample; 2, 3, 4, 5, 6

Solution:

$$\bar{x} = \frac{2+3+4+5+6}{5} = \frac{20}{5} = 4$$

Table 1.19: *Distribution of scores for class "D"*

x_i	$\bar{x}$	$\left|x_i - \bar{x}\right|$
2	4	2
3	4	1
4	4	0
5	4	1
6	4	2
n= 5		6

Thus, mean deviation (MD)

$$= \frac{\Sigma\left|x_i - \bar{x}\right|}{n} = \frac{6}{5} = 1.2$$

Therefore, the mean deviation is 1.2

Mean deviation for grouped data

This is obtained by using the following formular

$$\text{MD} = \frac{\Sigma f\left|x_i - \bar{x}\right|}{\Sigma f}$$

Example

Study the given scores for form five students in Benbella Girls Secondary School as shown in Table 1.20 and find the mean deviation (MD).

Table 1.20: *Scores for form five students in Benbella Girls Secondary School*

Scores	Frequency *f*
20-29	2
30-39	3
40-49	10
50-59	13
60-69	3
70-79	2
80-89	1

Solution

$$\text{MD} = \frac{\Sigma f\left|x_i - \bar{x}\right|}{\Sigma f}$$

Table 1.21: *Scores for form five students in Benbella Girls Secondary School*

Scores	f	Class mark (x)	fx	$\bar{x}$	$\lvert x-\bar{x}\rvert$	$f\lvert x-\bar{x}\rvert$
20-29	2	24.5	49	50.9	26.4	52.8
30-39	3	34.5	103.5	50.9	16.4	49.2
40-49	10	44.5	445	50.9	6.4	64
50-59	13	54.5	708.5	50.9	3.6	46.8
60-69	3	64.5	193.5	50.9	13.6	40.8
70-79	2	74.5	149	50.9	23.6	47.2
80-89	1	84.5	84.5	50.9	33.6	33.6
Total	$\sum f = 34$		$\sum fx = 1733$			$\Sigma f\lvert x-\bar{x}\rvert = 334.4$

From Table 1.21,

$$\bar{x} = \frac{\sum fx_i}{\sum f} = \frac{1733}{34} = 50.9$$

$$\bar{x} = 50.9$$

$$\text{MD} = \frac{\Sigma f\left|x_i - \bar{x}\right|}{\Sigma f} = \frac{334.4}{34} = 9.84$$

Therefore, the Mean deviation of score is 9.84

Advantages and disadvantages of mean deviation

The use of mean deviation in statistics has a number of advantages. It is simple to understand and easily calculated; it also takes into consideration all the dataset under observation and it is less affected by the extreme values. Since the deviations are taken from the central value, it is possible to make a meaningful comparison of the setup of different distributions.

However, mean deviation has the following weaknesses: it falls short of allowing further algebraic treatment; and it sometimes fails to give accurate results. Mean deviation gives best results when deviations are taken from the median rather than the mean. In a series, with wide variations in items, mean deviation is not a satisfactory measure; and from mathematical perspectives, the method is wrong for it disregards the algebraic signs when deviations are taken from the mean. Because of these limitations mean deviation is seldom used in geography studies. Such limitations pave the way to a better standard deviation which is often used in geography.

(c) ***Variance***

Population variance often denoted by s^2 is the mean of the squares of the differences between each data value and the mean. For the case of the sample, variance often denoted by S^2. Variance is also a measure of the spread between given scores or data set. Measures the distance of each number from the mean and from one number and the other. Therefore, the large variance indicates that scores are far from each other as well. It can be culculated for ungrouped and grouped data.

Procedures

The following are procedures for calculating variance

(i) Calculate the mean $\bar{x}$

(ii) Find the deviation from the mean $\left(x-\bar{x}\right)$.

(iii) Square the deviations from the mean $(x-\bar{x})^2$.

(iv) Sum all the square deviations and apply the formula.

Example:

The following distributions of scores; 2,7,3,12,9 can be used to calculate variance.

Solution

$$\bar{x} = \frac{2+7+3+12+9}{5}$$

$$= 6.6$$

Table 1.22 *Distributions of scores in a class of Practical Geography*

x	$\bar{x}$	$(x-\bar{x})$	$(x-\bar{x})^2$
2	6.6	– 4.62	21.16
7	6.6	0.4	0.16
3	6.6	–3.6	12.96
12	6.6	5.4	29.16
9	6.6	2.4	5.76
			$\sum_{i=1}^{n}\left(x-\bar{x}\right)^2 = 69.2$

The formular for computing variance is given below;

$$S^2 = \frac{\sum(x-\bar{x})^2}{N}$$

Where:

S^2 = Variance from sample

$\bar{x}$ = mean of sample

n = number in sample

From Table 1.20,

N = 5

$$\Sigma\left(x-\bar{x}\right)^2 = 69.20$$

Therefore;

$$S^2 = \frac{69.20}{5}$$

$$S^2 = 13.84$$

Advantage and disadvantages of variance

Despite the simplicity and accuracy in computation of the variance, its tendency to give more weight to extreme values by squaring them up remains a limiting factor.

(d) *Standard deviation*

It is the value which shows how far the scores are spread from the normal or how the numbers are spread in a distribution. It is the most common index of variability. Standard deviation (SD) can be calculated for individual or grouped data.

Procedures

Procedures involved in calculation of the standard deviation are:

(i) Calculate the mean of distribution;

(ii) Subtract the mean from each score;

(iii) Square each of these scores;

(iv) Add all the squares of these scores;

(v) Divide the total by the number of observation;

(vi) The result obtained in (v) above is called the variance; and

(vii) Take the square root of the variance; this will give the standard deviation(s).

The formula for computing standard deviation is given as:

$$S = \sqrt{\frac{\sum_{i=n}^{n}\left(x_i - \bar{x}\right)^2}{n}}$$

S = standard deviation from sample.

x = individual score

$\bar{x}$ = mean of sample

n = total number of observations in a sample

Standard deviation for individual data (ungrouped data).

Example:

Determine the standard deviation on scores for class "D"

1, 2, 3, 4, 5, 6, 6, 7, 8, 8

Solution

Table 1.23: *Standard deviation for individual data*

Score (x_i)	$\bar{x}$	$x_i - \bar{x}$	$(x-\bar{x})^2$
8	5	3	9
6	5	1	1
3	5	–2	4
7	5	2	4
2	5	–3	9
8	5	3	9
1	5	– 4	16
4	5	–1	1
6	5	1	1
5	5	0	0
$\sum_{i=n}^{n} x_i = 50$			$\Sigma\left(x_i - \bar{x}\right)^2 = 54$

$$\text{Mean } \left(\bar{x}\right) = \frac{\sum_{i=1}^{n} x_i}{n} = \frac{50}{10} = 5$$

Then standard deviation is computed by using the formula

$$S = \sqrt{\frac{\sum_{i=n}^{n}\left(x_i - \bar{x}\right)^2}{n}}$$

$$= \sqrt{\frac{54}{10}}$$

$$= \sqrt{5.4}$$

$$= 2.32$$

Therefore, the stanadard deviation on score for class 'D' is 2.32.

Standard deviation for grouped data formula:

$$S = \frac{\Sigma f\left(x_i - \bar{x}\right)^2}{\Sigma f} \quad \text{or}$$

$$S = \sqrt{\frac{\Sigma fx^2}{\Sigma f} - \left(\frac{\Sigma fx}{\Sigma f}\right)^2} \quad \text{or}$$

Example:

Study the Table1.24(a) which shows scores for Form Five students in school Y and find the standard deviation.

Table 1.24(a): *Scores for Form Five students in school Y*

Class interval	*f*
1 – 10	2
11 – 20	6
21 – 30	4
31 – 40	8
41 – 50	6
51 – 60	4
61 – 70	4
71 – 80	2
81 – 90	3
91 – 100	1

Solution

Table 1.24(b): *Scores for form five students in school Y*

Class Interval	Class-mark *(x)*	*f*	*fx*	$\bar{x}$	$(x-\bar{x})$	$(x-\bar{x})^2$	$f(x-\bar{x})^2$
1 – 10	5.5	2	11	43.75	–38.25	1463.06	2926.12
11 – 20	15.5	6	93	43.75	–28.25	798.06	4788.36
21 – 30	25.5	4	102	43.75	–18.25	333.06	1332.24
31 – 40	35.5	8	284	43.75	–8.25	68.06	544.48
41 – 50	45.5	6	273	43.75	1.75	3.06	18.36
51 – 60	55.5	4	222	43.75	11.75	138.06	552.24
61 – 70	65.5	4	262	43.75	21.75	473.06	1892.24
71 – 80	75.5	2	151	43.75	31.75	1008.06	2016.12
81 – 90	85.5	3	256.5	43.75	41.75	1743.06	5229.18
91 – 100	95.5	1	95.5	43.75	51.75	2678.06	2678.06
Total		**Σf=40**	**1750**				$\sum f(x-\bar{x})^2$ **= 21977.4**

$\sum f = 40$

$\sum fx = 1750$

$$\bar{x} = \frac{\sum fx}{\sum f} = \frac{1750}{40} = 43.75$$

$\sum f(x-\bar{x})^2 = 21977.4$

From the given formula:

$$= \sqrt{\frac{\sum f(x-\bar{x})^2}{\sum fx}}$$

$$= \sqrt{\frac{21977.4}{40}}$$

$$= \sqrt{549.44}$$

$$= 23.44$$

Therefore, the standard deviation of score for form five students in school Y is 23.44

Alternatively, data in Table 1.24(a) can be used to calculate the standard deviation for grouped data using the formula;

$$S = \sqrt{\frac{\sum fx^2}{\sum f} - \left(\frac{\sum fx}{\sum f}\right)^2}$$

The answer for S will be the same for same data.

Solution

Table 1.25: *Summation of scores for form five students in school Y*

Class Interval	f	x	x^2	fx^2	fx
1 – 10	2	5.5	30.25	60.5	11
11 – 20	6	15.5	240.25	1441.5	93
21 – 30	4	25.5	650.25	2601	102
31 – 40	8	35.5	1260. 25	10082	284
41 – 50	6	45.5	2070.25	12421.5	273
51 – 60	4	55.5	3080.25	12321	222
61 – 70	4	65.5	4290.25	17161	262
71 – 80	2	75.5	5700.25	11400.5	151
81 – 90	3	85.5	7310.25	21930.75	256.5
91 – 100	1	95.5	9120.25	9120.25	95.5
Total	**40**			**98540**	**1750**

$\sum f = 40$

$\sum fx^2 = 98540$

$\sum fx = 1750$

$$S = \sqrt{\frac{\sum fx^2}{\sum f} - \left(\frac{\sum fx}{\sum f}\right)^2} = \sqrt{\frac{98540}{40} - \left(\frac{1750}{40}\right)^2}$$

$$= \sqrt{2463.5 - (43.75)^2}$$

$$= \sqrt{2463.5 - 1914.0625}$$

$= \sqrt{549.44}$

$= 23.44$

Therefore, standard deviation of score for form five students in School Y is 23.44

Interpretation when using standard deviation for individual data

The result of the calculated standard deviation is 23.44. SD can easily be interpreted when calculated and compared from two or more separate groups on the same subject studied. For example, SD for students' scores in Geography terminal examination. The greater the SD in one of the group say stream A compared to stream B will mean that the spread of the scores in stream A is greater compared to that of stream B . While dealing with standard deviation it should be noted that if the calculated standard deviation is a large value, it means the scores are more spread. Thus, the greater the standard deviation the greater the spread of the scores. The closer the scores are to the mean, the less spread they are, hence the smaller the standard deviation.

Strength and weakness of standard deviation

Standard deviation is proved to have strengths as follows. It is strictly defined and its value is always definite and based on all observations. It uses the actual signs of observations; it is based on arithmetic mean; hence it has all merits of arithmetic mean. It is the most important and widely used measure of dispersion; and gives possibility for further algebraic expression. Furthermore, it is minimally affected by the fluctuations of sampling, hence it is stable and it creates a basis for measuring the coefficients of correlations and sampling.

Despite its strength, standard deviation has some weaknesses such as: it is complex to understand and calculate; its tendency to give more weight to extreme values by squaring them up during computation is a drawback; and it is an absolute measure of variability, hence it cannot be used for comparison purposes.

Activity 1.2

1. In a group of 10-20 students take measurements of height for each member in the group and record in a tabular form. Basing on tabulated data calculate the following:
   (i) Range
   (ii) Mean deviation
   (iii) Variance
   (iv) Standard deviation

   Then, present your results to the class for extensive discussion.

2. Combine your data with other three groups in the class and calculate the following:
   (i) Range
   (ii) Mean deviation
   (iii) Variance
   (iv) Standard deviation

3. Using Activity 2(iv) comment on the standard deviation obtained in different groups including yours in Activity 1(iv).

Exercise 1. 3

1. Calculate the mean deviation from the given data in the following table.

x	7	13	15	19	21	23
Frequency	4	4	3	2	4	6

2. Study the table below indicating the scores for Geography subject in a mid test at school 'H' and then answer the questions that follows.

1-20	20-40	40-60	60-80	80-100
11	29	18	4	8

Find;

(i) Mean deviation

(ii) Variance

(iii) Standard deviation

3. (i) Compare and contrast between mean and standard deviation.

(ii) Explain how variance can be obtained from:

(a) Mean deviation

(b) Standard deviation

Methods of presenting statistical data

There are different methods of presenting data in statistics and Geography. Generally, tables and graphs are among the effective communication technique that interpret and convey statistical data and information. They enable readers to understand the content of Geographical statistics, sustain their interest, and effectively present huge quantities of information. In this context, it is the role of a geographer and a researcher to choose appropriate methods of data presentation that will not only help the readers understand the content but also guide them through making a meaningful interpretation of the data presented.

Once the geographical data has been collected, it is classified and organized for easy readability and interpretation that is converted to information. Various methods can be used in presenting the data.There are three (3) major methods used in presenting data, namely statistical graphs, statistical charts and diagrams, and statistical maps (Figure 1.9).

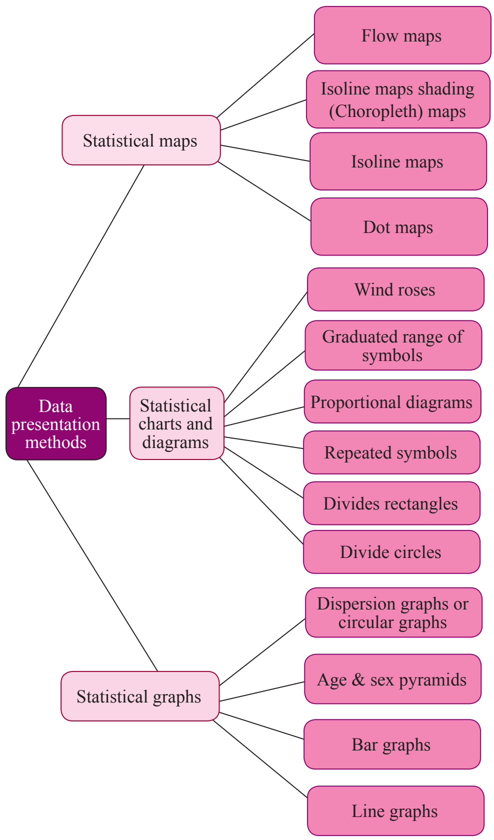


Figure 1.9: *The schematic presentation of statistical methods for data presentation*

Statistical graphs

This group is basically concerned with the relationship between quantities and does not stress the idea of location. Usually, the horizontal and vertical axis must appear as a basic and integral part of the drawing. These graphs are subdivided into line graphs, bar graphs, age and sex pyramids and dispersion graph or circular graphs.

Line graphs

Line graphs may be represented in four (4) ways: *Simple line graph, group line graph, compound line graph, and divergence line graph.*

Procedures for drawing line graphs

(i) The horizontal axis is normally used to represent the independent variable, for example time whether in hours, day, month's years or any other period of time;

(ii) The vertical axis is normally used to represent the dependent variable for example quantities or values, sometimes as percentages;

(iii) Select the suitable scale by considering the highest value in the graph space;

If drawn on plain paper, it is preferable to draw two vertical axes, one at each end of the horizontal axis;

(iv) Do not indicate large numbers with long strings of roughs, for example 100 000 or 200 000 but write either at the top corner or along the side, the value of the units expressed in figures. For example tonnes; and

(v) There must be a title, a scale and a key.

Note: The procedures above are stated in general way however, they may slightly vary depending on the type of line graph dealt with.

(a) Simple line graph

The simple line graphs are normally drawn to represent the time series data related to the temperature, rainfall, population growth, birth rates and death rates. They are called simple because they have a single line. They are commonly used in hospitals as well as meteorological and dermatological stations. The data in Table 1.26 show the mean annual temperature that has been used to construct a simple line graph shown in Figure 1.10.

Table 1.26: *Average temperature for Chololo village, in Dodoma from 2010 to 2018*

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Temperature in ^{o}C	28.7	28.2	29	28.2	29.3	31.9	32.2	32.4	32.2

Source: Tanzania Meteorological Agency (2018)

Procedures for drawing a simple line graph

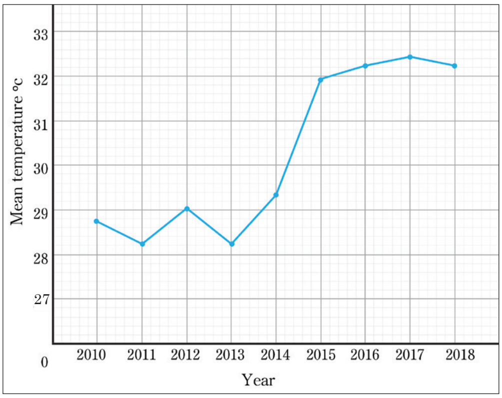
(i) Identify the types of variables from your given data to horizontal scale (independent) and another in vertical scale (dependent);

(ii) Select the suitable scale by considering the highest value and the graph space;

(iii) Draw the horizontal and vertical lines according to the scale;

(iv) Plot the points and join them by straight line; and

(v) Write the title and the scale.



Scale: V.S: 1 cm to 1 °C and H.S: 1 cm to 1 year

Figure 1.10: *Simple line graph showing trend of annual mean temperature in °c for Chololo village, in Dodoma (2010-2018)*

Advantages and disadvantages of simple line graphs

Use of simple line graphs in geographical data has numerous advantages including: Simplicity in drawing and interpreting them. The continuous nature of the line or curve makes the technique suitable for displaying continuous data like temperature and rainfall variations over time. The simple line graph is also useful in displaying the relationship of two variables as shown in Figure1.11 where the variation of temperature over years is shown. The line graph enables visualisation of variation of statistical data with rise or drop pattern. It is also, easy to read the exact values against the plotted point in straight line graph. Nonetheless, the simple line graph encounters some shortfalls such as the constrain of record limit which just represents only one item on the graph. Another limitation of simple line graph is that it gives false impression of continuity of data even when there are periods the data is missing. The method is also criticised for giving unclear visual impression of actual quantities.

(b) Group line graphs

Group line graphs also known as comparative or multiple grouped line graphs are graphs which present more than one item or series of data. Group line graphs display the relationship between sets of similar statistics for two or more items. Note that the drawn line should not be uniform and on the other hand presentation of five lines per graph is recommended. Table1.27 presents mean annual temperature from five stations in Tanzania. These data have been used to draw the graph in Figure 1.11.

Procedures

The following are procedures for constructing multiple line graphs

(i) Identify the variables from the given data;

(ii) Identify the item with highest value and use it to choose the scale;

(iii) Draw the horizontal and vertical lines;

(iv) Plot the points and join them with lines of different texture or colour; and

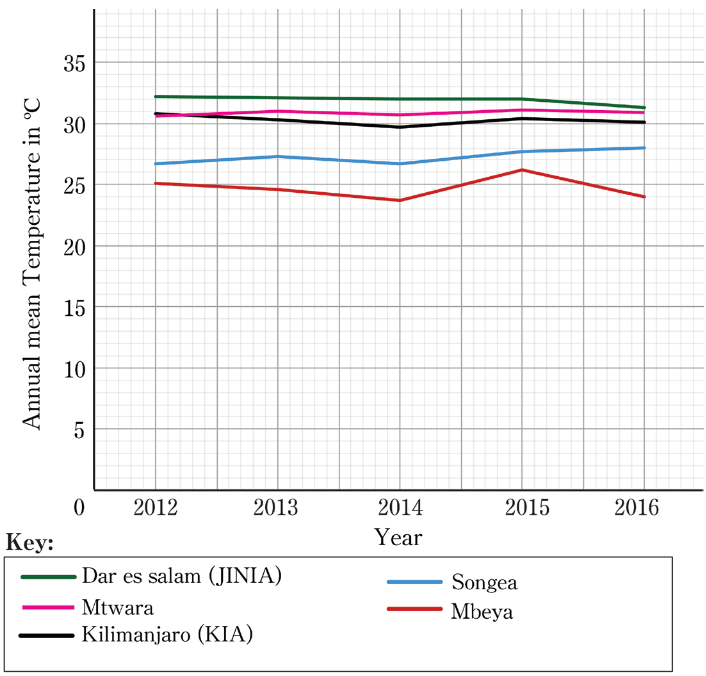
(v) Write the title, scale and show the key.

Procedures

Table 1. 27: *Annual mean temperatures from five stations in Tanzania from 2012 to 2016*

	Years				
Station	**2012**	**2013**	**2014**	**2015**	**2016**
Kilimanjaro (KIA)	30.8	30.3	29.7	30.4	30.1
Dar es Salaam (JNIA)	32.2	32.1	32.0	32.0	31.3
Mtwara	30.6	31.0	30.7	31.1	30.9
Songea	26.7	27.3	26.7	27.7	28.0
Mbeya	25.1	24.6	23.7	26.2	24.0

Source: *Tanzania Meteorological Agency (2018)*



Scale: V.S: 1 cm to 5 °C and H.S: 2 cm to 1 year

Figure 1.11: *Multiple line graph for the trends of annual mean temperature in °C from five stations in Tanzania from 2012 to 2016*

Advantages and disadvantages of multiple line graph

The use of group line graphs have a number of advantages, especially in making comparative analysis of data. They are detailed since they represent many items at once; and save time and space. They also have good visual impression especially if drawn correctly. The fluctuations of data can easily be noted. However, the line graphs face some limitations. They can be time consuming in both construction and interpretation. With crossing lines they may lead to confusion in interpretation. Sometimes they can be overcrowded in incidences of massive set of data and sometimes they can easily be confused with compound line graphs.

(c) Compound line graphs

Compound line graphs also known as composite cumulative or divided line graphs are drawn with several different components. On a compound line graph, the differences between the points on adjacent lines give the actual values. It is a good alternative to grouped line graph because the procedures for constructing are the same. The only difference is that instead of drawing lines in different colour or shade, they are all shown in bold form but the space between one line and the other is shaded differently. It is commonly suggested that values should be arranged in a certain order, with the highest values at the top and lower value at the bottom. Lines should not cross each other and data should be arranged in a cumulative manner. The data in Table 1.28(a) in a line graph showing electricity generation in Giga Watt per hour (GWh) have been used to construct a compound line graph as shown in Figure1.12.

Example

Table 1.28(a): *Electricity generation in Giga Watt per hour in Tanzania from 2011 to 2017*

Year / Fuel source	2011	2012	2013	2014	2015	2016	2017
Hydro	1 992.6	1 769.9	1 721.3	2 613.5	2 124.4	2 382.1	2 369.1
Gas	2 265	2 664	2 872.2	2 624	2 873.8	4 196.4	4 322
Diesel	781.1	1 083.5	1 133.2	784.9	1 188.2	389.1	294.4

Source: Tanzania Electric Supply Company (2017)

Procedures

The following are procedures for constructing compound line graph

(i) Prepare a cumulative table by adding individual items to previous items;

(ii) Draw the x and y axes and choose a suitable horizontal and vertical scale;

(iii) Plot the dots for cumulative values of independent variables corresponding with the dependent variables from each item by rearranging from largest to smallest or vice versa. This rearrangement should be for the first year then in other years items should follow the order of the first year;

(iv) Join the dots with portions of straight lines;

(v) The area occupied by each component presented on the graph, has to be coloured or shaded differently so as to give a clear distinction between the components;

(vi) Always start with the item with highest value and end with item with lowest value or vice versa;

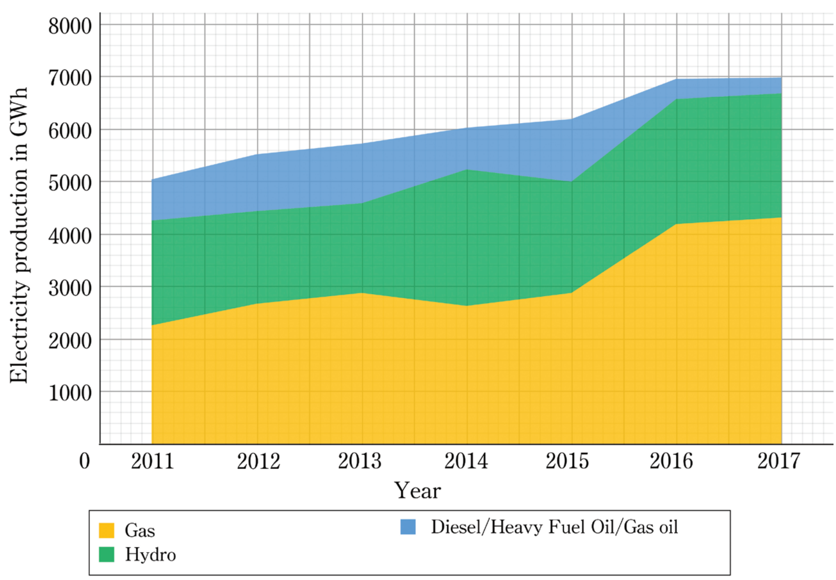
(vii) Lines should not cross each other and data should be arranged in a cumulative manner; and

(viii) Write the title, scale and key.

Solution

Table 1.28(b): *Cumulative table for EGW per hour in Tanzania 2011 – 2017*

Year / Fuel source	2011	2012	2013	2014	2015	2016	2017
Gas	2 265	2 664	2 872.2	2 624	2 873.8	4 196.4	4 322
Hydro	4 257.6	44 33.9	4 593.5	5 237.5	4 998.2	6 578.5	6 691.1
Diesel	5 038.7	5517.4	5 726.7	6 022.4	6 186.4	6 967.6	6 985.5



Scale :V.S : 1cm to 1000 GWh and H.S: 2cm to 1 year

Figure 1.12: *Compound line graph for electricity generation in giga watt per hour in Tanzania from 2011 to 2017*

Advantages and disadvantages of compound line graph

The compound line graphs are of beneficial in many ways specifically their ability to display multiple values for overall conclusion and suggestion; bringing visual impression that encourages understanding to interpreters; and combining several graphs at once. However, the method is associated with some drawbacks including calculations that may be difficult and time consuming. The interpretation of data is likely to be complicated. Cumulative data also hide the reality of original data.

(d) Divergent line graph

It is used to show fluctuations in value in terms of "positives" or "negatives" also known as 'profits or losses', 'gains or losses' and 'increases or decreases'. Such fluctuations are common in imports and exports, population trends, production of goods and commodities. The graph, can also address the increase and decrease pattern of temperature and rainfall trends. As such it can be used by climatologists, meteorologists and geographers in drawing insights on the extent of extreme weather events, climate change and variability as well as their effects to environment and welfare. Data in Table 1.29(a) which shows the average temperature for Chololo village in Dodoma from 2010 to 2018 has been used to draw Figure 1.13.

Example

Table 1.29(a): *Average temperature for Chololo village, in Dodoma from 2010 to 2018*

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Temp. in °C	28.7	28.2	29	28.2	29.3	31.9	32.2	32.4	32.2

Source: *Tanzania Meteorological Agency (2018)*

Procedures

The following are the procedures for construction of divergent line graph

(i) Find the sum of the number of observations in the set of data;

(ii) Calculate the mean;

(iii) Subtract the mean from each data/value given;

(iv) Plot the divergences (positive and negatives) on a graph with positive on the upper part of mean (zero) line and negatives below it by putting dots; (zero) line must be bolded; and

(v) Finally join the dots sequentially. The zero line represent the mean on one side of (zero) line should indicate the mean.

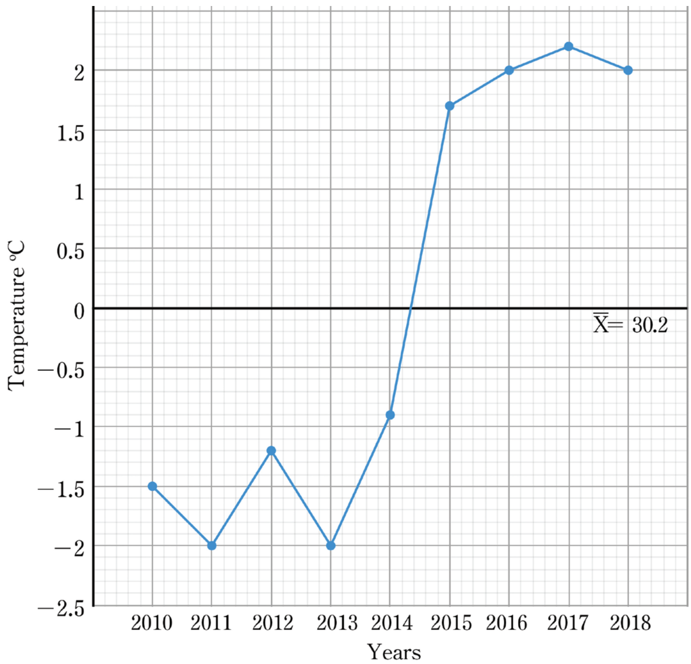
Solution

Table 1.29(b): *Average temperature for Chololo village, in Dodoma from 2010 to 2018*

Year	Temperature (x_i)	$\bar{x}$	$x_i - \bar{x}$
2010	28.7	30.2	– 1.5
2011	28.2	30.2	– 2
2012	29	30.2	– 1.2
2013	28.2	30.2	– 2
2014	29.3	30.2	– 0.9
2015	31.9	30.2	1.7
2016	32.2	30.2	2
2017	32.4	30.2	2.2
2018	32.2	30.2	2
	$\sum_{i=1}^{n} x_i = 272.1$		

Recall mean is given by: $\bar{x} = \sum_{i=1}^{N} x_i = \frac{272.1}{9} = 30.2$

The calculated mean is used in computing the deviation as shown in Table 1.29(b).



Scale: V.S 1 cm to 0.5 Temperature °C and H. S 1 cm to 1 year

Figure 1.13: *The divergent line graph for the average temperature for Chololo village, in Dodoma from 2010 to 2018*

Advantages and disadvantages of divergent line graph

Some of the major advantages of the divergent line graphs are: fluctuation from the mean can be noted easily, simple to read and interpret; and simple in presenting values. They easily compare the items hence facilitate sound conclusion. Other benefits include their merits in showing the positives (profits) and negatives (losses) and reasonably easy to construct, read and interpret. Despite such advantages still the divergent line graphs have the following limitations: inability to show the sums under the study instead they display only the positive and negative divergences. They can be difficult to interpret particularly to some individuals who have limited statistical skills. Normally, they are only restricted to one item per graph. Positive and negative values may mislead the interpretation if not skilled.

Bar graphs

Bar graph also known as a column graph refers to an x-y graph showing the tendencies of rainfall, population and other quantities like goods. Each tendency is shown by a column or bar whose length or height represents its value along y-axis. The purpose of the graph is to show numerical facts in visual form so that they can be understood quickly, easily and clearly. Bar graphs are appropriate when there is a need to present trends or comparison. In showing comparison it may consist of two or more parallel verticals (or horizontal) bars or rectangles.

a) Simple bar graphs

Simple bar graphs consist of parallel, usually vertical bars or rectangles with length proportional to the frequency with which specified quantities occur in a set of data. It can be defined as quantitative comparison by rectangles with lengths proportional to the measure of the data or things being compared. It can be drawn to show rainfall and total exports or imports. Data in Table 1.30 which show hydroelectric power generation in Giga Watt per hour (GWh) in Tanzania from 2011 to 2017 has been used to draw Figure 1.14:

Procedures

The following are procedures for constructing simple bar graph

(i) From the given data, identify the types of variables;

(ii) Select the suitable scale;

(iii) Draw horizontal and vertical line and construct bars vertically above the horizontal lines;

(iv) Shade the bars equally;

(v) Write the title and the key;

(vi) On a graph, draw two lines perpendicular to each other, intersecting at zero;

(vii) The horizontal line is x-axis and vertical line is y-axis;

(viii) Along the horizontal axis, choose the uniform width of bars and uniform gap between the bars and write the names of the data items whose values are to be marked;

(ix) Along the vertical axis, choose a suitable scale in order to determine the heights of the bars for the given values. (Frequency is taken along y-axis); and

(x) Calculate the heights of each bar according to the scale chosen and draw the bars.

Other things to bear in mind when constructing simple bar graphs include:

(i) The horizontal scale usually represents the independent variable whereby vertical scale represents dependent variable;

(ii) A vertical bar may occupy the space (either completely or partially) between two vertical lines;

(iii) All bars must start at zero. Bar graphs drawn for purposes of comparison must be drawn on the same scale; and

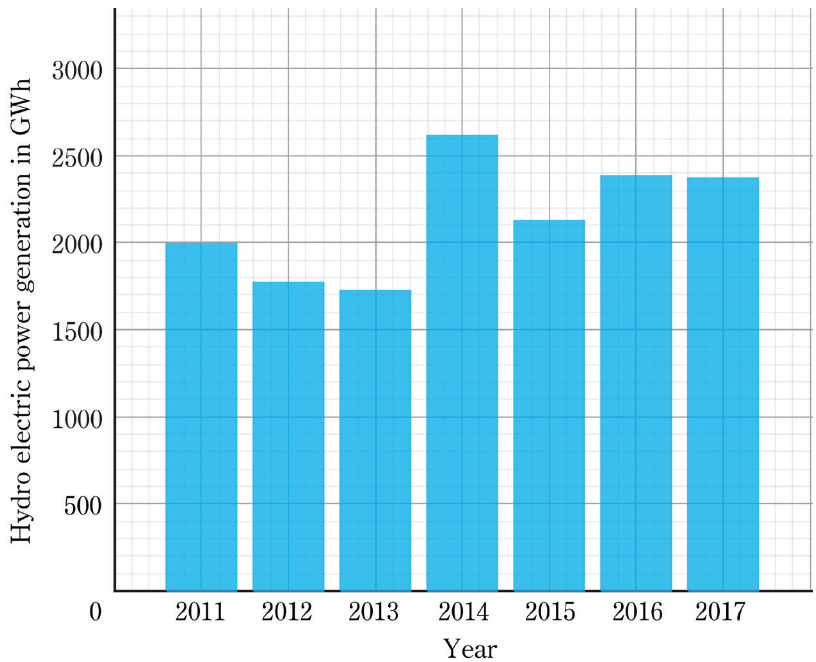
(iv) The width of the bar is a matter of choice, avoid bars that are too thick or too thin. The value of each bar can be assessed easily if a space or gap is left between each bar.

Example

Table 1. 30: *Hydroelectric power generation Giga Watt per hour (GWh) in Tanzania from 2011 to 2017*

Year	2011	2012	2013	2014	2015	2016	2017
GWh	1992.6	1 769.9	1 721.3	2 613.5	2 124.4	2 382.1	2 369.1

Source: TANESCO (2017)



Scale: V. S 1cm to 500 GWh and H.S: 1cm to 1 year

Figure 1.14: *Simple bar graph for hydroelectric power generation in GWh in Tanzania from 2011 to 2017*

Advantages and disadvantages of simple bar graph

The simple bar graphs are beneficial because: they are easy to draw and interpret; they can be used in conjunction with line graphs; their rise and fall patterns at a given time can be easily visualised; they also present tangible quantities better than line graphs and simple bar graphs. However, have some limitations. The major ones include inability to present many items and in cases of scale exaggeration the graph may be distorted. Furthermore, they consume more space in cases of huge data.

b) Grouped bar graph

Grouped bar graph also known as comparative or multiple bar graph is where two or more simple bars are grouped side by side on the same vertical scale for the sake of comparison. It is a graph that uses rectangular bars to represent different values for showing comparisons among categories such as the amount of rainfall in different months of a year, or the average salary in different states. Grouped bar graphs are commonly drawn vertically, though they can also be depicted horizontally. Data in Table1.31 which show electricity generation in Giga Watt per hour in Tanzania from 2011 to 2017 have been used in drawing Figure 1.15.

Procedures

The following are procedures for construction of group bar graph

(i) Draw and label the vertical and horizontal sides (axes);

(ii) Choose a scale that suits the data;

(iii) Place dots on the graph to represent the data;

(iv) Connect the dots in order;

(v) Write a title above the graph;

(vi) To give an impression of totality, bars are usually drawn touching each other that is without a gap between them, but attention may be drawn to individual components by leaving a small space between the bars. Also, groups of bars must be separated from each other with similar space or gap;

(vii) It is a custom to draw the bars of each group in ascending or descending order for comparison purposes;

(viii) All bars must be of the same width and drawn at right angles to the axis; and

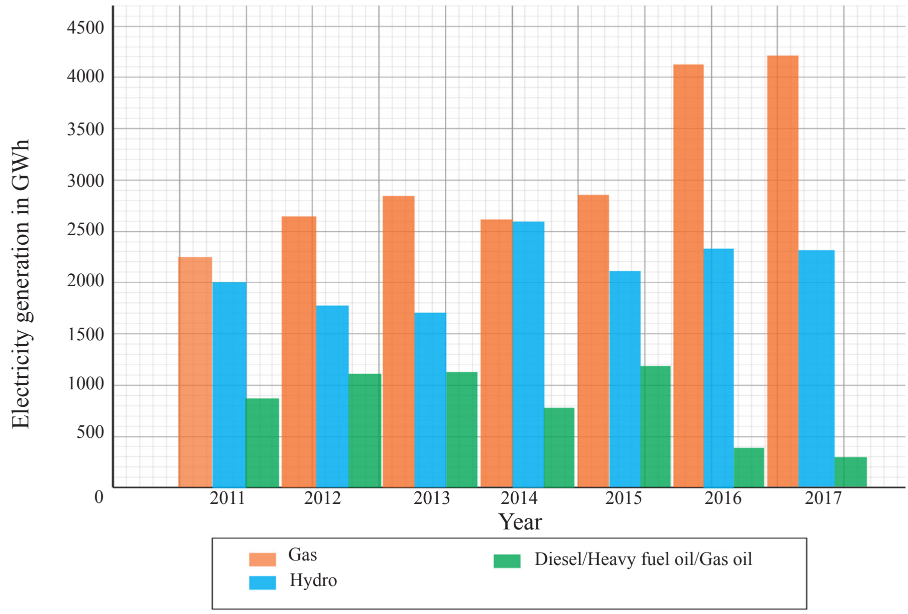
(ix) Write the title,scale and show the key.

Example

Table 1.31: *Electricity generation in Giga Watt per hour in Tanzania from 2011 to 2017*

	2011	2012	2013	2014	2015	2016	2017
Hydro-electric power	1992.6	1769.9	1721.3	2613.5	2124.4	2382.1	2369.1
Gas	2265	2664	2872.2	2624	2873.8	4196.4	4322
Diesel/heavy Fuel Oil/Gas oil	781.1	1083.5	1133.2	784.9	1188.2	389.1	294.4

Source: *Tanzania Electric Supply Company (2017)*



Scale: V. S: 1 cm to 500 GWh and H.S: 1.5 cm to 1 year

Figure 1.15: *Grouped bar graph for electricity generation in Giga Watt per hour in Tanzania from 2011 to 2017*

Advantages and disadvantages of grouped bar graph

The grouped bar graph is useful in the field of geography in many ways. It enables a reader to get a good visual impression about the totality and individuality of the studied item(s). It enables easy comparison of the investigated components. Interpretation is relatively simple and easy. The bars may be drawn within one another particularly for the overlapping bars. Lastly, many items can be presented together in the same graph hence, save space. Despite the given merits, grouped bar graph has limitations such as comparison of (sum) of items is relatively difficult, for example rainfall patterns with varying years cannot be expressed. Composing the scale is also challenging. Lastly they are time consuming in constructing and difficult to compare the sum in each year when there are many groups of bars.

(c) Compound bar graph

Compound bar graph refers to a graph which combines two or more types of information in one graph. It can also compare different quantities. A compound bar graph is a type of bar chart where columns can be split into sections to show breakdown of data. It is drawn by subdividing one bar into component parts. The total length of the bar represents the total value of the entire component in which parts are shown in such division. Data in Table 1.29 which shows electricity generation in Giga Watt per hour in Tanzania from 2011 to 2017 have been used to draw Figure 1.16.

Procedures

The following are procedures for constructing compound (divide) bar graph.

(i) Identify the types of variables;

(ii) Find the item with the highest total;

(iii) Prepare the cumulative table and enter the values cumulatively starting with the highest or the smallest to largest item. This rearrangement should be for the first year and the following years should follow the established order;

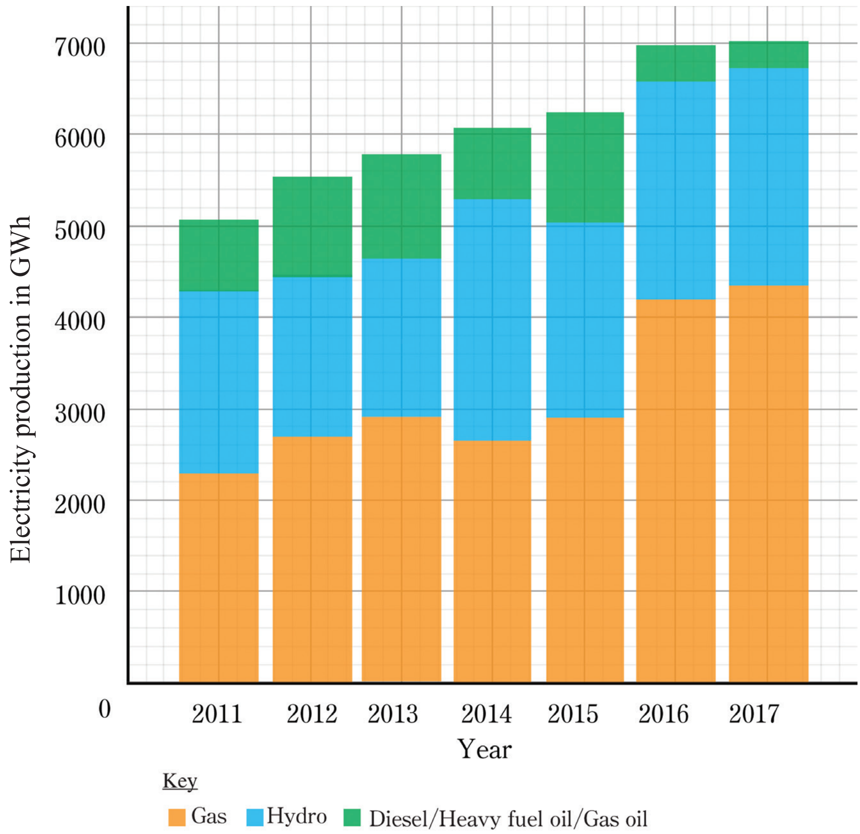
(iv) Use the highest total among the total in the table to select a suitable vertical scale. For the case of horizontal scale, the number of items of independent variable should be considered;

(v) Draw the vertical and horizontal lines;

(vi) Draw bars vertically above the horizontal line,the height of each depends on its total in the cumulative table;

(vii) Divide and shade bars, accordingly; and

(viii) Write the title, scale and the key.



Scale: V.S: 1cm to 1000 GWh and H.S: 1cm to 1 Year

Figure 1.16: *Compound bar graph for an electricity generation in Giga watt per hour in Tanzania from 2011 to 2017*

Advantages and disadvantages of compound bar graph

Compound bar graph is easy to construct and make comparison; the associated colouring and shading of the graphs improves visual impression and simplify interpretation. It allows expressing more than one quantities within the chart. However, the compound bar graph has some drawbacks including difficulties in assessing the value of one component or tracing its fluctuation over a period of time. It involves cumulative data which demand some calculation, so it is time consuming. Furthermore, compound bar graph has a limitation in presenting many components due to limited space of accommodating long graphs. It is difficult to compose scale if the range values is very large.

(d) Divergent bar graphs

In this type of graphs, data spread is both positive and negative and it is displayed divergently. These could be constructed on either the x or y axis. Divergent bar graphs are used when one set of data is provided for part of the period under consideration and then this dataset is split into separate components for another part of the period. Data in Table1.32 which shows passengers transport in thousand ('000) by Tanzania Railways from 2010 to 2015 has been used to draw Figure 1.17: Note that the Tanzania and Zambia Railway Authority (TAZARA) is excluded.

Procedures

The following are procedures for constructing divergent bar graph.

(i) Find the sum of the number of observations in the set of data;

(ii) Calculate the mean;

(iii) Subtract the mean from each data or value given to get deviation;

(iv) Select a suitable vertical and horizontal scales;

(v) Plot the divergences (positive and negatives) on a graph with positive on the upper part of mean (zero) line and negatives below it by putting dots; zero line must be bold;

(vi) Draw bars up and down the line of average and shade them equally; and

(vii) Write the title, and scale.

Note: The zero line must be clearly indicated usually by thickening. As the bar, the horizontal scale is in fact best written at the bottom and top of the graph. The vertical axis must be scaled both above and below the zero line, the upper part for positive and the lower for negative values.

Table 1. 32(a): *Passengers transport in thousand ('000) by the Tanzania Railways from 2010 to 2015*

Year	2010	2011	2012	2013	2014	2015
Passengers in thousand	284	227	339	373	170	196.4

Source: Ministry of Works, Transport and Communication (2015)

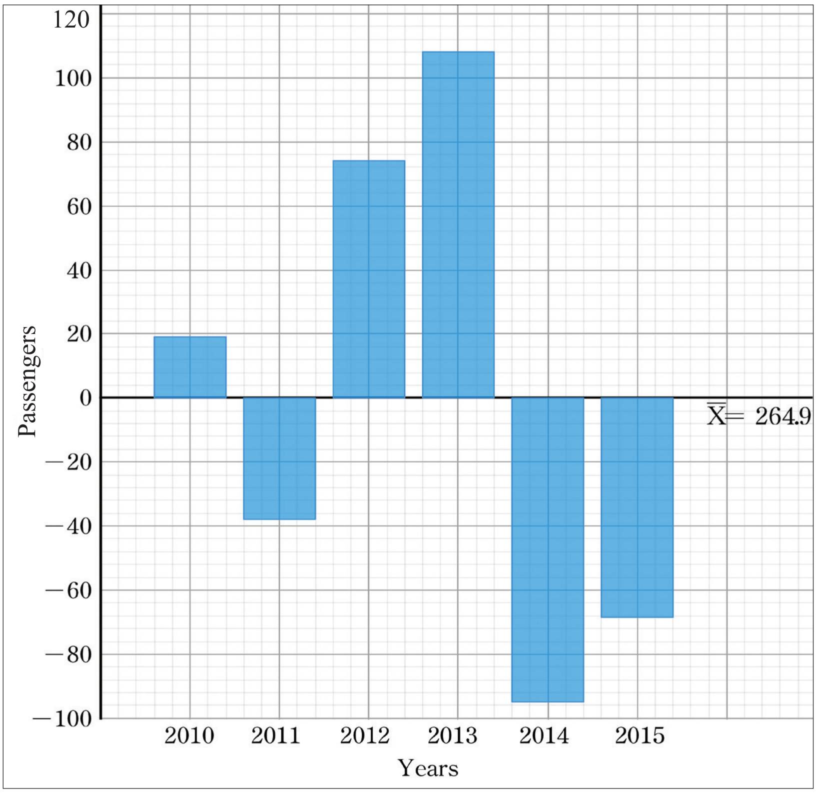
Solution

Table 1. 32(b): *Passengers transport in thousand ('000) by the Tanzania Railways from 2010 to 2015*

Year	Total number of passengers in '000 thousand (x_i)	$\bar{x}$	$x_i - \bar{x}$
2010	284	264.9	19.1
2011	227	264.9	– 37.9
2012	339	264.9	74.1
2013	373	264.9	108.1
2014	170	264.9	– 94.9
2015	196.4	264.9	– 68.5
	$\sum_{i=1}^{n} x_i = 1589.4$		

The mean is obtained by:

$$\bar{x} = \sum_{i=1}^{n} x_i = \frac{1589.4}{6} = 264.9$$



Scale: V.S: 1 cm to 20 passengers H.S: 1 cm to 1 year

Figure 1.17: *The divergent bar graph for passengers transport in thousand ('000) by the Tanzania Railways from 2010 to 2015*

Advantages and disadvantages of divergent bar graph

The divergent bar graphs have advantages including the fluctuation in values which are helpful in detecting problem in general terms as shown in Figure 1.17. It is also important in comparing the negatives and positives of the phenomenon under observation. It further enables easy deduction of the profit (loss/rise) or loss (failure or rise) of the phenomenon observed. It is simple to construct, read and interpret. However, the graphs have some limitations like time consuming as its construction involves many steps. It demands skills in mathematics and it is confined to analysis of only one variable. Also it does not present actual data but presents data showing variations from the mean.

A combined line and bar graph

Sometimes a simple line and a bar graph may be combined in the same graph to show more often climate data such as temperature and rainfall. This type of graph is termed as a climograph.

The hypothetical annual temperature (Table 1.33) for weather station X in Ikombe Village is used to present data by combining lines and graphs (Figure 1.18).

Procedure:

The following are procedures for constructing a combined line and bar graph.

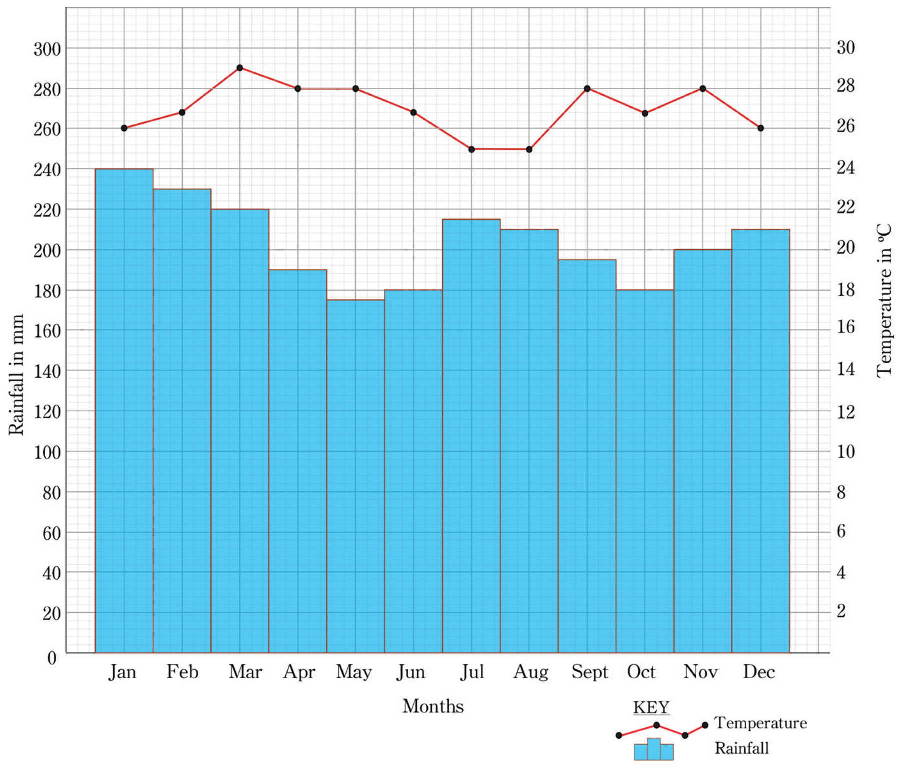
Similar procedure for the construction of simple line and bar graphs need to be used to construct a combined line and bar graph.

Note: You may choose a different scale for rainfall and temperature. In this case as well, rainfall will be in bars as shown but temperature is plotted in line which is above the bars.

Example:

Table 1.33: *Data for temperature and rain fall recorded at station X in Ikombe Village.*

Months	J	F	M	A	M	J	J	A	S	O	N	D
Temp. °C	26	27	29	28	28	27	25	25	28	27	28	26
Rainfall	240	230	220	190	175	180	215	210	195	180	200	210



Scale: HS: 1 cm to 1 month, VS for Temp: 1 cm to 2 °C, V.S for Rainfall: 1 cm to 20 mm

Figure 1.18: *A combined line and bar graph (Climography) for station X*

Age - sex graph

A population pyramid also known as *age and sex pyramid, population structure or age and sex structure* refers to the geographical representation of age structure or distributions of population according to age groups. The graph is commonly used by demographers. The graphs can be constructed to represent composition of a population in a region, country or worldwide. It is not only restricted to showing composition of age group but also extend to sex of the population composition. Normally, age groups appears along the vertical (y-axis) while sex is placed on horizontal (x-axis). Basically, female is located on the right side and male on the left side shown in absolute number or percentage in successive age groups (Figure 1.19). Pyramids are useful in presenting the population which depends on the birth, death rates and migration. These graphs are relevant in summarising the age and sex data collected from census survey. Through these types of graphs, the country can deduce various insights and information useful for decision-making such as distribution of social services and intervention measures as well as identifying the working group and the dependant, with regard to varying social groups. Often the population for comparison purposes is constructed on the same scale and should depict the same age groups. Bars should be of the same height. Demographers identify three types of pyramids namely: expansive or rapid growth, stationary or slow growth and constrictive or contractive or negative growth pyramids. The structure of the pyramids is dynamic depending on the changes of population structure. The demographics are changing from pyramid and finally to barrel which end the point of population pyramids.

Types of population pyramids

The population pyramids are of varying shapes. Though different countries can have unique pyramids, still the pyramid in the same countries can take different shapes over different periods of time. Normally, this is influenced by spatial and temporal variations over time. Changes in number of the population whether by age or sex are among the quantitative variables of interest in statistics in describing the population. The graphical representation of the population pyramids ultimately relies on age and sex structure of a given population. Such shapes may take the form of a triangular pyramid, have a columnar or rectangular (with vertical sides rather than sloped sides), or have an irregular profile. Below are the major categories of population pyramids:

Expansive pyramid: This is also known as rapid growth pyramid. It has a broad base with successive decline in the share of population of higher age groups. The pyramid represents a relatively high fertility and mortality rates; low life expectancy; higher population growth rates; and low share of old age persons. The pyramids portray the expansion of population as the size of each cohort gets larger than the size of the same in previous time. Expansive age pyramids are common for developing countries mainly in Africa and Asia. Figure 1.19 which shows the population distribution in Tanzania basing on the census survey of 2012 is a typical representation of an expansive pyramid. As such, distribution varies with time and space; the slight or complete change in structure of population in the country for the subsequent census survey will not be a surprise. In drawing population pyramids, you should consider the following.

(i) The age groups, are usually based on quinquennial (5years) periods (0 - 4, 5 - 9, 10 - 14) while the youngest age group forming the base of the graph;

(ii) In calculating percentage, two methods are possible either the individual male or female population or each group may be calculated as percentages of the total population; and

(iii) It should be noted that the procedures for constructing the population pyramids are common across all types of pyramids. The shapes of resultant pyramids are also the result of a population composition at a particular time and space.

Procedures

The following are the procedures for constructing age and sex pyramids graph

(i) Identify types of variables and suggest suitable scales. For vertical scale, consider the number of age groups, and for the horizontal scale, consider the highest value or percent;

(ii) Draw two vertically standing lines of not more than 2cm apart however, 2 cm wide is suitable; at the centre of the graph paper;

(iii) From the bottom of the lines, are two horizontal lines away from each other to represent the sex. Male is predominately on the left while female on the right side;

(iv) The bars are drawn horizontally and their length correspond to the size of the age groups. It is in fact a comparative bar graph drawn horizontally; and

(v) Shade the bars, write the title and indicate the scale.

Example

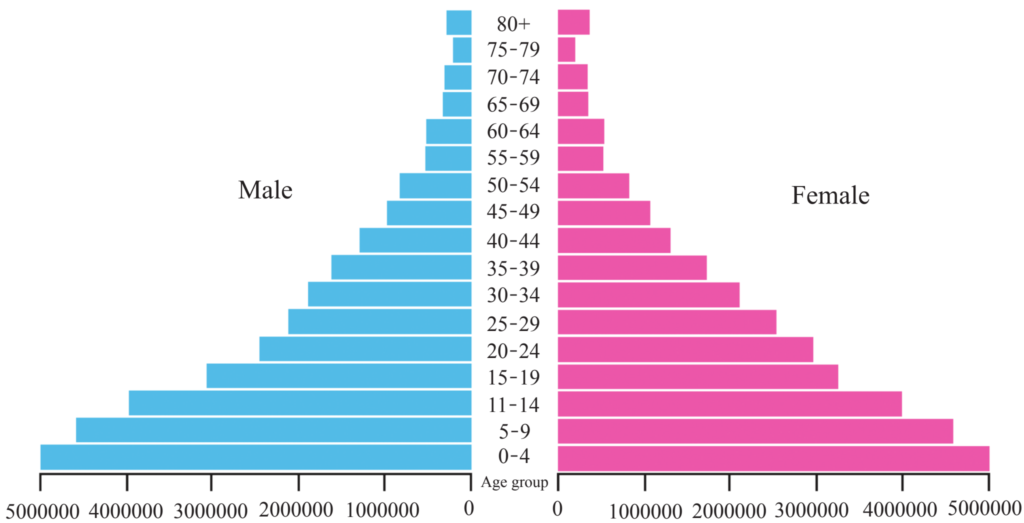
Study the data provided in Table 1.34 (a) which show the distribution of population by age and sex then construct age and sex graph by using absolute value.

Table 1.34(a) : *Population distribution by age and sex based on 2012 census survey*

Age group	Male	Female
0 – 4	3 535 673	3 534 222
5 – 9	3 242 111	3 233 253
10 – 14	2 809 113	2 816 735
15 – 19	2 171 355	2 295 319
20 – 24	1 737 849	2 093 249
25 – 29	1 503 841	1 789 025
30 – 34	1 342 110	1 485 372
35 – 39	1 149 418	1 219 682
40 – 44	916 020	924 316
45 – 49	694 318	759 147
50 – 54	5 87 555	585 004
55 – 59	3 9 627	371 783
60 – 64	368 814	380 318
65 – 69	232 811	248 460
70 – 74	220 651	245 426
75 – 79	149 974	145 122
80+	2 060 73	259 608

Source: *Tanzania population census Survey 2012*

(a) By the use of absolute value



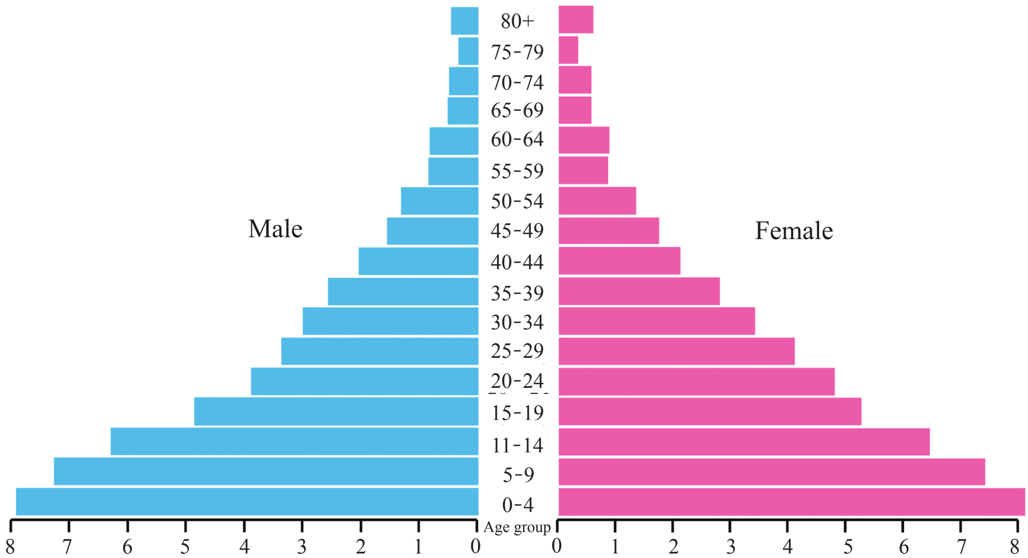
Scale: H.S: 1 cm to 100 000 and V.S: 0.5 cm to 1 bar

Figure 1.19: *Population pyramid of Tanzania mainland in 2012 census survey*

Table 1.34(b): *By the use of percentage value*

Age group	Male	Female	Total	%Male	%Female
0 – 4	3 535 673	3 534 222	7 069 895	8.103	8.100
5 – 9	3 24 2 111	3 233 253	6 475 364	7.430	7.410
10 – 14	2 809 113	2 816 735	5 625 848	6.438	6.455
15 – 19	2 171 355	2 295 319	4 466 674	4.976	5.260
20 – 24	1 737 849	2 093 249	3 831 098	3.983	4.797
25 – 29	1 503 841	1 789 025	3 292 866	3.447	4.100
30 – 34	1 342 110	1 485 372	2 827 482	3.076	3.404
35 – 39	1 149 418	1 219 682	2 369 100	2.634	2.795
40 – 44	916 020	924 316	1 840 336	2.099	2.118
45 – 49	694 318	759 147	1 453 465	1.591	1.740
50 – 54	587 555	585 004	1 172559	1.347	1.341
55 – 59	379 627	371 783	7 51 410	0.870	0.852
60 – 64	368 814	380 318	749 132	0.845	0.872
65 – 69	232 811	248 460	481 271	0.534	0.569
70 – 74	220 651	245 426	466 077	0.506	0.562
75 – 79	149 974	145 122	295 096	0.344	0.333
80+	2060 73	259 608	465 681	0.472	0.595
Total	21 247 313	22 386 041	43 633 354	50	50

(b) By the use of percentage value



Scale: H.S: 1 cm to 1% and V.S: 0.5 cm to 1 bar

Figure 1.20: *Age and sex pyramid of Tanzania mainland in 2012 census Survey*

Stationary pyramid: This is also, known as slow growth curve. Stationary pyramids are the pyramids describing a constant share of population in different age groups over the period of time. They displays a situation with low fertility and mortality rates and high life expectancy. They depict a slow population growth or stable population. The stationary or near stationary population pyramid displays some what equal share of juvenile and adult age groups (Figure 1.21).

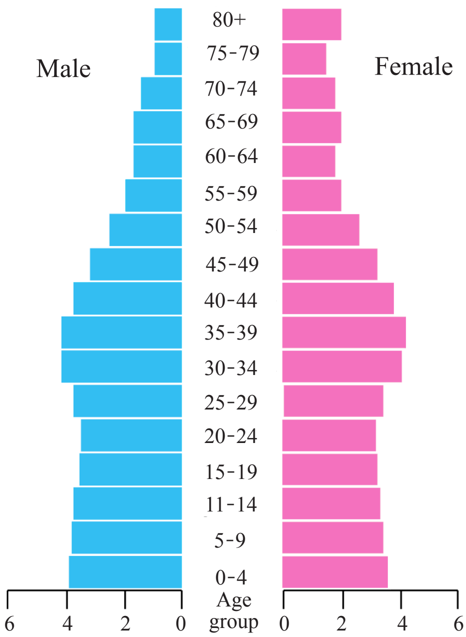


Figure 1.21: *Stationary pyramid*

Constrictive pyramid: This is also known contractive or negative growth pyramid. It is a pyramid with a narrow base. It displays a low fertility and mortality rate, life expectancy and ageing of population are high. The pyramids are typically common in developed countries where they have a high level of literacy, access to birth control measures and quality health care associated with improved medical facilities (see Figure 1.22).

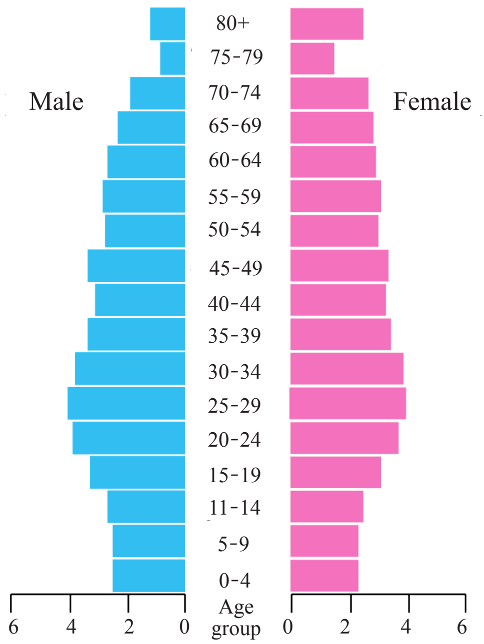


Figure 1.22: *Constrictive pyramid*

Advantages and disadvantages of age and sex graph or population pyramid

The age and sex graphs are beneficial in many ways. They clearly show the comparison between males and females. They give a clear picture of summary of population composition that is visually attractive. On one hand, they define economic status of a given country, its fertility and mortality rates and life expectancy. On the other hand, they show the trend of population change in terms of birth and death. The limitations of the population pyramids are time consuming caused by tedious steps of calculations involved in tabulating the pyramid and determining the scale.

A compounded population pyramid

This is also refered to as superimposed population pyramid. It is a population pyramid which comprises different population categories superimposed in one bar.

Procedures

The following are procedures for constructing a compounded pyramids graph

(i) Identify the types of variables for this case age,sex and employment variable and suggest suitable scales;

(ii) Draw two vertically standing lines of not more than two (2cm) apart;

(iii) The bars of sex and employment are drawn horizontally and their lengths correspond the size of the age groups; and

(iv) Other procedures are as in constructing the normal population pyramids in section (c) above.

Example:

Study the data provided in Table 1.35, then draw a comparative population structure to represent the following data for country x.

Table 1.35: *Data for population structure and employment for country x*

Age group	Total population		Population in employment	
	Male	Female	Male	Female
20 - 24	85 000	100 000	60 000	50 000
25 - 29	70 000	80 000	50 000	30 000
30 - 34	60 000	74 000	52 000	52 000
35 - 39	52 000	62 000	48 000	30 000
40 - 44	44 000	48 000	30 000	20 000
45 - 49	30 000	32 000	25 000	25 000
50 - 54	23 000	28 000	15 000	16 000
55 - 59	15 000	16 000	8 000	5 000
60 - 64	10 000	12 000	5 000	8 000
65 - 69	5 000	8 000	2 000	2 000

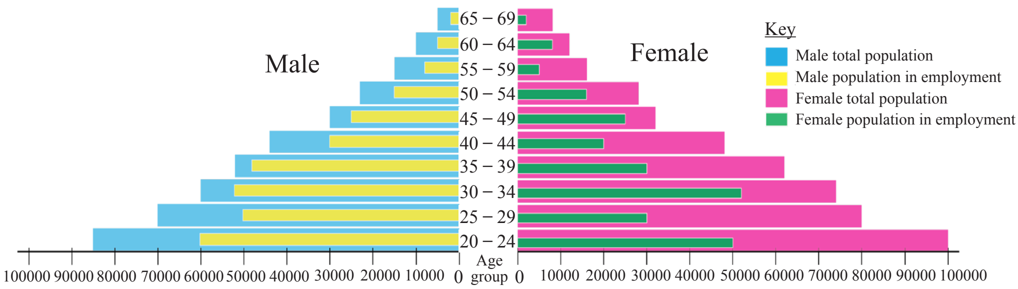


Figure 1.23: *Compounded population structure of country x*

Advantages and disadvantages of compound population pyramids

This type of pyramid is useful to show comparison between males and females in different categories: For example in employment and education. It also shows characteristics of population that is either from developed or developing nations. It gives a clear visual impression although the pyramids are tedious to construct.

Circular graph

A circular graph is also known as dispersion, clock or polar graph due to its resemblance to the face of a clock or lines of longitude radiating from the pole. The analogy between the twelve months of the year and the twelve hours of the clock face adds attraction to the use of this type of graph. It is mostly used to show farmers the seasonal calendar in a year for farmers.

Procedures

The following are pocedures for constructing a circular graph

(i) Identify the types of variables and select a suitable scale;

(ii) Draw seven concentric circles, the smallest at the center should be not more than 2cm in diameter; However, it depends on the size of the paper. Distance from one circle to another should be 1cm;

(iii) Draw 12 radii of 30° apart, starting from 12 o'clock radius clockwise. The 12 radii stand for months of the year, named clockwise from the 12 o'clock radius;

(iv) Along the radii, draw bar for rainfall;

(v) For temperature, plot the points and join them with a curved line;

(vi) Write the title, key and scale. Remember vertical scale represents rainfall and temperature, while horizontal scale represents months;

(vii) As clock graph is frequently used to represent climatic statistics, radii are scaled in °C. The scale is indicated on either the 12 o'clock or 6 o'clock radius. Points plotted are then joined as a continuous circle;

(viii) Bar can also be drawn along the radii to indicate monthly mean rainfall. In order to avoid congestion at the centre of the circle, zero is normally represented as a circle; and

(ix) Write the title, scale and key.

Example

Study the data provided in Table 1.36 and draw a polar chart.

Table 1. 36: *Monthly mean rainfall (mm) and temperature (°C) in Tanzania in 2016*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp °C	28.4	28.9	29.8	27.9	27.9	27.3	26.8	28.1	28.5	29.9	29.6	28.5
Rainfall (mm)	191.8	131.2	140	213.6	41.1	9.2	2.2	8.3	14.1	27.8	64.6	66.6

Source: *Tanzania Meteorological Agency (2016)*

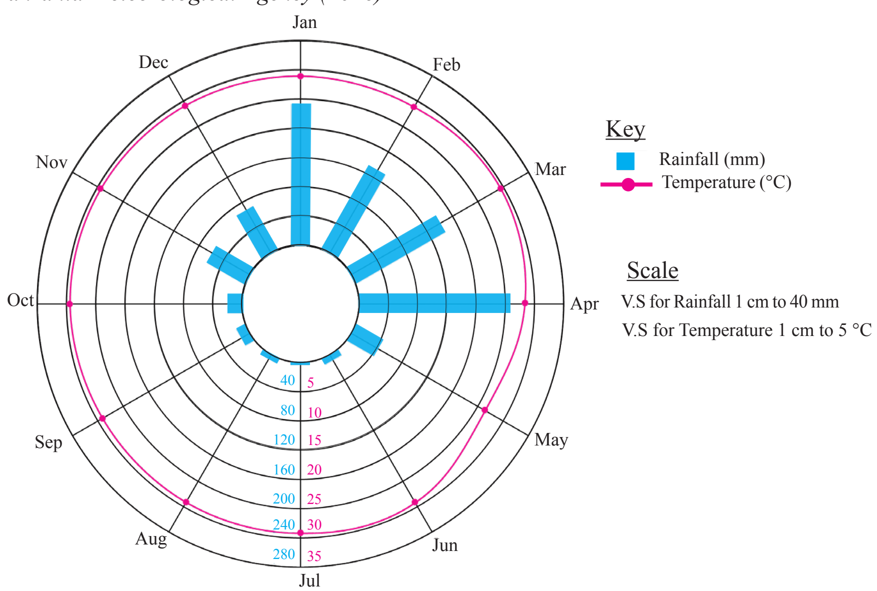


Figure 1.24: *Polar chart for monthly mean rainfall and temperature in Tanzania in 2016*

Advantages and disadvantages of polar chart

The polar charts is beneficial in many ways. The common use is to guide the farmers through identifying their seasonal calender in a year. It can also be used in calculating monthly mean rainfall and temperature data.It is detailed by drawing two concentric circles. Some of its limitations include inability to display much of information, as they are squeezed in a circle. It also time consuming as both organising the scale and drawing are complicated. Finally it is confined to weather conditions only.

Activity 1.3

1. (i) In group of five students, use the data from form five students' attendance sheet records over last six months to construct the following graphs:
   (a) Simple line graph
   (b) Simple bar graph
   (c) Divergent line graph
   (d) Divergent bar graph

   (ii) Present your work to the class for a wide discussion.

2. (i) In groups of five students, visit a nearby institution which engage in documenting crops production and collect data for production of three to five crops grown in your locality for the past three to five years. Use the data to construct the following graphs:
   (a) The compound line graph
   (b) The compound bar graph

   (ii) Present your work to the class for extensive discussion.

Statistical charts and diagrams

Statistical charts and diagrams methods differ from statistical graphs as they do not depend on squared paper or a map in data presentation. Rather they display data in circular graphs, rectangles, repeated symbols, proportional diagrams, graduated symbols and wind roses.They may be used in conjunction with a map for the purpose of defining or describing a location but they can also be drawn independently. They are not necessarily drawn on a graph paper but even plain or ruled papers. There are six (6) major statistical charts and diagrams, which include: divided circles (pie charts), divided rectangles, repeated symbols, proportional diagrams, graduated range of symbols and wind roses.

Divided circle

Divided circle also known as pie chart refers to a diagram consisting of a circle divided into the slices which are proportional in size to the value represented. The slice of the circle may be shaded or coloured and labeled. The largest slice is plotted first clockwise from 12 o'clock in ascending order for easy comparison. The divided circle can be sub-divided into three parts namely simple divided circle (pie chart), proportional divided circles and proportional divided semi-circles.

(a) Simple divided circle

It is a simple pie chart which is used to represent simple data such as exports, imports or production. Simple divided circle is also known as simple pie chart.

Data in Table 1.37(a) which show mineral imports in ('000) metric tonnes in Tanzania in 2015 have been used to draw Figure 1.25.

Procedures

The following are procedures for constructing simple divided circle

(i) Find the total amount of all values;

(ii) Change each of the values into percentage, and then into degrees;

(iii) Draw the circle of suitable radius;

(iv) Divide the circle into parts corresponding to the value of each radius of respective components. Drawing should be done clockwise from the 12`starting with the highest degree value;

(v) Shade each portion differently; and

(vi) Write the title and the key.

Note: The circle may be of any convenient size, too small circle must be avoided.

Example

Table 1.37(a) : *Mineral importsn ('000) metric tonnes in Tanzania in 2015*

Mineral type	Weight in '000 tonnes
Coal	269
Gypsum	38
Petroleum	52
Clinker	50

Source: Ministry of Minerals (2015)

Solution

Table 1. 37(b): *Percentage of mineral importation in ('000) metric tonnes in Tanzania in 2015*

Mineral type	Weight in'000 (X_i)	$\left(\frac{X_i}{\sum_{i=1}^{n} X_i} \times 100\%\right)$	$\frac{\%}{100\%} \times 360°$
Coal	269	66%	237.6^o
Gypsum	38	9%	32.4^o
Petroleum	52	13%	46.8^o
Clinker	50	12%	43.2^o
Total	**409**	**100%**	**360^O**

The angles drawn will represent the respective percentages of the data items in the distributions. For example 237.6° for 66% in the pie chart shown in Figure 1.25.

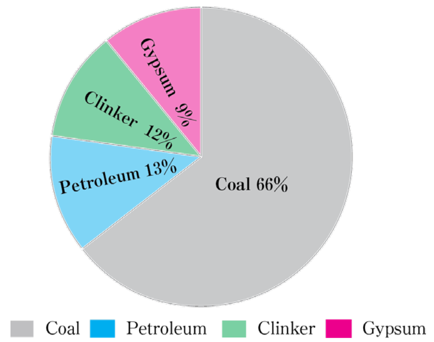


Figure 1. 25: *Mineral imports in ('000) metric tonnes in Tanzania in 2015*

Advantages and disadvantages of divided circles

The main advantages of divide circles are that they are simple to construct, useful for comparison purposes as items can be clearly seen. They are easier to obtain accurate data presentation. The circles however, have the following limitations: in case of zero degree, usually the data cannot be shown. Other weaknesses include accommodating limited data and they are time consuming due to calculations and drawing. Another weakness is on their rigid method of data presentation which requires using pie charts only when total observation of the parts makes a meaningful whole. Pie charts are not recommended to use if the observations of different parts are not mutually exclusive.

(b) Proportional divided circle

It is a graph drawn in a circle whose radius is proportional to the total figures represented by all sectors of circle. They are used for showing a quantity (for example, population of a country) that can be divided into parts such as different ethnic groups. A circle is drawn to represent the total quantity. Two or more circles are drawn in such a way that each one is proportional to the value it represents. It is then divided into segments which are proportional in size to the components. The actual size of the circle can also be used to represent data.

Procedures

The following ar procedures for constructing proportional divided circle

(i) Find the total of each item under observation;

(ii) Compute the radius for each by applying the square roots on each of the total items under observation;

(iii) Determine the scale to be used;

(iv) Divide the calculated radii to the scale determined;

(v) Draw the circle based on the calculated radii; and

(vi) Write the title and key.

Example

Table 1. 38(a): *Trend of some of the wild animals hunted from 2009 to 2012*

Year	Species				
	Elephant	Lion	Leopard	Hippopotamus	Buffalo
2012	41	37	40	40	53
2011	45	27	44	38	47
2010	96	98	205	158	1108
2009	98	120	249	153	1061

Source: *Ministry of Natural Resources and Tourism (2012)*

Solution

Table 1. 38(b): *Trend and total of some of the wild animals hunted from 2009 to 2012*

Year	Species					
	Elephant	Lion	Leopard	Hippopotamus	Buffalo	Total
2012	41	37	40	40	53	211
2011	45	27	44	38	47	201
2010	96	98	205	158	1108	1665
2009	98	120	249	153	1061	1681

The radii of two circles are determined by:

$Radius(R) = \sqrt{T}$

Where

T = the total value of the given item

$R_1 = \sqrt{211} = 14.52$

$R_2 = \sqrt{201} = 14.17$

$R_3 = \sqrt{1665} = 40.80$

$R_4 = \sqrt{1681} = 41$

Scale: Let 1cm represent 10 units (cm)

14.52÷ 10 = 1.4 cm

14.17 ÷ 10 = 1.4 cm

40.80 ÷ 10 = 4 cm

41 ÷ 10 = 4.1 cm

To calculate the degrees

Table 1. 38(c): *Trend of some of the wild animals hunted From 2009 to 2012 in degrees*

Year	Species				
	Elephant	Lion	Leopard	Hippopotamus	Buffalo
2012	$\frac{41}{211}\times 360° = 70°$	$\frac{37}{211}\times 360° = 63°$	$\frac{40}{211}\times 360° = 68°$	$\frac{40}{211}\times 360° = 68°$	$\frac{53}{211}\times 360° = 90°$
2011	$\frac{45}{201}\times 360° = 81°$	$\frac{27}{201}\times 360° = 48°$	$\frac{44}{201}\times 360° = 79°$	$\frac{38}{201}\times 360° = 68°$	$\frac{47}{201}\times 360° = 84°$

2010	$\frac{96}{1665}\times 360^\circ = 21^\circ$	$\frac{98}{1665}\times 360^\circ = 21^\circ$	$\frac{205}{1665}\times 360^\circ = 44^\circ$	$\frac{158}{1665}\times 360^\circ = 34^\circ$	$\frac{1108}{1665}\times 360^\circ = 24^\circ$
2009	$\frac{98}{1681}\times 360^\circ = 21^\circ$	$\frac{120}{1681}\times 360^\circ = 26^\circ$	$\frac{249}{1681}\times 360^\circ = 53^\circ$	$\frac{153}{1681}\times 360^\circ = 33^\circ$	$\frac{1061}{1681}\times 360^\circ = 227^\circ$

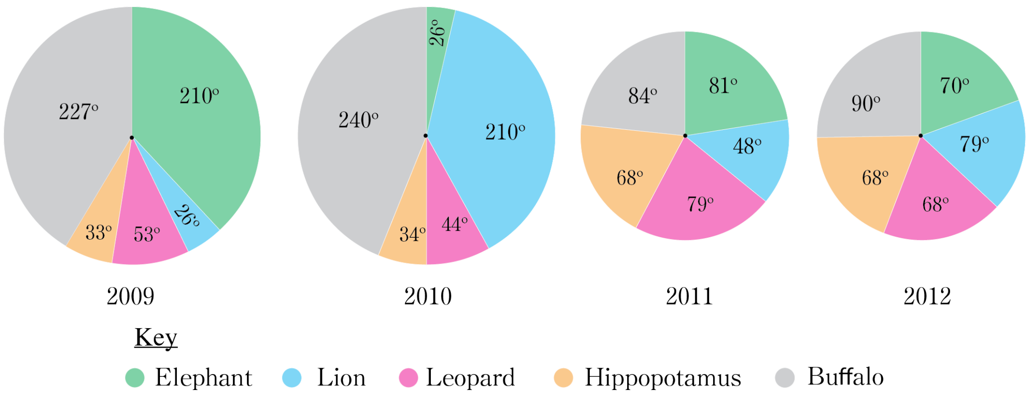


Figure 1.26: *Proportional divided circle showing trend of some of the wild animals hunted from 2009 to 2012 in degrees.*

Advantages and disadvantages of proportional divided circles

The proportional divided circle is beneficial in a number of ways including displaying relative proportions of multiple classes of data; size of the circle can be constructed proportionally to the quantity of data it represents; it is also useful in summarising a large data set in visual form and it is simple compared to other forms of graphs. It allows a visual checking of the accuracy of the calculations. However, it is associated with limitations such as failure to easily reveal the exact values. It can be easily manipulated to give false impressions.

Divided semicircles

These are half circle which are partitioned. There are two kinds of divided semicircles. These are, simple divided semicircles and Proportional divided semicircles

Simple divided semicircles

These are semi circular in nature but segmented accordingly. The segmentation are guided by 180 degree instead of 360 degrees as used in pie chart.

Procedures

The following are procedures for constructing simple semi-circles

Note: The procedures are similar to that of drawing simple piechart except the degrees are obtained by using 180 degree instead of 360 degrees.

Example:

Refer Table 1:38(a), draw a simple divided semi-circle to represent number of lion hunted from 2009 to 2012.

Solution

Find the total of items

Total = 37 + 27 + 98 + 120

Total = 282

To find radius $\sqrt{282}$

= 16.79

Scale: Let 1 cm represent 3 units(cm)

Then,

$$\frac{16.79}{3} = 5.5 \text{ cm}$$

Hence, radius = 5.5 cm

To find degree (180°) for each year

$$2012 = \frac{37}{282} \times 180° = 23.61°$$

$$2011 = \frac{27}{282} \times 180° = 17.23°$$

$$2010 = \frac{98}{282} \times 180° = 62.55°$$

$$2010 = \frac{120}{282} \times 180° = 76.59°$$

Note: Draw a divided semicircle to segment them accordingly. The segment should be portioned in a clockwise direction as in simple pie charts.

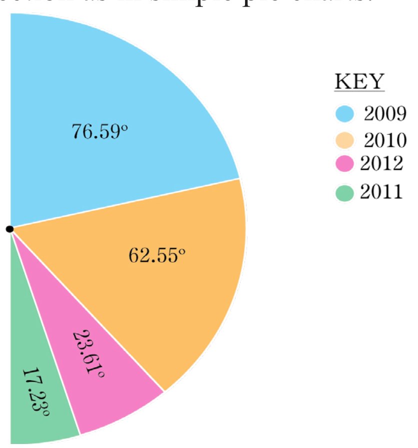


Figure 1.27: *A simple divided semicircle representing number of lions hunted from 2009 to 2012*

Proportional divided semicircle

Procedures

The following are procedures for construction of proportional divided semi-circles

(i) Calculate the total of two semicircles given, let radii be represented by R_1 and R_2;

(ii) Find the radius of both totals by applying the square roots to the obtained total;

(iii) Determine the scale of each semicircle first, then divide the totals by scales to obtain two radii;

(iv) Use the two radii to determine the size of semi circles;

(v) Express each semi-circle by percentage or degree (fraction of 360°) as in simple pie chart or proportional pie chart. It is recommended to follow either ascending or descending order;

(vi) Draw the divided semicircle; and

(vii) Write the title and key.

Example

Table 1. 39(a): *Gypsum production and export in '000 tonnes in Tanzania from 2013 to2016*

Year	Production ('000 tonnes)	Export ('000 tonnes)
2016	214	214
2015	255	225
2014	200	200
2013	281	172
Total	**950**	**811**

Solution

The radii of two circles are determined by:
Radius (R) = $\sqrt{T}$

Where;

T = the total value of the given item

Find the total of every item. The totality for the first item is 950 and the total for the second item is 811.

Find the radius for both totals

$R1 = \sqrt{950} = 30.82$

$R2 = \sqrt{811} = 28.48$

Determine the scale for every item

Scale: Let 1 cm represent 10 units (cm)

$30.82 \div 10 = 3.1$ cm

$28.48 \div 10 = 2.8$ cm

Calculate the degrees

Table 1. 39(b): *Gypsum production and export in'000 tonnes in Tanzania from 2013 to 2016 in degrees*

Year	Degrees	
	Production ('000 tonnes)	**Export ('000 tonnes)**
2016	$\frac{214}{950} \times 180° = 41°$	$\frac{214}{811} \times 180° = 48°$
2015	$\frac{255}{950} \times 180° = 48°$	$\frac{225}{811} \times 180° = 50°$
2014	$\frac{200}{950} \times 180° = 38°$	$\frac{200}{811} \times 180° = 44°$
2013	$\frac{281}{950} \times 180° = 53°$	$\frac{172}{811} \times 180° = 38°$

(v) Draw a proportional divided semi-circle

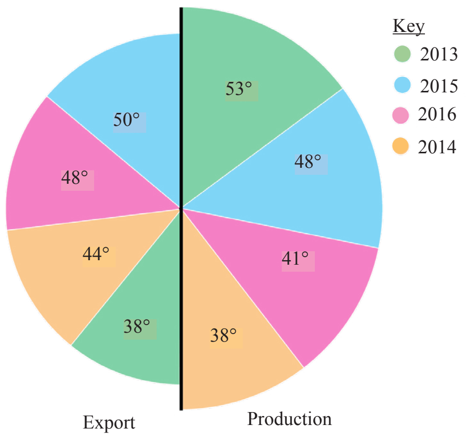


Figure 1. 28: *Gypsum production and export in Tanzania from 2013 to2016*

Advantages and disadvantages of proportional semicircle

The proportional semicircle, is used in making comparison that is why two semi circles are used; the value of each component can be analysed and provide accurate statistical information through percentage or degrees calculated. However, the method has some limitations including time consuming during calculations. On the other hand, the actual values may not be known easily as calculations involve percentages or degrees. Additionally, presentation of very small values cannot be accommodated by the method since their clarity can be distorted.

Divided rectangle

It is a rectangle whose total value or quantity is sub-divided into its constituents or parts. The divided rectangle is similar to compound bar graphs and even the procedures for drawing are the same. Divided rectangles can be categorised into two major groups, namely, simple divided rectangle and compound divided rectangle.

Simple divided rectangle

This is a single bar graph which is large in size. The bar is sub- divided into divisions or parts depending on the data given. The data in Table 1.40 have been used to construct Figure 1.29 which presents simple divided rectangle.

Table 1.40(a). *Production of perennial crops (000 tonnes) in Tanzania in 2012*

Crop	Production
Coffee	995
Sisal	58
Cane sugar	57
Cashew nuts	152
Tea and pyrethrum	18

Source: *Ministry of agriculture (2012)*

Procedures

The following are procedures for constructing simple divided rectangle

(i) Find the total values of all items in the table and; arrange the item values according to their size starting with the largest;

(ii) Change each item value into percentage; select the suitable length of the rectangle, width does not matter, but it should be smaller than the length. For example, let 1 cm represent 7%. Hence, length of rectangle will be 14.3 cm;

(iii) Use the percentage composition of each value to calculate unit lengths from the total horizontal length;

(iv) Each unit length should be carrying percentage composition of each value;

(v) Draw the rectangle subdivide into parts and shade each part differently starting with the smallest; and

(vi) Write the title and key.

Solution

Table 1. 40(b): *Production of perennial crops ('000 tonnes) in Tanzania in 2012*

Crop	Production ('000 tonnes)	Percentage (%)	1cm = 7% X cm = ?	Cumulative length
Coffee	995	77.73	11.1	11.1
Sisal	152	11.88	1.7	12.8
Cane sugar	58	4.53	0.65	13.45
Cashew nut	57	4.45	0.64	14.09
Tea and pyrethrum	18	1.41	0.20	14.29
Total	**1280**	**100**		

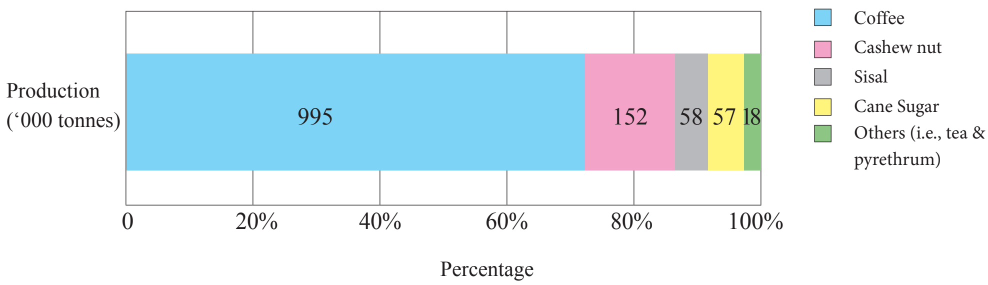


Figure 1.29: *Production of perennial crops ('000 tonnes) in Tanzania in 2012 tonnes*

Advantages and disadvantages of simple divided rectangle

The simple divided rectangle is convenient in presenting data on a diagram due to its simple scale. Only the scale for dependent variable is considered. It is not associated with application of complicated calculations hence easily drawn; the information displayed allows easy comparison of data given in the diagram. It also, presents numerous items with better visualisation due to colouring of the diagram which is attractive. Nonetheless, simple divided rectangle falls short of presenting few data as compared to the compound divided rectangle. Furthermore, the vertical scale is not considered when drawing the independent variable.

b) Compound divided rectangle

This is a type of divided rectangle which involves more information due to presenting several data as shown in Figure 1.30. It can be employed in describing land uses in different countries, states, regions or districts.

Often the information can be visualised simultaneously for comparison purposes in terms of extent and variations across the studied elements. The data in Table 1.39(a) which show the distribution of small-scale industrial development for 2015 in Songwe region have been used to draw Figure 1.30.

Procedures

The following are procedures for constructing divided rectangle.

(i) Find the total of each number of items (small scale industries) (Table 1.41(a)) in each given council. Totals will be used to determine the horizontal scale;

(ii) Calculate the % of each number of items for this case number of small industries (Table 41(c));

(iii) Find the horizontal scale using the grand total from sub-totals on procedure (i) above,;

(iv) Calculate the portion or segment for each number of items given basing on horizontal scale. That is the total length of horizontal baseline;

(v) The vertical scale: depends on percentages calculated for each council then present the data from each council, depending on the vertical scale which is usually1cm:10%;

Example

Table 1.41(a): *Number of small scale industries established in Songwe region by 2015*

Council	Welding	Carpentry	Maize milling	Sunflower processing	Total number of industries
Songwe DC	6	5	124	7	142
Ileje DC	15	75	216	11	317
Mbozi DC	79	374	646	55	1 154
Momba DC	4	1	214	3	222
Tunduma TC	54	104	128	10	296

Source: *Songwe Region (2019)*

Solution

From Table 1.41(a), then,

Total area (grand total)

= 142 + 317 + 1154 + 222 + 296 = 2131 units

From this grand total estimate the horizontal scale. Let say $\frac{2\,131}{10} = 213.1$units

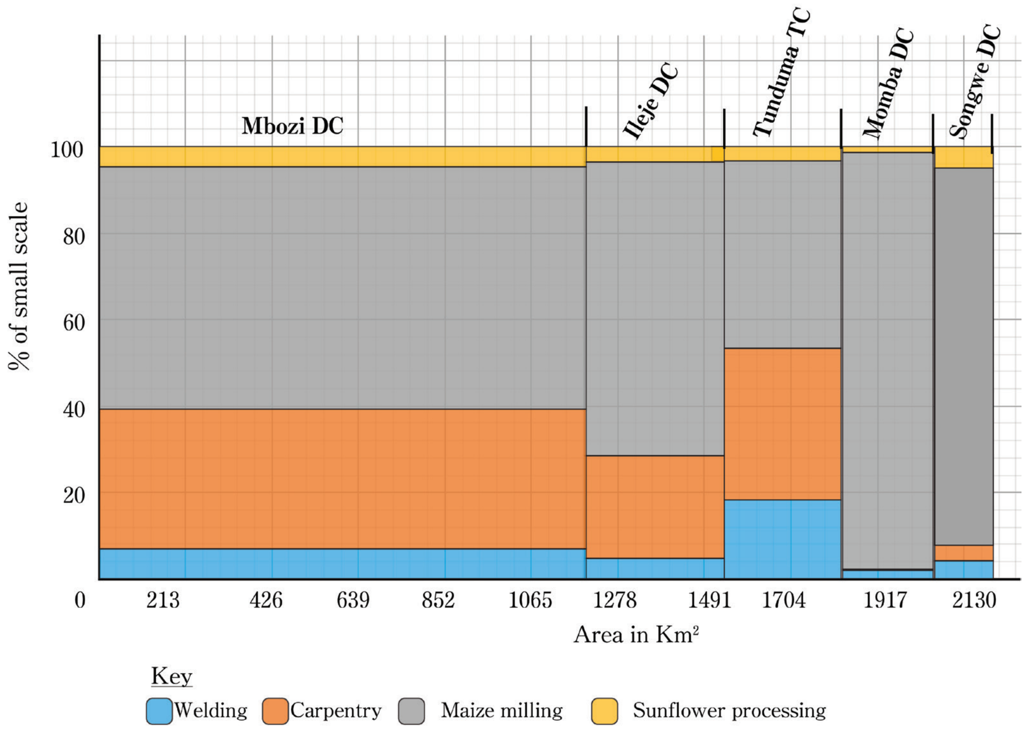
The diagram may extend to 10 cm horizontally it will be; 1cm: 213.1 units.

Table 1. 41(b) : *Number of small scale-industrial establishment in Songwe region by 2015*

Council	Unit length	Cumulative length
Mbozi DC	$\frac{1154}{213.1} = 5.4$ units	5.4 units
Ileje DC	$\frac{317}{213.1} = 1.5$ units	6.9 units
Tunduma TC	$\frac{296}{213.1} = 1.4$ units	8.3 units
Momba DC	$\frac{222}{213.1} = 1.0$ units	9.3 units
Songwe DC	$\frac{142}{213.1} = 0.7$ units	10 units

Table 1. 41(c): *Cumulative frequency for the number of small scale-industrial establishment in Songwe Region by 2015*

Council	Number of industries	Percentages				
		Welding	Carpentry	Maize milling	Sunflower processing	Total
Mbozi DC	1154	7	32	56	5	100
Ileje DC	317	5	24	68	3	100
Tunduma TC	296	18	35	43	4	100
Momba DC	222	2	1	96	1	100
Songwe DC	142	4	4	87	5	100



Scale: V.S:1cm to 20%; H.S:1cm to 213 Km^2

Figure 1. 30: *Number of small scale industries established in Songwe Region by 2015*

Advantages and disadvantages of compound divided rectangles

The compound divided rectangle is useful in the following ways: it can convey much more statistical information than a compound bar graph and a divided circle. The comparison of data can be easily visualised and interpreted. Furthermore, it is capable of displaying for example area in square kilometers in relation to economic activities. However, its limitations include the methods being too tedious in calculating and identifying a scale which should be compromised between vertical and horizontal scale. It is also, time consuming due to complex procedures to access data for constructing the graph.

Repeated symbols

Symbols are simple signs that are used to represent different features. Since maps require large amounts of information to be conveyed in a limited space, the use of symbols to represent particular features is necessary. Symbols are small but many are immediately recognisable. This means that they have an advantage over drawing or writing all of this information onto a map. It is a method in which statistical information can be represented on a map by the repetition of one symbol of uniform size or character or by a variety of symbols placed on their location on a map. Therefore, two types of repeated symbols can be distinguished. These are the qualitative and the quantitative symbols. Repeated symbols are the simplest methods of conveying non statistical and statistical information on a map and they are commonly observed on maps dealing with agricultural products, minerals, economic development and maps and guides generated for specific purposes; for example, tourism for promotion purposes.

The qualitative symbols

It is basically pictorial or descriptive in nature, for example, crops by their initial letters such as **CN** for cotton; **FR** for fruits; **SS** for sisal and **R** for rubber (Figure 1.31). Others are illustrations of plants for crops, drawings of cattle for ranching, pictures of tree for forests or a range of symbols for minerals and so on. The symbols can either be pictorial or descriptive. The qualitative repeated symbols are essentially descriptive devices which give a visual impression of the represented data item. They do not represent the actual characteristics of the observed variable.

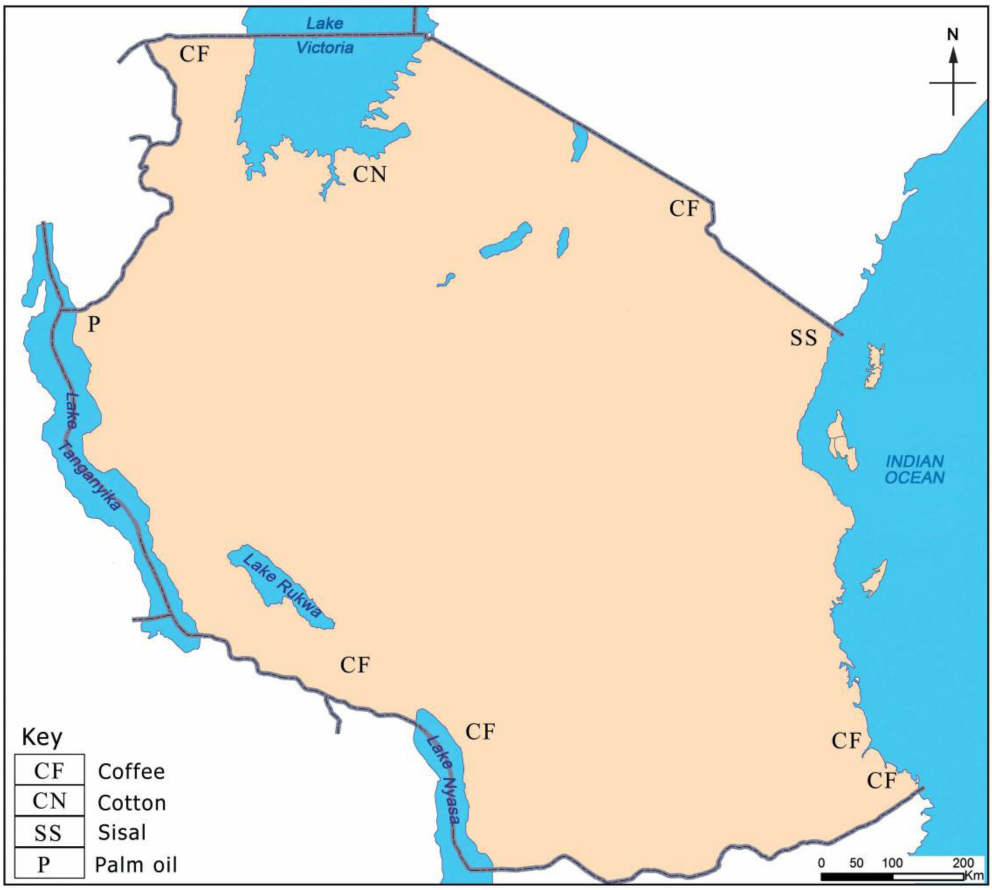


Figure 1.31: *Cash crops production in Tanzania*

The quantitative symbols

These are symbols of the same size and shape placed at a place to show the quantity of what the symbol represents. For example, each symbol represents a given quantity. Fish = 10000 tonnes (one fish represent 10000 tonnes of fish). Therefore, the number of fish on a map are counted and then multiplied by 10000 to get the total amount of tonnes (Figure 1.32).

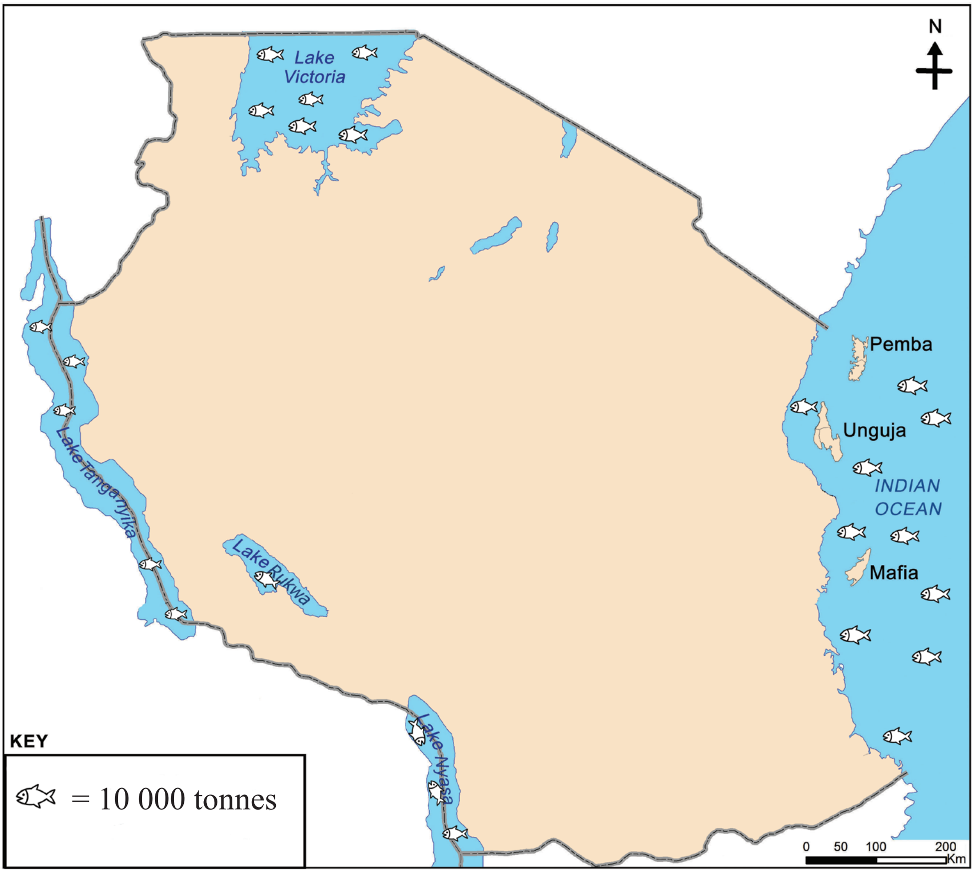


Figure: 1. 32: *Number of fish in Tanzania's water bodies*

Advantages and disadvantages of repeated symbols

Repeated symbols have both advantages and disadvantages; some of the benefits of the symbols include their usefulness in presenting statistical information which is easy to read and interpret; simplifying comparison of the presented data items such as economic production related data. Simple construction of the scale and the use of calculation is minimised in the cases of qualitative symbols. On the other hand, the symbols have some drawbacks such as; limitations of drawing symbols of the same size by free hand. The needs for drawing sketch map may be difficult. The limited use of scale especially in qualitative approach may cause problems in understanding the actual product in terms of amount. Another drawback with repeated map symbols is congestion and or overlap, especially if there are large variations in the size of symbols if numerous data locations are close.

Proportional diagrams

A proportional diagram is a diagram that compares two or more values by using the area of shapes, usually squares, rectangles, or circles. They are popular because they instantly communicate the differences in the values to a viewer. These diagrams are commonly used in newspapers and magazines. The proportional diagrams can be regarded as an extension of the proportional divided circles (pie chart). Proportional diagrams can be presented in four (4) ways, which are proportional circles, proportional squares, propositional cubes and proportional sphere.

Proportional circles

Proportional circles can be used to represent various items, for example population, crop yield, quantities of imported and exported goods. The scale is drawn to show the value of a given circle. Usually, each circle is proportional to the quantity it represents.

Procedures

The following are procedures for constructing proportional circles.

(i) Find the square roots of each item of data that will denote a radius of the circle;

(ii) Estimate the length of the radius for the largest circle first, example if the population of a village is 3000 people, the square root will be 54.7. Therefore, it should be noted that a radius of 54.7mm could be too large to draw;

(iii) Thus, it should be halved, it may be suitable at 27.3mm;

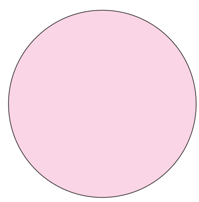
(iv) For this case all other radii must also be halved;

(v) The proportional of circle will be drawn in the ascending order by starting with that of the smallest circle to the largest depending on the number of data items;

(vi) Label each of the circle with respective quantity represented by the proportional circle; and

(vii) Indicate the unit of the items represented and a scale.

Example of procedures for constructing proportional circle

(a)	Items	Population 625
(b)	Square root	$\frac{\sqrt{625}}{2} = \frac{25}{2}$
(c)	Therefore, a circle is drawn with a radius 12.5 mm	
	 Showing a proportional circle of a population.	

Example 1

Draw proportional circle showing trend of leopard hunted from 2009 to 2012

Table 1.42 : *Leopard hunted from 2009 to 2012*

Year	Leopard
2012	40
2011	44
2010	205
2009	249

Table 1.43 : *Leopard hunted from 2009 to 2012*

Year	Leopard	Square root	Radius
2012	40	6.3	$\frac{6.3}{7} = 0.9$ cm
2011	44	7.6	$\frac{6.6}{7} = 0.9$ cm
2010	205	14.3	$\frac{14.3}{7} = 2.0$ cm
2009	249	15.8	$\frac{15.8}{7} = 2.3$ cm

Since square root has low amount of value; let estimated radius be 1cm represent 7 items number of square root.

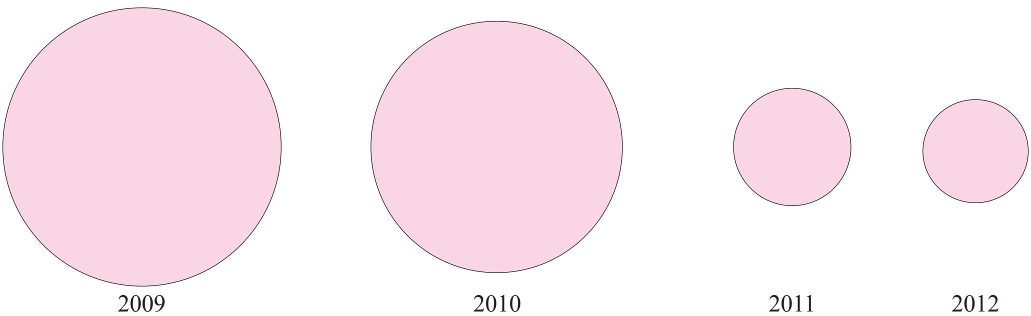


Figure 1.33: *Proportional circle for leopard hunted from 2010 to 2012*

Advantages and disadvantages of proportional circle

The proportional circle is essential for making comparison of the data items under the study. It can be combined with other method in the same map. It can also be used where other methods such as dots may result in overcrowding. The cycle has some limitation such as: the comparison posing difficulties in making when the size of circles becomes almost the same due to small differences of represented values. Other limitations involve time consuming due to long processes of scale calculation and the method falls short of presenting absolute values.

Proportional squares

Proportional squares may be used in the same way as proportional circles. The area of the square proportionally reflects the quantity it represents. On the other hand, the length of the side of the square related to the square root reflects directly the square root of the number to be represented. This method is useful in cases where there are relatively numbers to be dealt with, such that by applying the square roots, numbers are reduced and become manageable. Proportional squares may be employed without reference to the map.

Procedures

The following are precedures for the construction of proportional squares

(i) Calculate the square root of the total values to be represented. Having drawn the scale, value will be the length of the side of the square; and

(ii) Show the key clearly.

Advantages and disadvantages of proportional squares

Even though the proportional squares are more difficult to draw, their relative areas are probably easier to assess than circles; and are more suitable for comparison of items under observation.

Proportional cubes

Proportional cubes can be drawn independent of a base map. They are usually located on a base map as presentative of quantity distribution or production. Cubes have additional component on dimensions that is, length × width × height which differentiate them from rectangles. Cubes have a strength of presenting statistics which have greater values as compared to linear methods. The side of the proportional cube bears a direct relationship to the square root of the quantity being represented. For instance, if the length of the side of the proportional is square 5 mm it means it represents 25 units of production while a cube of the same measurements will represent 125 units.

Procedures

The following are precedures for constructing proportional cubes

(i) Calculate the cube root of the quantity to be represented such as $\sqrt[3]{R}$, where R is the quantity to be represented;

(ii) Draw the cubes independently of the base-map, for purposes of comparison;

(iii) Cubes can be drawn in several ways either *isometrically,* in which all sides are of equal lengths or *prospectively* the sides are one-halved to three quarters the length of the front. In single map all drawn cubes should be with same pattern; and

(iv) Provide a key.

Advantages and disadvantages of cubes

The advantage of proportional cubes is the easy with drawing than spheres and the assessment of volume of two cubes of different sizes is perhaps less difficult that the relative volumes of two different spheres. Proportional cubes however, disapproved of less visualisation, unless the presented items by themselves have a cube shaped like bales of cotton. Another disadvantage is that the components of the cube cannot be splited . Moreover, the use of cubes is limiting in making comparison of the quantities being represented, unless statistical information is provided on the cube.

Proportional sphere

Usually, concept of proportional sphere is somewhat similar concept to the proportional cube. Likewise, the three-dimension characteristics possessed by the spheres widens that horizon of serving nearly the same purpose as the cube. Three dimensions enables it to accommodate a wide range of values to be represented, the volumes of the sphere are usually proportional to the quantity represented.

Advantages and disadvantages of proportional spheres

The proportional spheres enable easier visualisation of items under the study same as proportional cube. They serve as alternative options in incidents great quantity of elements which become impractical on others methods. However, the sphere has some disadvantages including difficult in drawing, calculations challenges and limitations of some readers to assess relative volumes of different spheres

Activity 1.4

In group of five students visit the nearby government/private institution engaged in documenting data on agricultural production in your locality and collect data on the production of three to five crops grown in the area for the past three to five years. Use them to construct a simple divided circle (simple pie chart) and present the results to the class for the detailed discussion.

Wind roses

Wind roses are used to show the average frequency and directions of the wind in different speed at a given area. They can also be used to show the delivery of quantities such as milk, newspapers or other goods through star diagram. Wind roses are of two types namely; simple wind rose and compound wind rose.

Simple wind rose

Simple wind rose is a simple linear method used to show the direction and frequency of the wind only.

Example: Study the data given in Table 1.44 and draw a simple monthly wind rose.

Table 1. 44: *Simple monthly wind rose data*

Direction of wind	N	NE	E	SE	S	SW	W	NW	Calm
Number of days	3	2	1	1	3	7	7	5	2

Procedures

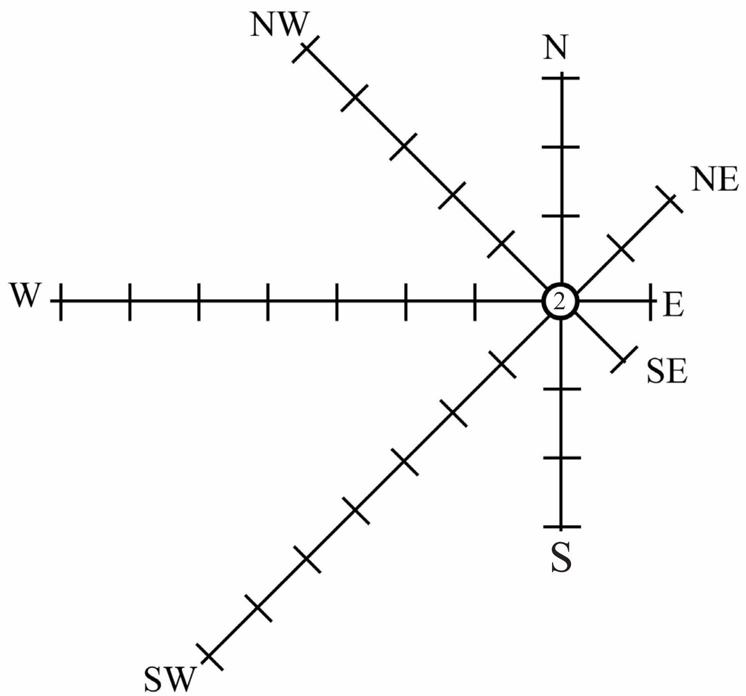
The following are procedures for constructing a simple wind rose

(i) The centre of the wind rose is usually a circle of any convenient size;

(ii) Average wind direction and speed values recorded monthly or annually are presented separately. Eight cardinal points of the compass are usually sufficient;

(iii) The length of the columns or aims can be drawn proportional to the actual number of days; and

(iv) Draw the simple wind rose, put the title and indicate the scale.



Scale: 1cm to 1 unit

Figure 1.34: *Simple wind roses showing monthly wind direction*

Compound wind rose

Compound wind roses may be used to display wind direction, frequency and speed.

Procedures

The following are procedures for constructing compound wind rose

(i) The basic method of construction is similar to that of simple wind rose, only that compound wind rose uses either actual or percentage values;

(ii) The speed of the wind is then indicated by adjusting the width of the column. An increase in width signifies an increase in wind speed;

(iii) The divisions chosen are usually less than 4 mph;

(iv) When it is calm the force is zero (0) and the speed is less than 1mph;

(v) Compose a convenient scale for depicting the number of hours per direction;

(vi) Determine the pattern of speed as a key;

(vii) Plot diagram and put a good title; and

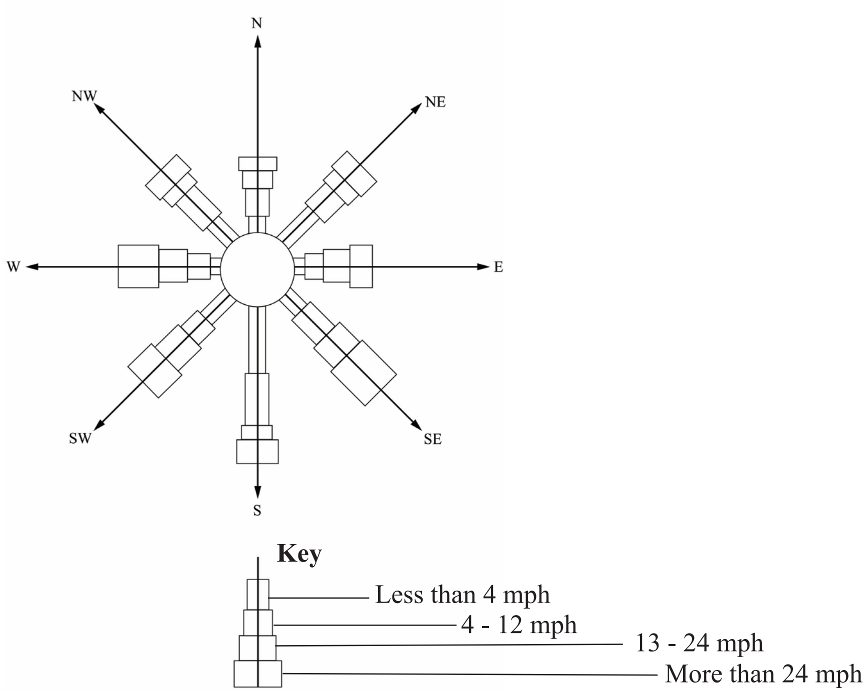
Note: Much attention is needed in drawing and in scale selection.

Example:

Table 1.45: Shows the mean annual wind speed and direction for hypothetical station X

Table 1.45: *Mean annual wind speed and direction for station X*

Wind speed	N	NE	E	SE	S	SW	W	NW
Less than 4 mph	1.2	4.2	1.1	2.1	6.2	3.3	1.2	3.3
4 - 12 mph	2.8	3.0	1.6	4.2	5.0	2.4	2.4	3.9
13 - 24 mph	1.8	1.4	3.0	3.3	1.1	4.1	3.3	1.2
More than 24 mph	1.0	2.0	2.1	6.1	2.3	3.1	3.9	2.4
Total	**6.8**	**10.6**	**7.8**	**15.7**	**12.6**	**12.9**	**10.8**	**10.8**



Scale: 1cm to 1unit

Figure 1.35: *Mean annual wind speed and direction for an imaginary station X*

Advantages and disadvantages of wind rose

The pattern of shading gives the diagram a good visual impression. Comparison is easy in terms of the direction in which the wind blows. It shows the speed of the wind in different directions. However, wind rose has some demerits such as time consuming since it involves measuring and scale construction.

Activity 1.5

Draw a compound wind rose to represent the following data

Wind speed		Direct
Less than 4 mph	6 mm	N
4 -12 mph	8 mm	E
13 -24 mph	10 mm	W
More than 25 mph	12 mm	S

Exercise 1.4

1. Compare the proportional circles and proportional spheres.
2. With a map of Tanzania use a non-qualitative symbol to show the location of two mineral resources of your choice.
3. With specific examples explain five procedures of constructing a proportional circle.

Statistical Maps

Statistical map is another method of data presentation in geography whereby statistical data can be presented through with a sketch map. Statistical maps are classified into four (4) groups namely; dot maps (distribution of maps), isoline maps (isopleth maps), chloropleth maps (shading or destiny maps) and flow line maps (flow maps).

Dot map

Dot map is the simplest and most widely used type of distributions map that uses a point to visualize the geographical distribution of a phenomena. The dot map results from a combination of repeated symbols of uniform size and a dispersion map. A distribution map is essentially the representation of absolute or actual quantities on a map in such a way that a single quantitative dot has a specific and fixed value of a quantity represented. Therefore, it is imperative (though not always practical) to count the number of dots on a map and multiply with the quantity they are assigned to for accurately estimation of total value.

Construction of dot maps

The construction of dot maps (distribution dot maps) is established by the components, namely: dot value, size, location and followed by drawing. Deciding on dot-value can possibly affect the representation of quantity on a map so it should neither be undermined nor exaggerated. That is, if not carefully considered, it would result into unnecessary placing of too many dots while the dot-value is too low (overcrowded maps) especially in areas with greater concentration. Similarly, placing too few dots where the dot-value is too high could give an equally wrong impression. Decision on dot map should be guided by the range of figures to be represented that has implication to the value and number of dots to be drawn. It is recommended to prepare a trial map which despite consuming time will guide you through obtaining reliable results.

Dot size in terms of its diameter is importance. Dot size cannot be thought in isolation with the dot-location. Extreme sizes of dots should be avoided, the number and size of dots must be in a way that they bring a clear visual impression of the differences in distribution, contrasting with regard to the varying concentration across areas such as, areas with greater concentrated versus sparsely or scattered areas.

Dot location however, is concerned with placing the dots based on two methods namely, distributing evenly over the area concerned or based on quantities represented by the precise location of the dots on a map. The former is of limited value although it can be resorted to in case of absence of precise distribution of the dots on a map.In this method dots are evenly distributed after calculation of the number of dots. This method falls short of conveying limited information except the total quantity (the number and value of dots) and it is impractical in indicating the possible true distribution of the dots. It is however, useful in presenting the visual impression of comparative densities.

For the case of the latter method, consideration is on the prior first-hand information of the area. However, in the absence of first-hand information relies on other reasonably accurate maps of the same area. For instance, maps showing relief, drainage, geology, soils, vegetation, rainfall, land use, communication, water supply and settlements. Basing on analysis and collating of such information give hints though not perfectly accurate on possible areas to be distributed with either sparce or concentrated kind of dots. In case concentrated areas, it is advised to address those areas first by calculating the number of the required dots and thereafter complete the rest of the dots in other areas.

Importantly, drawing the dots can be unclear particularly to non-professionals. However, preparation should thoroughly be done by marking on the map the position of all dots, very slightly, with a special pencil. Some of the recommended material for drawing are dotting pens, since the subsequent drawing of dots with correct size, circular and uniform character, cannot successfully be done with an ordinary pen or pencil. Probably the non-professionals are advised to use fibre -or nylon-tipped pens which are commonly available and affordable. A good drawing result can be achieved by a firm and vertically held pen on the non-absorbent paper. Data in Table 1.43(a) which shows the hypothetical number of antelope in the selected gazetted national parks in Tanzania have been used to draw Figure 1.36.

Procedures

The following are procedures for constructing dot maps

(i) Calculate the scale by identifying the dot value;

(ii) Determine the size of a dot whereby too large or small dot is not appropriate;

(iii) Draw the sketch map where dots will be allocated; and

(iv) Prepare an appropriate scale. For example, let 1 dot represent 300 people.

Example:

Study the data in Table1.46(b) and draw a distribution dot map showing hypothetical number of antelope in the selected gazetted national parks in Tanzania.

Table 1. 46(a): *Hypothetical number of antelope in the selected gazetted national parks in Tanzania by 2019.*

S/N	The National Park	Number of antelope
1	Katavi	4 471
2	Kilimanjaro	1 668
3	Mahale	1 613
4	Mikumi	3 230
7	Mkomazi	3 254
6	Ruaha	20 300
7	Saadani	1 062
8	Serengeti	14 763
9	Tarangire	2 830
10	Udzungwa	1 990

Solution

Scale: Let 1 dot represent 500 antelope

Table 1.46(b): *Hypothetical number of antelope in the selected gazetted national parks in Tanzania by 2019*

S/N	The National Park	Number of antelope	Calculations	Average	Number of dots
1	Katavi	4 471	4 471÷ 500	8.94	9
2	Kilimanjaro	1 668	1 668÷ 500	3.34	3
3	Mahale	1 613	1 313÷ 500	3.23	3
4	Mikumi	3 230	3 230÷ 500	6.46	6
5	Mkomazi	3 254	3 254÷ 500	6.51	7
6	Ruaha	20 300	20 300÷ 500	40.60	41
7	Saadani	1 062	1 062÷ 500	2.12	2
8	Serengeti	14 763	14 763÷ 500	29.53	30
9	Tarangire	2 830	2 830÷ 500	5.66	6
10	Udzungwa	1 990	1 990÷ 500	3.98	4

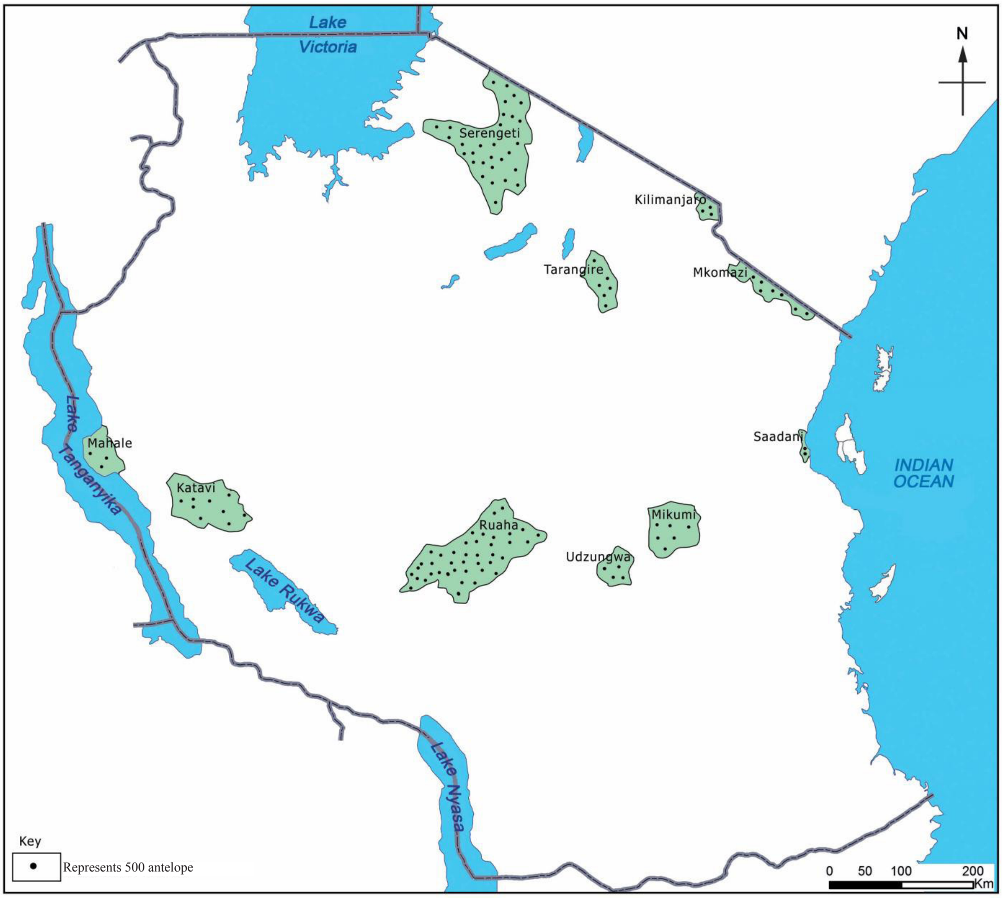


Figure 1.36: *Distribution of antelope in the selected gazetted national parks in Tanzania by 2019*

The advantages and disadvantages of dot maps

The dot maps are simple to use since the lower the dot value, the more accurate the picture of distribution and value. The map can be interpreted quantitatively, that is the number of units within each boundary can be counted. The value and location of several items can be shown on the same map by using different colours and symbols. For example, goats and donkey, different ethnic groups and range of crops or minerals. Similarly, calculation and drawing may be fairly easy and the result is graphically pleasing. It is also simple to delete the dots used on the map.

However, the dot maps have some limitations, such as the possibility of faults in construction, if dots merging may not become apparent until the map is nearly completed, this may lead to re-calculation and redrawing of the map. If no topographical information is available, evenly spaced dots will give a false impression, like the chrolopleth.

Moreover, with large dot value, spatial distribution cannot be accurately shown, only the general distribution. Dots must be placed in the gravitational centre of the actual distribution. Furthermore, the approximation of decimals for example, 6.51 ≈ 7 distorts numbers of the total population. Finally the method is time consuming due to scale calculation and sketch map drawing.

Isoline map

Isoline map is also known as isopleth map. It is one of the popularly used methods of statistical data representation. Isoline stands for line joining places or points with equal value. The term isoline is interchangeably used with isarithm and isometric lines. The word isoline is derived from Greek Word *isos* meaning equal. The following are phenomena on a map which can be represented by isolines:

Table 1. 47: *Phenomena on a map which can be represented by isolines*

S/N	Types of line	Variable represented
i	Contours	Height
ii	Isotherm	Temperature
iii	Isobars	Pressure
iv	Isohyet	Rainfall
v	Isoneph	Cloudiness
vi	Isobath	Ocean depths.
vii	Isohalines	Salinity
viii	Isohel	Sun shine
ix	Isohume	Humidity

Procedures

The following are precedures for constructing isoline map .

(i) Choose a suitable isoline interval for example scale 5 °C;

(ii) Interpolate or insert intermediate value or lines on the map that is interpolate or insert intermediate value or lines on the map, for example areas with less than 20 °C, 21°C, 25 °C and above 26 °C.

The example Figure 1.37 shows temperature in °C at different parts.

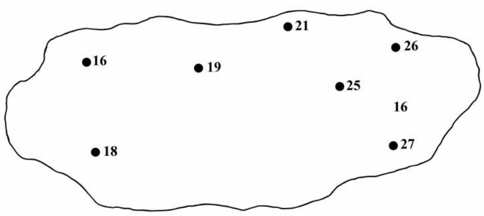


Figure 1.37 (a): *The map showing temperature in °C at different parts.*

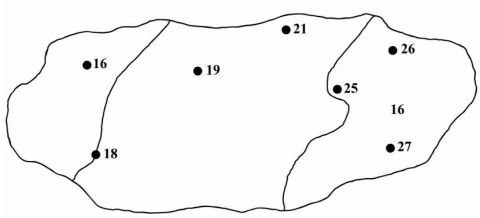


Figure 1.37 (b): *The map showing temperature in °C at different parts*

(iii) Then shade the spaces between the isoline. The shades should become more concentrated or dense and indicate scale.

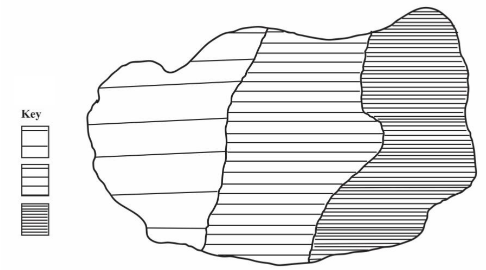


Figure 1.37 (c): *The map showing temperature in °C at different parts.*

Advantages and disadvantages of isoline maps

Isoline maps have both merits and limitations. The main benefits with isoline map, value can be obtained at any point on the map. Where points are not on isolines is that the , their values can be obtained by interpolation. The interval between each isoline suggests gradual and abrupt change, hence shading must be well graded to maintain this aspect. Furthermore, isolines can be combined with other data for example, population and crop distribution and related to isohyet (rainfall map). Some of its limitations include the interpolation of value points which is subjective and relies on the judgment of the individual cartographer. Some data distributions can be interpreted in different ways and can result into duplication of isoline maps. Furthermore, in a situation with a large number of data points much time can be required to accomplish the process of drawing isoline maps.

Another disadvantages, is lines drawn for one feature may automatically interfere with other linear features on a map. In short, it is difficult to represent more than one feature in a single map.

Choropleth map

A Choropleth map is derived from Greek word *choros* means area or region and *plethos* means multitude. It is a type of a thematic map which is proportionally shaded, coloured, patterned or striped to indicate the pre-defined areas to a statistical variable represented on a map as an aggregate summary of a geographical characteristic within an area. Furthermore, Choropleth map is a map in which population densities of different areas are shaded in different coulours or patterns. Choropleth map is also known as the real density map.

Procedures

The following are procedures for the construction of choropleth map

(i) Calculate average densities (population density) for each statistical unit as required;

(ii) Choose and draw according to scale of densities; and

(iii) Shading should be heavier or dense as values increases.

Example: Construct a choropleth map for population density in selected regions in Tanzania as shown in Table 1.48.

Table 1. 48: *Population density in selected regions in Tanzania*

Region	Population	Area in sq km	Density
Mbeya	1 250 605	87 567	14.28
Njombe	1 030 805	38 906	26.49
Arusha	1 355 685	84 567	16
Dodoma	1 020 815	47 311	21.57
Kigoma	855 807	45 066	18.99
Rukwa	1 000 825	35 705	28

Source: *Tanzania census survey (2012)*

Geometric progression classes
11 - 15.9 Mbeya
16 - 20.9 Arusha, Kigoma
21 - 25.9 Dodoma
26 - 30.9 Njombe, Rukwa

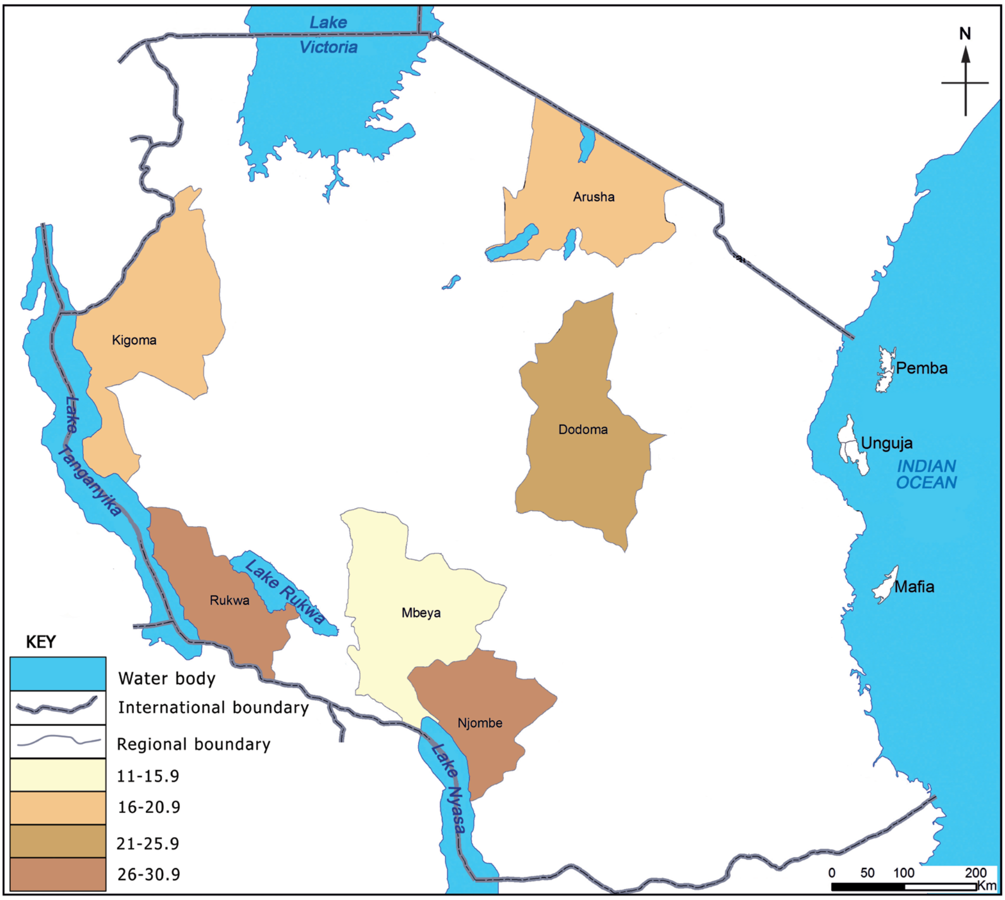


Figure 1.38: *Population density in selected regions of Tanzania.*

Advantages and disadvantages of choropleth map

Basically, choropleth maps are useful in a number of ways in the statistical information representations. The major ones include providing a good visual impression of the elements studied; easy to compare the population densities of each unit, easy to interpret with the aid of key and simple to draw when a map and a table have been provided. More over, choropleth map can accommodate any scale. Conversely, some limitations of the choropleth maps included giving a wrong impression that density changes suddenly at boundaries in a given map. Furthermore, variations of the density within each boundary are not shown hence, giving impression that there is uniform density within each administrative unit. Shading may obscure/hide other features.Lastly, drawing of the Choropleth maps is tiresome and time consuming particularly shading of large data.

Flowline map

Flowline map also known as flow chart is a diagrammatically presentation of the movement of goods or number of vehicles, people, cattle etc. from one place to another. It may show the movement of goods from production area to the market or point of export. The volume of flow is shown by line, whereby the width of the flow is an important factor which varies proportionally with the varying number of goods or people traveling along the given routes. Also, width may be determined by the types and frequency of traffic (by road, rail, air or water) of the migratory movement of people, or stock, the paths of cyclone or ocean currents, the direction, quantity or character of exports or imports and many other statistics involving movement.

Procedures

The following are procedures for constructing flowline map

(i) Choose a scale which is appropriate to the data given;

(ii) Consider the width of the flow line, which must be proportional to the quantity or value of the element to be represented;

(iii) Draw the sketch map and indicate the important towns and cities involved such as along the pass and the destination of movement in question;

(iv) In drawing the flow line on the base map, it is not necessary to follow all the twisting and windings of road or railway; and

(v) The meeting place of various flow line (for example, a market town, bus station, port of import or export, collecting centre and so on), can be shown by various methods and the easiest method being to bring shaped nucleus. It should be noted that the nucleus may develop but the interest is in the movement of commodities and not representation of meeting places.

The data in Table 1.49(a) which shows the movement of rice from Morogoro to other regions in Tanzania has been used to draw flow line map (Figure 1.39).

Example

Table 1.49: *Movement of rice in tonnes from Morogoro to other regions in Tanzania*

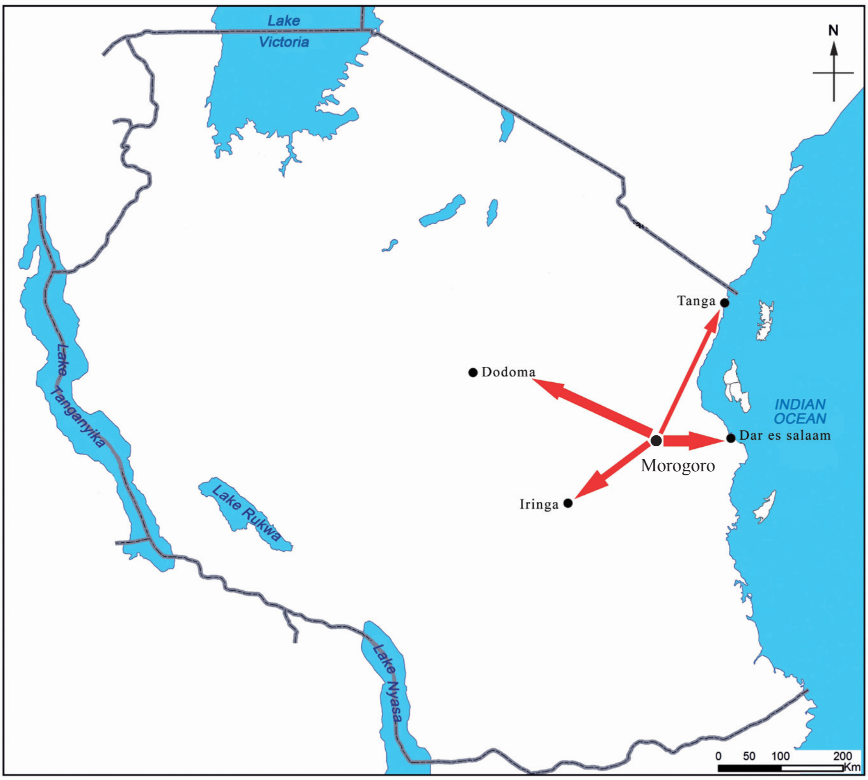
Region	Tones exported
Iringa	12 000
Dodoma	18 000
Tanga	8 000
Dar es Salaam	20 000

Solution

Table 1.50: *Movement of rice in tonnes from Morogoro to other regions in Tanzania.*

Region	Tones exported	Scale	Divide by two
Iringa	12 000 ÷ 4 000	3 mm	3 mm ÷ 2 = 1.5 mm
Dodoma	18 000 ÷ 4 000	4.5 mm	4.5 mm ÷ 2 = 2.3 mm
Tanga	8 000 ÷ 4 000	2 mm	2 mm ÷ 2 = 1 mm
Dar es Salaam	20 000 ÷ 4 000	5 mm	5 mm ÷ 2 = 2.5 mm

Note: Absolute scale 4000



Scale: 1 tonne represents 4 000 units

Figure 1. 39: *Flow line map to portray the movement of rice in tonnes from Morogoro to other regions in Tanzania*

Advantages and disadvantages of flowline maps

The flowline maps are widely useful as flow data in statistical form are replaced by simple methods of presentation and interpretation. The flowline chart maps can clearly and insightfully give clue on the problems that are likely to hinder movement for example, traffic congestion. Flowline maps are very versatile and can show two traffic and various methods of transport. Additionally, the method of construction is fairly easy once the scale has been decided. However, the flowline maps have some limitations such as very low volumes represented by a non-scaled line. Moreover, log or square root flowlines lose their direction proportions and the reader has to use the key frequently. Furthermore, the wide variation between the highest and the lowest volume of data makes the scale difficult to assess.

Activity 1.6

1. Visit your school library or any other nearby library, study geographical maps from geography books and resources. Then;
   (a) Identify the geographical maps found in the surveyed books and resources
   (b) Identify the geographical data presented through the maps.
   (c) Choose and draw three types of statistical maps in your exercise book.

Present your work to the class for an extensive discussion.

Limitations of statistics

Despite the practicality of statistics in many fields, The following are some of its limitations: Firstly, statistics deals with a group or set of data and attach less importance to individual items. Statistics is inadequate where knowledge of individual items becomes necessary. It is most suited to those problems where aggregate characteristics are required. Secondly, statistics deals with quantitative or numerical data. Basically, not all subjects can be expressed numerically. There are situations where qualitative data are required. For example, poverty, behaviour, intelligence and health are all qualitative data which cannot be directly quantified. So, these types of data are not suitable for statistical analysis. Thirdly, errors during sampling can lead to establishment of wrong conclusions if not handled by experts. Incorrect application of methods could lead to the drawing of wrong conclusions in statistics. Fourthly, statistical data in most cases is usually approximated and not very exact. Emphasis is often put on sampling method of data collection, that means if a limited number of items are selected, the result of the sample may not be a true representation of the population.

Statistics and computer

After surveying various methods for data analysis and presentation, it is important to shade light on the existing sophisticated means of data management and storage for statistical geography.

The growing wave of science and technology has attracted the statisticians in integrating the field of computer and information technology in statistics. Though not covered extensively in this book it is important to understand how the era of computer science has usefully simplified management of numerical data in statistics. It is undeniable truth that to date computer can usefully be used in recording and storing of a massive numerical data collected from the field and in turn be summarised to make meaningful information for interpretation and reporting. The modern electronic computer can be used in performing a number of statistical calculations within a short time. Geographers can make use of computer in number of ways including recording, analysing, summarising data and commanding the computer software to generate figures and tables based on recorded data thus simplify interpretation. The increasing knowledge and skills on computer has enabled drawing of computer-based maps indicating distributions of data such as temperature, rainfall and population in a given location or area.

Currently, geographers are developing interests in understanding computer software and programme that are vital in managing statistical data. Some useful computer software and programme that can be employed in data analysis include Microsoft Excel and Statistical Product and Service Solution (SPSS) which were known for the past several decades. The desired statistical output of data from the computer relies on the good data entry for analyses and the choice of the appropriate output command.

Application of statistics

Today the methods used in statistics are universal. Basing on this fact, will suffice to show how statistics is important. However, there are many people who in one way or another practise statistics unknowingly not familiar with statistics. Statistical methods are common ways of thinking something practised by many people. A number of examples can be made to link human behaviour statistical methods. It should be clear that statistical methods are so closely connected with human actions and behaviour, thus practically all human activities can be described through statistical methods. From this broad view of the importance of statistics and its universality, below are some significant uses of statistics in daily life.

Statistics in planning

Statistics is crucial in planning different forms of systems, it may be in business, environmental and natural resources; management economy and in other sectors in the government. Statistics is used by different organisations and social institutions in informing and helping to formulate policy decision. Because of the position of statistics in our daily life; to date, we commonly hear people talking about statistical data either relating to production, consumption, birth, death, investment, income, environmental quality, rate of environmental degradation or status of environmental rehabilitation. All these are helpful in making informed decisions in our practices in life. Generally, environmental policy making and implementation, monitoring and evaluation are of planning and decision-making activities that are supported by the use of statistics.

Statistics is beneficial in many ways to the government. Most of the decision making made by the government are largely informed by the findings from various statistical studies. Statistics is useful tool for policy framing, implementation and evaluation. It is also utilised in the planning and distributions of various resources in different government sectors such as education health, transportation, infrastructures and many others.

Statistics in mathematics

Statistics depends on mathematics in achieving its role and objectives. The modern theory of statistics has its grounds in mathematics for example, statistical probability and statistical reasoning. Ever increasing role of mathematics into statistics has led to the development of a new branch of statistics called Mathematical Statistics. Essentially, statistics is one among the branches of mathematics. Thus, Statistics may be considered to be an important component of the mathematics discipline and it is a branch of applied mathematics which is confined on data.

Statistics in economics

Statistics and Economics are inseparable. The advancement made in the modern statistical methods have led to an extensive application of statistics in Economics. The main important branches of Economics such as consumption, exchange, distribution and public finance are making use of statistics for the sake of comparison, presentation and interpretation. Furthermore, problems resulting from spending of income on and by different sections of the people, production of national wealth, adjustment of demand and supply and effects of economic policies on the economy etc, simply justify the use of statistics in the field of economics and in its different branches. Essentially, statistics of public finances helps us to impose tax, to provide subsidies to spend on various sectors and determine, amount of money to be borrowed or lent. Hence statistics can never be thought of without economics or economics can never be thought without statistics.

Statistics in social sciences

In daily life every social phenomenon is in one way or another affected to a marked extent by several factors which bring out the variations in observations from time to time, place to place and object to object. That is why statistical methods strive in establishing and describing the relationships and independence between factors by studying and isolating the effect of each of these factors on the given observation. The most important application of statistics in human geography is in the field of demography for studying mortality (death rates), fertility (birth rates), marriages, population growth and so on.

Statistics in trade

Statistics is embodied with methods for making wise decisions in the face of uncertainties. It is clear that business is often full of uncertainties and risks. In this case we always need to forecast at every step and time. The future trend of the market can only be projected if we make use of statistics. Failure in anticipation will mean failure of business. For example, changes in demand, supply, habits and fashion can largely be anticipated through the statistical methods. Statistics is vital in determining prices of various products, determining the phases of boom and depression. Hence, the use of statistics smoothens the process of running a business, reduce uncertainties and thus contributing to the success of the business.

Statistics in research work

The task of a researcher is to disseminate the findings of the research to the community. The explanations on the effects of a certain variable on a particular problem, under varying circumstances and situations, can better be known by the researcher only after making use of the statistical methods. Statistics is basic to research activities. Researchers maintain and enliven their research interests and research activities, by employing knowledge and skills from statistics.

Statistics in weather forecasting

Understanding weather information and climate behaviour are crucial to human well being. Weather information is needed on a daily basis in the course of planning from the national to the individual level. For examples, farmers need it for planning their farming activities for good harvest. Also, weather can be used in prediction and forecasts of extremely weather events that may require some measures to reduce its effects. Similarly, climate is a determinant of life on Earth, particularly the distribution of resources and determination of activities. Following this, statistical information will is significant in facilitating the making of informed decision hence contributing to the development in different spheres of life.

Revision exercise 1

1. Study the following table which indicates fish production (mega tonnes) in Tanzania from 2005 to 2016. Then, answer the subsequent questions.

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Fish production (Mega tonnes)	625	715	806	865	936	952	959	972	2990	3000	3118	3840

(i) Draw a divergent line and bar graphs for these data.
(i) Interpret the resultant graphs.
(ii) Identify alternative methods which may be used to present statistical information from the given table.

2. Study the following table which shows livestock products for five years from 2012 / 2013 to 2017 / 2018 and answer the questions that follow;

Livestock Product	Livestock production per annum in tonnes					
	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018
Beef	20 587	40 167	9 226	22 899	32 524	7 403
Chevron	12 062	10 153	4 631	5 918	8 838	2 326
Mutton	1 643	1 831	1 309	1 168	1 718	374
Chicken	272	280	298	325	319	462

Source: *Dodoma region investment guide (2019)*

(i) Draw the compound line and bar graphs.
(ii) Interpret the results.

3. Study the annual rainfall (mm) from the selected stations in Tanzania for the year 2016 and answer the questions that follows;

S/N	Station	Rainfall in mm
1	Bukoba	1452.9
2	Dar es Salaam	782.9
3	Mwanza	1039.3
4	Musoma	627.2
5	Kilimanjaro	492.5
6	Morogoro	587.6

Source: *Tanzania Meteorological Agency (2016)*

(i) Draw the multiple line graphs and interpret the results.
(ii) Find total rainfall in the regions and construct a simple pie chart,
(iii) Describe the results.

4. Study the data in the following table which shows forest (ha) planted in new forest plantations established by the Tanzania Forest Services (TFS) between 2014 and 2017 and answer the questions that follows;

S/N	Plantation name	Total area planted by 2017 (ha)
1	Morogoro (Morogoro)	37
2	North Ruvu (Pwani)	523
3	Chato Biharamulo (Geita)	440
4	Mpepo (Ruvuma)	395
5	Iyondo Mswima (Songwe)	200
6	Korogwe (Tanga)	220
7	Buhigwe (Kigoma)	60

Source: *Tanzania Forest Services (2017*

(a) Construct the following;
   (i) Simple divided rectangle.
   (ii) Simple divided circle (simple pie chart).
   (iii) Simple divided semicircle.
   (iv) Proportional cirles
(b) Interpret each of result in (a) (i) -.(iii)

5. The following data shows revenue collection from NDITA investment in million shilling as per 2021. Use the data to answer the questions that follows;

Items	Revenue in million shilling Tsh	
	Mainland shop	Zanzibar shop
Electronics	37	30
Used machines	48	61
Utensils	20	31
Sugar	55	19
Clothes	40	26

(a) Present the data using proportional divided semi-circles.
(b) Comment on the methods.
(c) Identify the alternative method (s) to depict the same data.

6. The following table shows temperature in degree centigrade and rainfall in millimeter for Kwero meteorological station in 2007.

Months	J	F	M	A	M	J	J	A	S	O	N	D
Temp(°C)	22	23	29	24	25	26	28	27	25	25	24	20
Rainfall(mm)	250	250	300	350	360	380	370	150	200	250	300	350

(a) Present the data by using:
   (i) Polar chart
   (ii) Climography

(b) With reasons suggest the climatic region of the station.

(c) In which hemisphere is the station located?

(d) Find the median temperature.

7. The following data shows hypothetical population in the respective regions.

Region	Population
Songambele	830 000
Cheju	310 000
Makikisa	570 000
Guben	180 000
Choro	270 000
Total	**2 160 000**

(a) Present the data using a dot map.
(b) Comment on the distribution of the population.

8. (a) Using the data given, draw a flowline map to show the movement of vehicles between Mwanza and Dar es salaam.

From	To	Vehicles	From	To	Vehicle
Mwanza	Tabora	1 500	Dar es salaam	Morogoro	2 500
Tabora	Dodoma	2 000	Morogoro	Dodoma	2 000
Dodoma	Morogoro	2 400	Dodoma	Tabora	1 200
Morogoro	Dar es salaam	3 000			

   (i) What are the disadvantages of the method used in (a)?
   (ii) Comment on the statistical map you have drawn in (a)

(b) Describe the stages employed in constructing dot maps.

(c) What are the limitations of dot maps?

9. Study carefully the following data and answer the questions that follow

Class interval	Frequency
0 - 4	2
5 - 9	11
10 - 14	37
15 - 19	54

20 - 24	28
25 - 29	09
30 - 34	01
35 - 39	03

(a) Find the range

(b) Calculate the standard deviation.

(c) What are the advantages and disadvantages of range in a given geographical data?

10. Carefully study the following table which shows the average number of people per tractor and the % population in agriculture by country. Then; answer the questions that follow.

Country	% of population in agriculture	Number of people per tractor
Kenya	76	3 006
Korea	45	1 900
China	56	1 247
Egypt	49	1 117
Sudan	34	142
Burma	12	120
Ghana	04	38

(a) Draw a pie chart to show the number of people per tractor per country.

(b) Comment on the level of agricultural mechanisation of each country.

11. (a) Describe the isopleth map and show the procedures of constructing it.

(b) Identify the merits and demerits of isopleth maps.

12. Read carefully the hypothetical data showing cash crops production in Tanzania in '000' tonnes and then answer the questions that follow.

Cash crops production in Tanzania in '000' tonnes.

Year	Types of cash crops		
	Rice	Maize	Wheat
2021	2 000	1 000	3 000
2020	1 500	1 300	2 000
2019	1 200	1 000	1 000

(a) Represent data above using a compound bar graph.

(b) Comment on the trend of production from the graph.

(c) Explain how the compound bar graph value to you?

13. With examples, explain how measures of central tendency and measures of dispersion can be used in our daily activities.

14. Find the standard deviation of the following data:

    85, 80, 55, 70, 50, 60, 45, 40, 30, 25

15. Alex has grades of 84, 65, and 76 on three Math tests. What grade must he obtain in the next test to have an average of exactly 80 for the four tests?

16. The following table shows the values of 11 houses at Magogoni Street.

Value per house in '000 Tsh.	Number of houses
100	1
175	5
200	4
700	1

(a) Find the mean value of these houses in Tanzania shillings.

(b) Find the median value of these houses in Tanzania shillings.

(c) State which measure of central tendency, between the mean and the median, best represents the values of these 11 houses? Justify your answer.

17. Study the following table which shows the natural gas production for the two sites in Tanzania from 2012 to 2017 and answer the questions that follow.

Year	Gas field in million cubic feet (MCFT)	
	Songosongo	Mnazi Bay
2012	36 233.01	672.14
2013	35 217.41	712.02
2014	33 062. 00	784.69
2015	31 384.00	5 799.41
2016	29 747.48	15 792.28
2017	29 497.32	17 960.30

Source: Tanzania Petroleum Development Cooperation (TPDC).

(a) Calculate the standard deviation of the gas product at each site.

(b) Compare the standard deviations between the two sites and explain the variation of standard deviations (if any).

Based on the comparison observed in question 17 (b); what recommendations could you provide to TPDC?

18. Range is always regarded as the least useless measure of central tendency. Substantiate on the basis of statistical geography.

19. As a geographer, explain the relevancy of mode and mean in daily life.

20. Why measures of dispersion are regard as superior as compared to the measures of central tendency?

Chapter Two

Field research techniques

Introduction

Geography as a subject which is often studied theoretically in the classroom, can be validated through the real-life field experiences using sense organs. In this chapter, you will learn about sources of scientific knowledge acquisition, types, and importance of research, research problem formulation, literature review, hypotheses or questions formulation and process of selecting relevant research designs. Furthermore, you will learn about sample and sampling designs, methods and tools for data collection, data analysis, and interpretation of the results and reporting. The competencies developed from this chapter will enable you to identify the existing gaps in geographical knowledge and practices, conduct geographical research and use the evolved solutions in promoting proper human practices on the interaction with the environment.

Conceptualising research

Research refers to a search for knowledge in order to discover the truth. It is done systematically on a particular topic or issue for explaining, describing, or predicting it. Field is an area or environment where the research is being carried out. Thus, field research is normally carried out in a natural setting rather than structured environment like laboratories and classrooms. It is the science of observing, evaluating, selecting and reporting on geographical phenomena from a specific area. It involves physical data collection from the real-life environment. Before conducting a research, there are important things to consider. These include identification of research problem selection of an appropriate research site, identifying methods and preparing tools for data collection. Also to some extent having clues on the attitude of the respondents and carrying out a pilot study. Field research allows the researcher to interact with the natural environment through observations and conversations to elicit information concerning the data sought to answer the research questions. A number of methods and techniques are used in field studies. Some of the commonly methods and techniques used include; observation of events in the natural settings, studying of information from the existing records (archival research), field experiments (experiments carried out in natural settings) to understand relations among variables. Furthermore, field research can use surveys for collecting data from people's actions, thoughts, and behaviours through asking questions related to their natural settings. The process of conducting field research needs good preparation from budgeting, time schedule and well set research tools for data collection.

Criteria of a good research

A common characteristics to all types of research is application of scientific method. Research being a process of collecting, organizing, analyzing and interpreting information to answer per-determined questions adhere the established criteria. A good research has to be;

Systematic: meaning that, any research should be carried out in a well-structured framework with a clear step by step process in attaining the solutions or conclusions. In this case, research starts by defining the research problem followed by review of literature then stating research questions or formulating hypothesis, selecting a research design, selecting the study area, collecting data, organizing data, analyzing data to answer questions or to test hypotheses, and finally writing a report.

Logical: this means that, any research should be guided by the rules of appropriate organisation and flow of ideas throughout the research process. This is mainly focusing on inductive and deductive reasoning approaches which are compulsory in decision making process.

Empirical: meaning that a research should basically be related to one or more aspects of a real-life situations or conditions from which data are gathered in achieving valid research results. In other words, conclusions are being drawn based on true evidences collected through life experiences and repeated observations.

Replicable: this means that research methods and findings of a given study should be stated in such a way that they allow to be verified or tested by other researchers. In this regard, a research is thought to be replicable if independent researcher (s) elsewhere will apply the same methods used by the previous researcher and arrive to the same conclusion made in the previous study.

Cumulative: knowledge is accumulated as a result of time to time studies, in the sense that new studies should be built over what has already been done on the subject matter of interest. Therefore, new knowledge adds up to the existing one.

Theory driven: theories are very important in research since they connect researchers with the existing knowledge as they offer a conceptual model from which data are collected. Generally, there is no research without a theory. It may start with theory or end-up generating a new theory.

Objectivity; means that any research should be strongly related to the research problem and it relies on observations from actual studies which can be either cross-sectional or longitudinal. Similarly, conclusions should be drawn from the available set of evidence with the aim of avoiding biasness.

Generalisability: research as a scientific process allows conclusions to be generalised and universal. In the case, generalisation is made from a sample to the population.

Clarity: scientific research should be precise and with good explanation.

Rigorous; research should ensure that the methods used in answering the research questions are relevant and justifiable.

Sources of knowledge acquisition and approaches

Throughout our lifetime we have accumulated a body of knowledge. The curiosity to know the environment and the need to improve our life is natural to human beings. Humans have used numerous methods and sources to acquire knowledge. Knowledge acquisition has been mainly from; authority from which human being learns. Some of these authorities are teachers, parents, leaders at work or any expert who may provide the needed knowledge. Such authorities may be a source of knowledge, experience or both. The authorities also can be books, newspapers, dictionary, encyclopedia, journal, articles or websites. Knowledge is also obtained from our traditions in which human being accepts many traditions of their forefathers or culture. For example, aspects such as food, dress, religion, home remedies, discipline, ways of behaving and others can be learned from traditions.

Furthermore, knowledge can be acquired through experiences. That is through education, own experiences on problem solving or understanding of a phenomena. These are the most commonly sources of gaining experience which we are familiar with and are fundamental sources of knowledge. In sharpening comprehension and accept learning through these sources, several approaches are used. Among them are:

(a) Empiricism: this is based on our senses. For example, through hearing and seeing we can associate some phenomena like sounds and their sources. Through senses we can compare objects, phenomena or events. Hence, our senses help us to study and understand relationships between various concepts. For example, we can associate changes/variations in temperature with climate change by observing temperature trends for over 30 years.

(b) Rationalism: this relies on mental reflections on ideas rather than materials. The logical links between two or more ideas, can lead us into accepting those ideas. For example, we may reason that, appropriate farm management is expected to improve crop yield per piece of land.

(c) Fideism: through beliefs, emotions and reactions. We acquire knowledge from religion by believing through the teachings provided by our religious leaders rather than the use of our own senses or need for logical proof.

Activity 2.1

In groups of five students:

(a) Classify the common sources of knowledge acquisition.

(b) Discuss on how the knowledge acquired is verified and accepted to be true.

(c) To what extent can such means of verification (in 'b' above) be trusted?

Exercise 2.1

Answer all questions

1. To what extent is research a science?
2. Assume you are planning for a normal visit to a nearby site at your school to appreciate geographical features found there. Describe how you will visit the same site for a field research?
3. 'Knowledge acquisition is normally intrinsic in nature.' Explain.
4. How will you prepare yourself for a conducting field research?

The purpose of doing research

Normally, research strives to answer questions through the use of scientific procedures. The aim of a researcher is to uncover the hidden or undiscovered knowledge. Though there are varieties of research yet the following research purposes may suffice. Firstly, to gain familiarity on the researched phenomenon or acquire new insight. Secondly, to depict accurately the characteristics or nature of a particular individual, situation or a group under the study; thirdly, to determine the frequency or recurrence of some subjects and fourthly, to test hypothesis or causal relationship between variables in order to develop theories and criticisms.

Types of research projects

Search for new knowledge has resulted into multiplication of researches. The emerged variety of researches can be classified into four main categories; basing on the nature of information sought, utility of content, the research approach employed and objective perspectives.

On the basis of nature of information sought: research can be grouped into two categories namely, *qualitative research* and *quantitative research*. Qualitative research is a study which deals with non-numerical data. This is a form of field research which is carried out in a naturalistic setting that mainly generates qualitative data through observations and interviews. Qualitative research aims at describing the characteristics of samples. Quantitative research is the study which uses numerical data to address behaviour and attitude. It is used when quantitative data are sought of. It is mainly concerned with making inferences from randomly selected samples to a larger population. However, with time there has been a growing need for integrating both qualitative and quantitative data in order to cross-check the results obtained from the combined methods and this has given rise to *mixed methods research.* Recently, most of the researchers have found it logical to opt for mixed methods research in answering research questions.

Basing on the utility of content or nature of subject matter, the research streams into two categories: first category is basic research which is also known as fundamental research, pure or theoretical research. The aim of these researches are to find out the basic truth or principles. Normally, the generated findings in this case are universal likewise the utility is universal. These researches are generally guided by theories for example, Newton's law of universal gravitation, Newton's laws of motion, Albert Einstein's general theory of relativity and many more. The second category is experimental or applied research or action research. This is concerned with finding new applications of scientific knowledge to solve scientific problems such as development of new system. Normally, the findings from this research has a confined utility to the individuals who benefit from them.

With regards to the approach of research applied there are two main categories namely, longitudinal research and cross-sectional research. Longitudinal research deals with studying the same site at varying intervals of time in order to establish change. This is exemplified in historical and case study research. Cross-sectional is concerned with collecting data at one point in time from a predetermined sites and individuals. An example, of crossectional research is studying child development behaviours using different groups of children with different ages but examining them at one point in time.

Concerning objectives perspectives as criteria we have a descriptive research. Descriptive research is confined on explaining the conditions of variables based on the situation at which data were taken. This type of research is further streamed into observational, survey and case study researches. While observational research is concerned with seeing and tapping data in a natural condition of the research participants or objects, a case study deals with an in-depth study confined to a single participant or group. Whereas, survey research deals with the study of the present phenomena and it is quantitative in nature.

Other types based on objective perspectives are correlation, explanatory and exploratory research. Correlational research is devoted on explaining or discovering the extents at which two or more variables have associations or interdependence. Whereas explanatory research focuses on giving reasons and mechanisms on the existing relationships between two aspects or phenomena that are studied. The last category is exploratory research which deals with investigating a situation where little is understood in the body of knowledge. It is used to examine the possibilities of undertaking a study in defined areas. Because of its flexibility the findings from this research provide answers to what, who and why questions.

Activity 2.2

1. In groups, brainstorm and take note of data that may be collected daily at school from early in the morning to when classes end. Using the brainstormed data, categorise and indicate the type of research in which they belong, each data should fall into one research category. The answers should be well organised and submitted to the teacher for marking.
2. Visit your school library or use internet sources to search and read on the types of research. Then;

(a) Discuss research scenario which each of these types would be most appropriate and write down the information you have obtained.

(i) Explanatory research

(ii) Descriptive research

(iii) Exploratory research

(iv) Experimental research

(v) Applied research

(b) Share and discuss with your fellow students, the information about the research types and their appropriate features.

Exercise 2.2

1. Explain the role of a research purpose in determining the dimensions of body of knowledge.
2. Comment on the statement that, "Knowing a research type is one of the ways towards solving a research problem."

Importance of research

Most of the researches conducted aim at solving practical or theoretical problems existing in the society. Based on such view, research provides the basis for decision-making and planning for government policies formulation, implementation, monitoring and evaluation. On the other hand, research may be geared towards addressing the problems that directly affect the community.

The importance of research cuts across the scientific and non-scientific fields. Furthermore, it extends to our emerging life problems, events, phenomena and processes that we often come across. Hence, the generated solutions and suggestions are required to solve the frequently occurring problems. The role of the researcher is to find their causes, explanations, solutions and applications. In short, research familiarises us with the man-made and natural phenomena or issues surrounding us. Specifically, research is important in the following areas.

Firstly, in addressing a research problem which may be an existing issue or phenomenon that requires solutions based on scientific studies. Such issues may emerge anywhere in the society and fields. Provided the problems require scientific analysis, our interests are to get an understanding of the problems and propose possible solutions. Secondly, research is one of the most potential sources of knowledge that provides us with guidelines on how to verify knowledge which we acquire. Thirdly, researches directed to the existing theories and concepts are helpful in understanding such theories and finding out ways to utilize them. Fourthly, research plays part as a basis for governments' planning and decision-making. This demand enhances the emphasis that researchers should always strive for valid and reliable researches for backing up the decisions. Research provides a basis for many government policies in a variety of dimensions. For example, research on the effectiveness of strategies to empower community adaptation to climate change and dynamics of the crop farming practices can improve decision making in the formulation of environmental and natural resources management policies.

Fifthly, research can benefit a number of sectors in improving practices for example, in production, markets of goods and services and shade light on the environmental management options like clean production for sustainable development. Sixth, research can lead to identification and characterisation of brand-new goods and services. Through research we can also widen our understanding of various phenomena such as climate change, its effects and suggested measures to be taken for either mitigation or adaptation. Seventh, research findings act as one of the sources for deliberating further actions in areas with noticeable progress, such as the case of malaria. Despite measures taken to eradicate malaria, the cases have kept on increasing. Thus, research directed to this problem will be helpful in changing practices and measures to readdress the problem. Eigth, research results enable us to address the existing social problems and phenomena and seek solutions. Ninth, research can provide us with some new life style and ways of living. For example, the increased understanding of COVID -19 through research on the way it spreads and preventive measures, we have experienced a drastic change in the custom of shaking hands when we meet as one of the ways of preventing the spread of the pandemic.

Exercise 2.3

1. Describe roles of research in our daily life.
2. Why is research important to our lives?
3. Discuss, how the government of Tanzania can use research as basis for planning and decicison making.

Research proposal and report writing

Field research should be preceded by a research proposal and finalised by report writing. Writing of a report must be carefully done in three major sections which are the preliminary pages, the main text and appendices.

Research proposal

A research proposal is a document written by a researcher that gives detailed explanations on how a researcher plans to do the research. It is a plan suggesting what the researcher intends to do, means of doing it, and proposes resources to accomplish the plan. It is a descriptive plan of action, which is to be followed in carrying out a particular research. It is like an outline of the whole research process that gives a reader the summary of the information discussed in the plan. Preparation of research proposal is needed since it facilitates the planning of different research operations, hence making the research as efficient as possible, yielding adequate information with minimal expenditure. In fact, the research proposal is the conceptual structure within which research is conducted; it comprises of the plan for the collection, organisation and analysis of data. A good research proposal quickly and easily answers the following questions; what do you want to do? How much will it cost? How long will it take? What difference will it make to your school, society or nation? What has already been done in the topic of your interest? How do you plan to do it? Will the results be evaluated? How will the results be communicated? The questions will be answered in different ways depending on the nature of the proposed plan. Most proposals are between ten and twenty pages in length. The proposal should not be longer than 2500 words without list of references.

Importance of a research proposal

Research proposal helps the researcher to focus on important issues about the study. It enables the researcher to focus on which research questions need to be answered, how the data will be collected, who will provide the data and where will the data be obtained. It gives the researcher a chance to evaluate the study by predicting the difficulties which are likely to appear and planning to solve them before. The proposal acts as a guide to general strategies from the beginning of research to its completion. It shades light on the expected costs of the research to enable budgeting for its completion. It also provides time schedule for the research. It guides the researcher to prepare material and resources in a logical manner. The proposal enables the researcher to define the boundaries of the study and the concepts to be included. It should be noted that, the better you organise your ideas at this stage, the more effective time and resources will be spent. Normally, a research proposal is written in future tense, since it is a plan to be implemented in future.

The format of a research proposal

The research proposal has a format which is the general pattern of the organisation and arrangement of the study. This involves the following parts; *preliminary pages* which include the title of the study, the name of the researcher, year of the study, abstract, table of contents and list of tables; *the main body* of the research proposal and *the appendices*. Basically, the main body of a research proposal is made up of the following:

Title of the proposal: It should be short and precise ranging between 10-15 words written in such a way that it gives a very quick picture on what the proposal is about. When writing the title there should be a consideration that, it draws attention, creates interest and desire to the reader to go through the entire document.

Abstract: This section offers an overview of the entire research proposal ranging from the title to the methodology. The abstract has to be short but, capturing all important issues.

Background to the research problem: In this part, a researcher provides background information on the topic of interest and arguments starting from global, regional to local levels. It is under this part a researcher highlights on what is already known in the field, what is not known, and what the researcher wishes to be known in the proposed study.

Statement of the research problem: This refers to the statement on what is the issue that need a researcher's attention and its magnitude. The origin of the research problem may come as a result of reviewing literatures, own life experiences, discussions with colleagues or experts in the same field and others.

Research objectives: In this section a researcher should have the general and specific objective. The general objective articulate what the researcher intends to achieve while specific objectives show how the main objective will be attained.

Research questions or hypotheses: In this section the researcher prefers to use either research questions or hypotheses, depending on the nature of the problem and the field of study. For example, questions are very common in social sciences while hypotheses are widely used in natural sciences.

Significance of the study: In this section, a researcher explain why a particular research work is needed. Basically, it offers justification of conducting the proposed research and the impact it will develop. Moreover, it clarifies possible contributions to knowledge and highlights on how other researchers will benefit from it.

Scope of the study: This section narrows down specific issues which will be addressed in a particular research work. Given the challenges in time and finances, it is practically not possible to study everything but focusing on one issue at a time.

Limitations of study: In this section it is important to highlight on the challenges that the researcher is likely to encounter. They are basically potential weaknesses to the study that are out of the researcher's control associated with choice of research design, statistical models, funding and other factors. Generally, limitations affect the study design, results and conclusions. Thus, the researcher should explain how each limitation will be managed without affecting the quality of the study.

Delimitation of the study: It addresses how the study will be narrowed down in scope. The purpose of this section is not to respond to the question that, 'why I did this?' but focusing on the question 'why I did not do it like this?' in other words, it provides reasons for rejecting a certain course of actions in the research process. As such delimitation are in the researcher's control.

Review of the literature: This involves reviewing sources which are related to the subject matter stated in the title. It is a continuation of the information provided in background section but not repitition also it has several subheading. It includes both theoretical and empirical reviews. Through reviewing literature, research gap is identified; hence the researcher avoids repeating what has already been done by other researchers. Therefore, the researcher becomes familiar with the area of study choosen.

Research methodology: In this section, a researcher precisely gives reasons for the choice of the study area, define methods, tools, and techniques that will be used in selecting sample, data collection, data organisation, data analysis, and results presentation. Additionally, the researcher indicates how the study will adhere to research ethics.

References: It refers to all documents which have been used in preparing a research proposal and are cited in the text. It includes published and unpublished sources such as reports, journal articles, books, book chapters, Newspapers, conference proceedings and others.

Appendices: It consists of important supportive attachments such as;

(i) Data collection tools that will be used in the field.

(ii) Time frame: This is the time that will be taken from writing of the proposal to data analysis and reporting.

(iii) Funding and sources of funds: This is the proposed budget and the breakdown which specifies how funds will be used to complete the work.

Activity 2.3

In groups of five students:

(a) Discuss and choose a research topic from any topic of your interest in geography.

(b) Write a research proposal of not more than ten pages on the research topic that you have choosen. The research proposal should be geographically related and organised in accordance with the format presented in this chapter.

(c) Present your assignment (research proposal) to the class for extensive discussion.

(d) Note down suggested improvements and write the final draft for submitting to the subject teacher for grading.

Exercise 2.4

1. Explain the role of abstract in the research proposal?
2. What is the importance of background to the research problem in a research proposal and how is it linked to the literature review?
3. Why is research methodology important in a research proposal?

Research report

Report writing is the last step in the research process. In this step the researcher has to write a complete report of scientific research undertaken. Research report is the process of communicating the results and the care that has been exercised throughout the study. In general, research report is a detailed account of the study conducted or systematic report of the findings of a research which describes the process and the data used in the study.

Components of a research report

Normally, the research report should have the following format as shown in Table 2.1.

Table 2.1: *Research report format*

Preliminaries	title page, abstract, table of contents, list of figures and tables, certification, declaration, dedication, acknowledgement and acronyms/abbreviations used.
Chapter 1	**Introduction** – background to the research problem, statement of the research problem, research hypotheses or questions, objectives of the study, significance of the study and scope of the study.
Chapter 2	**Literature review** – discusses related works, it discusses what is already known about the research topic as a whole and outlines the key ideas and theories for familiarising the current research.
Chapter 3	**Methodology** – describes procedures used in research, data collected and how it was obtained, organised, analysed and presented.
Chapter 4	**Results and discussion**– show the meaning of the presented research results, compares results from different sources included in the study (for example from question and observation) and relates the results to other researchers' works in the same topic. This is followed by conclusion in each of the subsection.

Chapter 5	**Summary, conclusion and recommendations** – the conclusion normally summarises and interprets the major findings to describe what they mean. This part gives reasons as to why the findings are in that manner. That is, answers the question, "So what?". The recommendations explain what should be done and who should act to make the findings of the study meaningful to the society. Recommendations should be done in relation to research findings and not otherwise. In addition, this section also provide /identifies area for furthery study according to stud findings.
References	A collection of resources such as books, documents and reports that were used by researcher in writing the report and appear in the text are listed down in alphabetical order.
Appendices	Attachments which may contain some of the information related to the study such as research tools, figures, tables and photographs.

Activity 2.4

In groups of five students, visit the school library or internet sources and read about research stages and format. Summarise the read resources and organise your work well. Present the work to the class for a wider discussion. Note down contributions from others and write your final draft which will be submitted to the teacher for evaluation.

Exercise 2.5

Answer all questions

1. Why the conclusion and recommendations are based on the results of the research?
2. Compare the features of introduction and Literature review as chapters in a research report.
3. Compare and contrast research proposal and research report.
4. Why is it important for research report to be organised in separate chapters?
5. Distinguish between the role of results and discussions of findings in a research report

Research process

In order to study and solve a problem, a research has to undergo several stages in a well regulated and systematic manner. Failure in any stage is likely to affect the whole research process. In order to work systematically, a research process or stages goes through a series of actions which are:

Formulating the research problem

Formulating of a research problem is an important step that will uncover what problem is worthy studying by explaining clearly what has been documented, what has not been documented and what needs to be documented. The main function of a research problem is to determine what needs to be researched. Basically, the main sources of a research problem include conversation with people you can gain insight and find out the existing imbalances, research gaps and issues to be researched. Moreover, a research problem can be identified by exploring the interventions and programmes that have been in place. For example, exploring from the projects and activities aiming at empowering the community adaptation to the impact of climate change. Similarly, exploring from projects on promoting students' performance in secondary schools, poverty eradication programmes, restoration of soil fertility programmes and intervention on increasing the dissemination of weather and climate change information. Therefore, through critical studying in such areas one may decide to evaluate the effectiveness of one of those interventions. Another way of establishing a research problem is based on experiences evaluating some existing phenomena and establishing some areas worth to be researched. For example, one may decide to focus on the problem of water scarcity in arid and semi-arid areas and decide to study the existing mechanism for water scarcity. As a starting point in thinking how to develop a research problem the following samples of a research problem can be useful guides to you:

Sample A: It is generally accepted that the use of contraceptive pills is one of the effective methods of controlling conception. However, one of the studies found out that forty percent of women who were administered with contraceptive pills, conceived. Some of the possible explanation on this could be timing of the use of the pills, health conditions of the users, the effectiveness of the pills themselves in terms of chemical composition, genetic variations among the users, the body resistance to the pills and the integrity of information given by the clients. Despite having detailed studies on contraceptives which address types and their advantages to women health, there have been limited studies on the factors affecting the use and functioning of contraceptives among women. Lack of studies in this area increases confusions and suffering among women and their families. Therefore, this study is going to determine factors affecting effectiveness of contraceptive pills among post-user women.

Sample B: Various measures have been taken by the government of Tanzania in collaboration with various internal and external stakeholders in eradicating malaria in the country. Such measures include improvement of health facilities; diagnostic measures and medications; awareness raising on environmental cleanliness; removal of stagnant water in our neighborhoods; and provision of protective gears such as mosquito nets. Despite all these measures, malaria incidences have kept on increasing in various areas including the village in which this study will be conducted. Although various studies have been conducted on the challenges of malaria and the effectiveness of malaria control measures, information is lacking on the sociocultural factors influencing control of malaria in the country. Therefore, this study is geared towards that end. Lack of studies of this nature is likely to limit the government efforts towards creating a malaria free society, thus government's burden on treating the victims will keep on increasing.

Sample C: It is an acceptable fact that the impact of climate change is affecting all people equally but different in different parts of the world with slightly variations across gender differences. Most of the studies have documented on how women have been affected by the impact of climate change and associated adaptation measures. However, there are limited studies on the extent of impact of climate change to the elderly population and the adaptation measures to this social age group. Failure to document this area means that the vulnerability to the impact of climate change and social disturbance will keep on increasing and many of the elderly in society will be negatively affected. Therefore, this study is an attempt to that end.

Considerations in selecting a research problem

For manageable and sustainable motivation, a researcher should consider the following when selecting a research area or a research problem. Firstly, interest in the area make the researcher to be motivated throughout the research process. Secondly, it is important to consider the magnitude of the selected topic. This will enable the researcher to balance time and resources for completing the study on time. Therefore, a researcher is required to narrow down the topic hence make it manageable, specific and clear. Thirdly, the researcher should make sure that the indicators and concepts studied are measurable and verifiable. Fourthly, the researcher should have adequate and appropriate research knowledge and skills to address the problem to be studied. Fifthly, the researcher should focus on a relevant research problem that is likely to fill the existing knowledge gap, add new knowledge and improve practices in the researched area. This will be an additional aspect to sustain the interest of the study. Sixthly, consideration of ethical issues in relation to the area the researcher plans to study is of great importance. This item requires the researcher's professionalism and flexibility especially when the previous plans affected the research ethics. For example, dealing with sensitive researches in areas like rape, early marriages, HIV/AIDS and other diseases, flexibility and professionalism are highly required in order to approach the problem wisely and successfully.

Criteria for a good research problem

There are a number of criteria that need to be considered in writing a research problem. A good research problem is likely to adhere to the following qualities: Firstly, it should be novel that, the problem should come up with a new process, product or principle that can help in improving practices.

Secondly, it should be interesting in the sense that it draws attention and interest to other people. Thirdly, it should be innovative meaning that it improves the current or existing state of affairs and possibly technology. Fourthly, it should be cost effective in such a way that it produces good value for money, time and resources. It should be addressing the problem of the community.

Challenges of writing a research problem

There are many challenges facing researchers in their attempt to write quality research problems. Some of these challenges include; difficulties in deciding on the topic for research, lack of good knowledge of the methodology to be used, inability of finding current, specialized and related references such as books, lack of interest in research, lack of understanding the subject matter, structure of time limit and lack of good research guidance. Others are misconception of the research problem for example, one may think if some people in the community do not have money, therefore, a research problem will be inadequate fund. This will make a study something different from the problem, because lack of money is an outcome of something else such as unemployment.

Research objectives

Research objectives are normally developed after stating research problem. They emerge from the problem as they intend to make the research focused and answer the research questions or cover the gap developed in the statement of the problem. Research objectives should be closely related to the statement of the problem and summarise what is intended to be achieved by the study. Good research objectives are useful in defining the focus of your study; clearly identifying the variables to be measured; describe action to be taken in establishing the limit of the study; they guide the researcher through avoiding collecting unwanted data for answering the research questions. Normally, research objectives are stated in such a way that they start with *action verbs* that can easily be measured for example, 'to compare'..., 'to calculate', 'to assess...', 'to determine...', 'to verify...' 'to identify...', 'to ascertain...', 'to measure...', 'to explore...'. Strictly, avoid the use of vague non-active verbs in stating objectives such as: to appreciate, to understand, to believe, to study, and to think because it is difficult to evaluate whether they have been achieved. Also address an abstract situation, such that even in the field it will be difficult to get data from respondents in case of research dealing with people.

Activity 2.5

1. In groups of five students select an interesting topic in geography, visit the library or internet sources to search for the current documentation. While reading, write a summary of the current knowledge then;

(i) Brainstorm on what is still not documented on the topic and what will happen if it remains like that.

(ii) Present your work to the class for an extensive discussion.

(iii) Write a summary of what is not known and highlight on what will happen if the unknown will not be uncovered with reference to the discussion of your presentation.

(iv) Formulate statement of the research problem on the topic you have chosen.

(v) Formulate research objectives on the topic you have chosen.

Exercise 2.6

1. Why is statement of the research problem referred to as the heart of any research study?
2. Assume you have been appointed to assess the quality of the Form Four student's research proposals, explain the attributes that you will consider in the assessment.
3. Clearly describe the link between the statement of the research problem and research objectives.
4. Why are research objectives stated in action verbs?

Review of the literature

Once the problem is formulated, a brief critical review and summary of it should be written down. At this point, the researcher should undertake extensive literature survey connected with the problem. Literature review is concerned with reading of various previously related publications in order to enable a researcher to be aware of how other researchers have addressed the same or related research problem. Literature review helps to avoid unnecessary repetition of studies which have already been conducted. It helps the researcher to redefine his or her research problem, to select appropriate sample, appropriate tools and the research design. Generally, literature review is important in clarifying and focusing the research problem; and in sharpening the research methods that you will use in your study by looking at how others have used them. Literature review will also enable the researcher to broaden knowledge in the selected area to situate the study against other related research to avoid duplication. Furthermore, it helps to identify the research gap and challenges likely to face the research process.

A good literature review can be distinguished by several criteria. First of all, a literature review should be capable of outlining the important study trends showing the current situation, information and documentation done in the area being studied. The second criterion is that, literature review needs to assess the strengths and weaknesses of the existing researches in different orientations including whether methodological approaches used in the existing studies they were relevance or not. Furthermore, literature review should assess the strengths and weaknesses of arguments, conclusions and assumptions made by the existing studies. The third criterion is that, literature review should be capable of identifying knowledge gaps from the existing studies. In other words, literature review should not be written plainly that is, agreeing with most of the past literature in their entire dimension. In this case there would be no need of conducting another one because it will be a duplication of the research unnecessarily and wastage of resources and time. The fourth criterion is that, a good literature review should be based on most recent existing literature of which one can establish research gap and position their work among other related studies. To sum up literature review acts as a lock and key that well specifies the research gap. In this part you will be in a better position to know what is needed in the research you are conducting, where to conduct it, and how your findings fill in the gap you have established.

Activity 2.6

1. In groups of five students revisit the topic you have chosen in statement of the problem and the research objectives (items iv and v in Activity 2.5). Then conduct a thorough literature review on the chosen topics, thereafter do the following questions.
   (i) Briefly state how others (from literature) have addressed the research problem.
   (ii) Briefly redefine the research problem.
   (iii) State the main and specific objectives.

Exercise 2.7

1. Why do we do literature review?
2. How does the literature review link stages of research?
3. 'Literature review has its own features.' Elaborate

Hypothesis formulation and research questions

After extensive literature survey, a researcher should state in clear terms the working hypothesis. Hypothesis is a tentative assumption made in order to draw out and test its logical or empirical consequences. It is a tentative statement about the relationship between two or more variables. It provides the focal point for research, guide the researcher by delimiting the areas of research and keep him/her on the right track. Hypothesis also indicates type of data required, methods of data analysis and draws conclusion.

Basically, there are two types of hypotheses; null hypothesis and alternative hypothesis. Null hypothesis is stated in a negative way or by using negative statement for example, *there is no relationship between population growth and development; rate of survival will not increase after surgery; a high cholesterol intake is not associated with development (risk) of cancer; smoking is not a cause of cancer; existence of informal institutions is not associated with minimal conflicts in project areas.* Alternative hypothesis is stated to indicate the actual expectation or relationship. It is usually a positive statement about certain variables, for example, *there is a relationship between truancy in schools and poor performance in academics; Other examples, the rate of survival will increase after surgery; a high cholesterol intake is associated with the development of heart disease; cigarette smoking is a cause of cancer; existence of informal institutions in water projects is associated with minimal conflicts in the project areas.* Generally, there are many sources that can enable a researcher to formulate a hypothesis. The main sources of hypothesis formulation include personal experiences, imagination and thinking, observation of phenomena, scientific theories, reviewing previous studies and cultural disposition.

A good stated hypothesis can be identified by observing the following criteria: it should be stated in the simplest terms which ensure easy understanding by others; it should not conflict with any law of nature which is known to be true; and it permits the application of desirable reasoning. Other qualities are hypothesis should be limited in scope and must be specific; it should be capable of being tested within specific time; and should allow the application of deductive reasoning.

Research questions

Research questions are the specific issues that the study wants to investigate from data collection and that data will answer them. In writing research questions, one can replace the first words used in the hypothesis "*There is*" with the words *"Is there"* and also replacing the period with question mark. *For examples, Is there any relationship between population growth and development?*

Types of research questions

There are three types of research questions which are;

Firstly**,** *a descriptive* research question; this seeks to identify and describe some phenomenon. *For example*: *Will the rate of survival increase after surgery?* Secondly, a *differences* research question; this asks if there are differences between groups on some phenomenon. *For example*: do students who engage in remedial classes perform better than students who engage in sports activities? Thirdly, *a relationship* research question; this asks if two or more phenomena are related in some systematic manner. For instance, *Is the existence of informal institutions associated with minimal conflicts in the areas?*

Activity 2.7

1. In groups of five students use personal experiences, imaginations, thinking, observation of phenomenon or scientific theories to:
   (a) Brainstorm about ten hypotheses in your area of interest in geography.
   (b) Assess the quality of hypotheses.
   (c) Present your hypotheses and research questions to the class for an extensive discussion.

Re-write your hypotheses and research questions with improvements you got from the class discussion.

2. In groups of five students, visit your school library or internet sources and read to answer the following questions:
   (a) Identify challenges faced by researchers in formulating good hypotheses and research questions.
   (b) Present your work to the class for detailed discussion.
   (c) After discussion, write answers in your exercise book.
   (d) Rewrite the work with amendments recorded during the discussion in class.

Exercise 2.8

1. How does hypothesis and research questions play part in narrowing the study?
2. Explain how you would differentiate a collection of hypothesis.

Research design

Research design is concerned with a systematic and well-planned means for conducting a research. It is a systematic way of finding out new knowledge. A research design is a conceptual structure for conducting the research. Preparation of the research design will smoothen the processes of sampling, methods and tools for data collection, analysis, interpretation and reporting. It will also reduce unnecessary expenditure by having predefined activities and resources. Usually, research designs vary with varying nature of studies. The commonly used research design are, 'snap-shot' or baseline sometimes called case-study, cross-sectional, longitudinal and experimental research design.

Snap-shot or baseline is concerned with in-depth studies aimed at searching of the current and past behaviors and experiences for a single person, family, group, or organization. Usually, the findings from this kind of design cannot be generalized. Cross-sectional research design is a survey design in which data are collected at one point in time from a predetermined population. Data from this design is normally used to describe the characteristics of the studied sample with regard to the population when data were collected. Longitudinal research design is a form of survey in which data from the same area is collected at different time interval for the sake of investigating the changes of a studied population over time. It can be after several months or years. For example, studies of climate change in mountain climate before awareness on climate change and studies at different intervals after awareness have enabled us to note rapid decrease in icecaps over the mountain than it was in the past. Meanwhile, experimental research design can be used to establish cause - effect relationships between the independent and dependent variables by means of manipulating the variables studied through controlling them or randomisation. Alternatively, the studies conducted by using this design can compare groups that are closely related or introduce an intervening variable from which a researcher can examine changes among the groups. For example, studying two groups in which one of the two was intervened with an activity or project and the other not subjected to an activity.

Activity 2.8

1. In group of five students, brainstorm on researches which you know, match them with relevant research designs and give reasons for the matching obtained. Present your work to the class for an extensive discussion.
2. In a group of five students attempt the following;
   (a) Use the internet, reference books and text books to read about research designs.
   (b) Discuss the strengths and weaknesses of longitudinal research design and explain when a longitudinal research design would be preferred over cross-sectional research design. Summarize your answers.
   (c) Present the summary of (a) and (b) to the class for a more intensive discussion.
   (d) Take note of all important contributions given and write the final draft of your work.

Exercise 2.9

Answer all questions

1. Why is a research design regarded as a road map of the research work?
2. Researchers are selective on research designs. Explain.
3. In what ways does a research design act as a determinant of research?

Target population, sample and sampling techniques

In statistical geography, sampling is concerned with the selection of a subset of elements or individuals from a population to estimate characteristics of the whole population (also, known as target population or universe). Each observation measures one or more properties (such as weight, location or colour) of observable bodies distinguished as independent objects or individuals. Below are important definitions of the commonly terminologies used in studies dealing with population.

Target population: This is entire population that the results of the survey should be representing. The target population can be the entire country, region, district, intervened villages, cropland or rivers or cattle. Normally, the sample is selected from the target population. For the case of smaller population, it is advised to study the entire population.

Elements: These include individual persons, objects, or units about which information is collected. Thus, totality of elements forms population.

Sample: The sample is also known as the subset of the target population because it is selected from the population. It is also referred to as the composition of the set of elements from the population. It must be selected according to principles of sampling and this will make it a more representative of the total population.

Sample Size: is a proportional set of elements selected from the target population. Often in probability studies it is recommended that sample to be optimal enough for data collection. Too small size is likely to increase errors in the data collected while too large sample size will have implications on time and cost. However it is generally recommended that sample size should be proportional to the size of population in case of finite universe. That is the larger the population, the larger the sample and the smaller the population the smaller the sample. In probability studies sample size can be estimated by using scientific methods as shown in the formula (a) and (b) below.

(a) For the finite population

$$n=\frac{N}{1+N(e)^2}$$

Where;

n = sample size, N = population size (for example total households), and

e = the level of precision (desired margin of error)

Examples:

Assuming the basic population amounts to 1000 persons and the desired margin of error is 0.05, then the minimum sample size would be:

$$n=\frac{1\,000}{1+\left(1\,000\times(0.05)^2\right)}=\frac{1\,000}{1+2.5}\approx 286$$

This means data from a minimum of 286 randomly selected respondents would be needed for the survey.

(b) For infinite population

$$n=\frac{Z^2\times p\,(1-p)}{e^2}$$

Where;

Z= the area under the normal curve corresponding to the defined level of confidence;

p= the true share of the population that displays a certain characteristic (for example, female population)

e = the desired margin of error

For most common levels of confidence equals as follows: 90%: Z = 1.645; 95%: Z = 1.960; 99%: Z = 2.575; 99.9%: Z = 3.290

For example, for a population in which 48% are female and the desired margin of error is 0.05, the minimum sample size would be:

$$n=\frac{1.96^2\times0.48\times(1-0.48)}{0.05^2}\approx 384$$

Sampling frame: is a list of units in the population, for example a register of workers at an X secondary school in Mwanza, students' enrollment from the attendance register, group members in sports and list of pastoralists in ward or village Y. The sampling frame should be checked from time to time to avoid people who were not in the list to be counted. The list should also be up dated as required. For instance, it is better to get the sampling frame from the studied village rather than depending on the census survey which may sometimes be out of date.

Activity 2.9

1. (a) In groups of five students, visit the school office and ask for the attendance register for at least two different classes and record the registered number of students as per the respective attendance. Consider the number of students as a population and use it to estimate the sample size. Give reasons for variation of sample size of the different classes.

   (b) In groups of five students use the number of all prefects with their respective classes as a population to estimate the sample size. Give detailed description of your findings.

Exercise 2.10

1. Explain why researchers strive to maximize the size of the sample for collecting data?
2. Compare and contrast population and sample size.
3. Compare and contrast target population and sampling frame.

Sampling techniques

Sampling is a process of selecting a representative of a population from which the data will be drawn on behalf of the entire population. Carefulness is crucial at this stage as the researcher narrows the data source to the sample. Dealing with a sample is rewarding in many ways. The appropriately selected sample will save resources and time; ensure accuracy and produce manageable data. A well-designed sample can represent the intended population. The major categories of sampling techniques are probability and non-probability sampling.

Probability sampling

It is a method of selecting sample whereby every individual in the population has equal chance of being selected. Probability methods include; simple random sampling, systematic sampling, stratified sampling, cluster sampling, and multi-stage sampling.

Simple random sampling technique

It is the basic sampling technique whereby each member from the population has an equal chance of being chosen. Each individual is chosen entirely by chance and each member of the population has an equal chance of being included in the sample. For example, a class of twelve students may write their names on a piece of paper, and then the papers are rolled and mixed. Then one of the students can pick randomly only four names to be included in the sample (Figure 2.1).

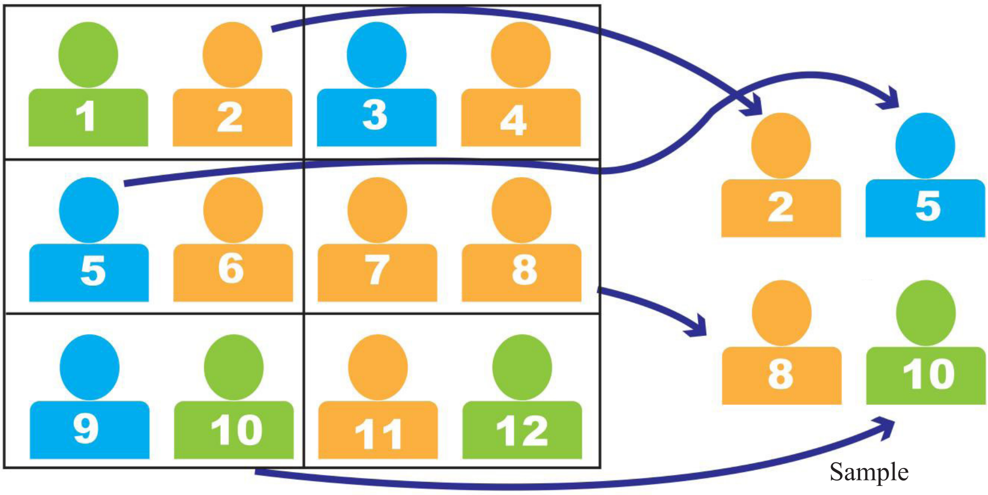


Figure 2.1: *Simple random sampling technique.*

One of the best things about simple random sampling is its ease of use in extracting the sample. It is also considered as a fair way of selecting a sample from a given population since every member within a target population is given equal opportunity of being chosen. Another interesting feature of the simple random sampling is the representation of the population. It is unbiased and the representative sample enables drawing conclusions from the results of a study. Therefore, simple random sampling is reasonable in generalising the results of the sample to population from which it is drawn. However, the technique has the following limitations. It needs a complete list of all the members of the population. It is only convenient when working with small population that has already been identified and listed. Simple random sampling can provide accurate results but it will not give you detailed information about specific groups of people. Furthermore, the technique is not practical to a large sampling frame, distortion of representation of the minority groups of interests, and it is time consuming with high labour requirements in case of large population.

Systematic sampling technique

Systematic sampling is a random sampling technique in which members from a larger population are selected based on regular interval and systematic order. Thus, a sampling interval is required.

Sampling interval $K = \frac{N}{n}$

Where;

N = The number of element in the population.

n = The number of elements for the sample.

In systematic random sampling, the researcher first randomly picks the first item or subject from the population.

Then, the researcher will select each subject from the list. For example, in a class a researcher may decide to pick every third student in a row to get the total of four students as a sample, for example, if N = 12 and n = 4, therefore $K = \frac{12}{4} = 3$. In the first 3 elements number 2 is picked randomly. Then for the next three numbers, one number is picked at every third member (Figure 2.2).

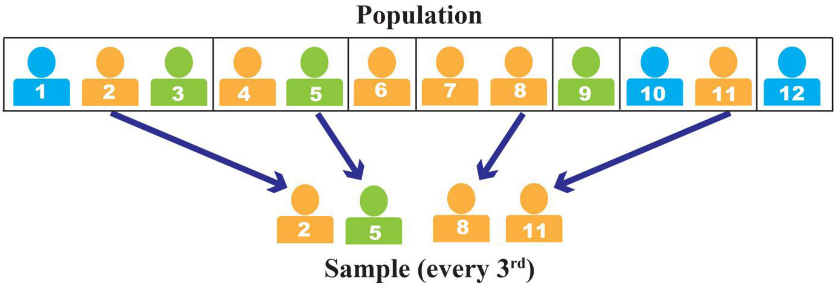


Figure 2. 2: *Systematic sampling technique*

Systematic sampling is simple since it allows the researcher to add a degree of system or process into the random selection of subjects. The assurance that the population will be evenly sampled to ensure even coverage of an area is another advantage. It is very simple to use since it saves time and cost. However, systematic sampling technique is accompanied with some shortfalls including the hidden periodicity within the population may distort the representation of a population. Furthermore, systematic sampling is difficult to adjust sample to suit the circumstances and it is not practical for fragmented strata.

Stratified sampling technique

This is a probability sampling technique whereby the researcher divides the entire population into different sub-groups or strata, then randomly selects the final proportionally from different strata. The population is based on strata. Stratification is the process of dividing members of the population into homogeneous subgroups before sampling. Every element in the population must be assigned to only one stratum; then simple random sampling or systematic sampling is applied within each stratum. Examples of strata or sub-groups from a population include men and women, rich and poor, employed and unemployed.

The measurements within strata have lower standard stratification which gives a smaller error in estimation. Many applications, measurements become more manageable and/or cheaper when the population is grouped into strata. It is often desirable to have estimates of population parameters for groups within the population. Several conditions must be met for it to be used properly. Researchers must identify every member of a population being studied and classify them into one, and only one sub-population. However, the sorting process becomes more difficult and inaccurate for each member of the population stratum. It is also inconvenient as it may require more administrative clearance in various strata and the computationally complexity is another constraint. Figure 2.3 shows three strata, A, B, and C, one stratum with 6 members and the other two with 3 members each. Proportionally the 2 strata with 3 members each were presented by 1 member and the one with six was represented randomly by 2 members.

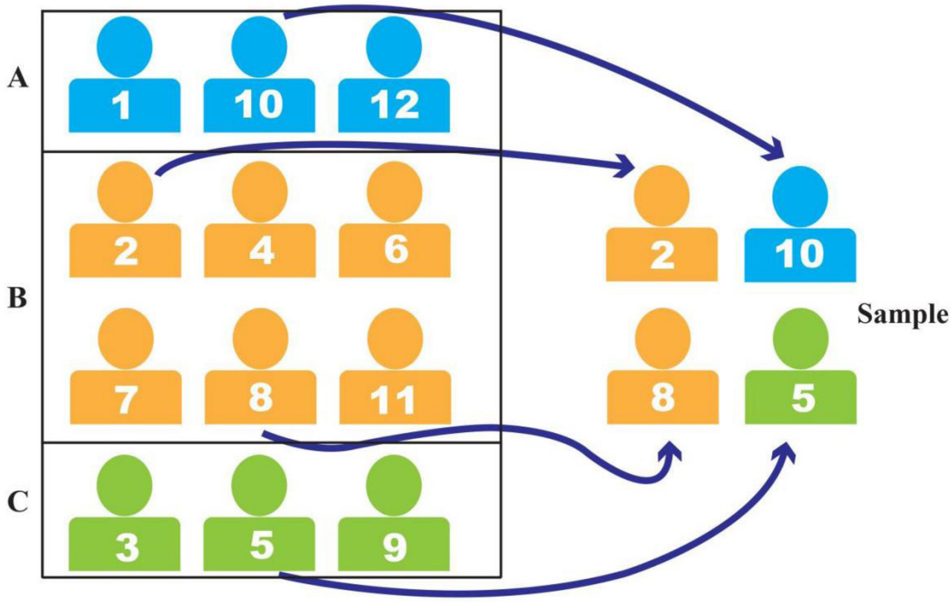


Figure 2. 3: *Stratified sampling technique*

Cluster sampling technique

It is a method of sampling used when the total area of interest is large. The sample is obtained by dividing the area into a number of small non- over lapping areas and then samples are selected randomly from these smaller areas called clusters (Figure 2.4) This is applied when the entire population is unclear or unknown and the sample clusters are geographically convenient. When the clusters are natural in a population, cluster sampling is less expensive and quicker. Cluster sample permits each accumulation of large samples. The loss of precision per individual case is compensated by the possibility of studying larger samples without extra cost. A cluster sampling procedure enables obtaining information from one or more areas.

In a cluster sampling, each cluster may be composed of unit that are not similar. This pattern has a likelihood of producing large sampling error and reduce the representatives of the sample. In cluster sampling, when unequal size of some of the subsets is selected, an element of sample bias will rise. This type of sampling does not allow generalisation of its findings to another area. In Figure

2.4 there are six clusters; A, B, C, D, E, and F where two clusters C and F have been randomly picked.

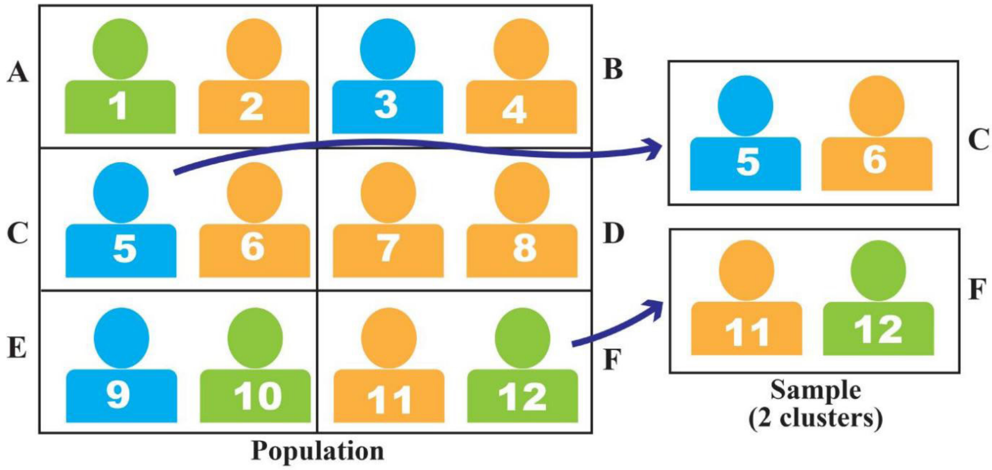


Figure 2. 4: *Cluster sampling technique*

Multi-stage sampling technique

Multi-stage sampling is concerned with taking samples of preceding random samples. This sampling technique is more complex than cluster sampling which contains two or more stages in a sample selection. In simple terms in multi-stage sampling large clusters of population are divided into smaller clusters in several stages in order to make primary data collection more manageable (Figure 2.5). This technique probably solves more of the problems inherent in random sampling. It is more useful in incidents when there are completely no sampling frames. Moreover, by avoiding the use of all sample units in all selected clusters, multistage sampling avoids the large and perhaps unnecessary costs associated with traditional cluster sampling. By considering a study with already pre-determined households in Tanzania, through simple random sampling one can choose number of regions let us say five, and out of five may choose through randomisation four districts in each region. Furthermore, from the districts chosen may choose four wards and lastly two villages from all wards. From these villages, it is where the households will be picked randomly for administering a questionnaire (Figure 2.5). This technique is effective in primary data collection from geographically dispersed population when face-to-face contact is required. It is also time and cost effective and has high level of flexibility. However, it has limitations such as, high level of subjectivity, lack representation of a population and complex planning and administrative issues are required to accomplish.

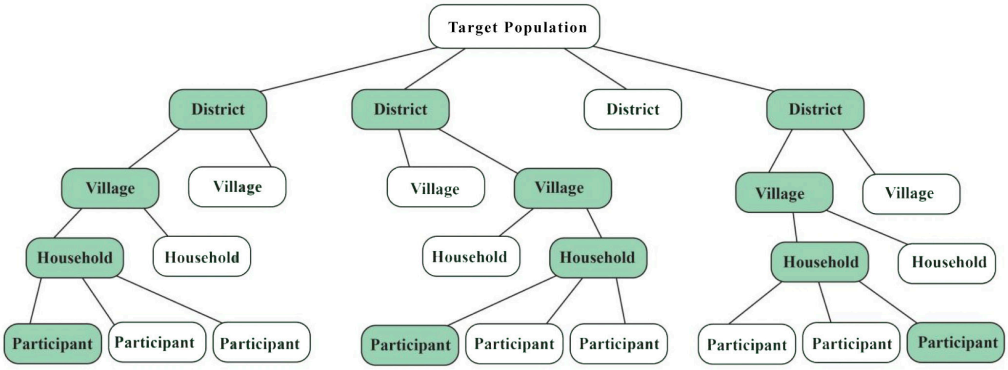


Figure 2. 5: *Multi-stage sampling technique*

Note: The shaded boxes indicate the randomly selected cluster or a participant who has been selected.

Non probability sampling

This is a type of sampling in which members of the population have equal chance of being included in the sample. Members to be included in a sample are chosen from the population in some non-random manner. Non probability sampling consists of quota sampling, convenience sampling, purposive sampling, snowball sampling and voluntary (self-selected) sampling.

Quota sampling technique

Under quota sampling the interviewers are simply given quotas to be filled from different strata with some restrictions on how they are to be filled. In other words, the actual selection of the item for the sample is left to the interviewer's discretion. For example, the researcher may be asked to draw a sample of 35 females and 45 males aged between 45 and 60 from a certain population. The technique lacks the representativeness and it is biased.

Convenience sampling technique

This is the type of non-probability sampling method which is applied when the members of the population are convenient to the sample. Convenience sampling is also known as grab or opportunity sampling or accidental. In this technique, most of the elements in a population that happens to be present at the time of conducting research are selected for study. The researcher opts for it when he/she is interested in obtaining information cheaply. Like many other non-probability sampling it faces the limitation of lacking representativeness and it is subjected to biasness.

Purposive sampling technique

This is the type of non-probability sampling where a researcher selects only those cases, thought to be typical characteristics of the population. Purposive sampling is also known as judgmental sampling. The researcher selects the samples based purely on the self knowledge and credibility. In other words, researchers choose only those people whom they deem fit to participate in the study. It is one of the most cost and time-effective sampling methods available. However, the technique has the following limitations: vulnerability to errors in judgment by researcher, low level of reliability and high level of biasness which subjects the research to inability to generalize research findings.

Snowball sampling technique

Snowball sampling is a special non-probability method used when the desired sample characteristic is rare. It may be extremely difficult or cost prohibitive to locate respondents in these situations. It relies on referrals from initial subjects to identify additional subjects. This technique is preferable in sensitive areas like drug abuse, domestic violence and investigative studies on sex workers. Though the costs of conducting research are lowered; however, it introduces biasness because the technique itself reduces the likelihood that the sample will be representative of the entire population.

Activity 2.10

In a group of five students do the following:

(a) Identify all the subject combinations available at your school and consider them as a target population and establish the total number of students. (based on the attendance sheets/ registration lists).

(b) Then pick small pieces of paper and list the names of classes/ combinations (for example Form I, Form II, Form III Form IV or EGM, HGL, HGK, PCB and PCM) collect those paper put them in a container shake and pick one at a time. Repeat the exercise until you get the number of classes you wish to study (make sure classes to be studied are more than 2).

(c) Find the total number of the chosen classes and apply the formula for finite population to determine the sample size to be studied.

(d) Proportionately distribute the calculated sample based on the total number of the specific chosen group.

(e) Summarise all the results obtained in each step and present your work to the class for an intensive discussion.

(f) Later organise your work properly after effecting amendment from the discussion and submit it for evaluation.

Exercise 2.11

1. Describe the probability and non-probability sampling techniques and show their merits and demerits.
2. What are the advantages and disadvantages of studying a sample rather that entire population?
3. Clearly, compare cluster and stratified sampling techniques.
4. "Multi-stage sampling technically integrates other sampling techniques to achieve its goal." Explain.

Data collection

Proper planned methods and tools for data collection is one among the means for increasing accuracy, correctness, precision and validity of data to be collected. Data collection is a fieldwork where the researcher goes to the field and collects facts expected to answer the identified problem.

Data collection methods

Data may be collected from primary and secondary sources. Primary data are the data collected directly from the field by the researcher using his or her own sense organs such as, mouth, eye, ear, skin and nose. They are first-hand data collected through the use of various methods such as survey, observation, interview, focus group discussion and documentary review or measurement. Secondary data refers to data collected by the researcher from existing sources such as books, magazines, pamphlets, journal articles and other unpublished documents. These are second hand information obtained from already made material or documents. Methods for data collection are defined depending on mode of conducting research and types of data collected. Data collection tools also known as instruments for data collection stands for various pre-designed means for capturing data in the field. The research tools are classified with respect to the data collection methods. The following are data collection methods:

Household survey

Household survey is a method of collecting data achieved by asking a sample of participants questions in order to get information about a population represented by the sample. Usually, it has slightly different names depending on the type and extent of data required. For example, there are households' surveys, census surveys, land surveys and engineering surveys. In the context of this topic, the focus is on household survey. Despite survey being preferred in gathering of data related to perceptions, opinions and ideas still they have several limitations such as less accuracy in measuring behaviour, too much demand for sample representativeness and low response rates.

The data collection instrument in the household surveys is called questionnaire. The questionnaire can be divided into structured and unstructured. Structured questionnaire refers to systematically prepared questions in a written form with a range of pre-determined responses (options/answer) that the respondent can select. The prepared questions with answers are called *closed-ended-questions*. For the case of unstructured questionnaire the same questions are composed but mostly dominated with *open-ended* questions. For example, are you aware of cigarette smoking? How did you come to know the effects of smoking? Can you list those effects? How can the non-smokers be affected with smoking? What is your opinion to people addicted with smoking? The following is an example of the structured questionnaire for household survey;

Survey questionnaire (Sample)

This research aims at collecting data to complete a research project as a requirement to successful completion of advanced level secondary school education. Therefore, the data collected from this research will strictly be for educational purposes and not any other uses.

Household's data

1. Are you the head of the household? Yes/No
2. Total number of members in your household: Male…; Female….; grown-ups .... (>18 years); children ….. (<18 years).
3. Level of education of the household member: 1. Illiterate 2. Primary 3. Secondary 4. Above.
4. How many members have been employed?............
5. Information on employment of the household head: 1. Unemployed 2. Petty trade 3. Civil servant 4. Own business 5. Private employee 6. Other (please specify) ………...
6. The average monthly income in a household: 1. Less than Tsh 50 000 2. Tsh 50 001-100 000 3. Tsh 100 001- 500 000 4. 500 001- 1 000 000 5. Greater than Tsh 1 000 000
7. How often do family members watch Television? 1. (>3 hours) 2. Everyday 3. Once a week 4. Once a month 5. Almost never.
8. Do you think the media has raised awareness on solid waste management? 1. Yes 2. No (if yes, cont. to Qn 9, if not, cont. to Qn 10).
9. Which mass media has been most useful for you in awareness raising? 1. Radio 2. Television 3. Newspaper 4. Social media (WhatsApp/Facebook /Instagram/ twitter/) 5. Mobile short message service (sms).
10. Where do you normally store your household waste?

Storage type	**Number of days per week**
Pit/rubbish halls	………………………
Plastic bags	………………………
Other (please specify)…………………	………………………..

Usually, structured questionnaires are tedious to prepare but easy to fill in. They are easy to analyse and more efficient when dealing with large sample. On the contrary, unstructured questionnaires are easy to construct since they are dominated with open ended questions but difficult for the respondents to fill in cases when they are required to do it on their own time. For example, those which are sent through mail. In addition, they pose difficulties in analysing although they provide rich data. Furthermore, their interpretation is subject to bias. The questionnaire can be administered to the respondents in different ways commonly through face-to-face interaction which is helpful in overcoming language barriers and influencing good response rates. However, it is time and resource consuming. Other methods are phone call and mailing or posting questionnaires in websites but the methods are more challenging in terms of response rates and managing language barrier which has additional limitation related to the unguaranteed turn-up of answered questionnaire.

Interview

Key informant interview is mainly concerned with collecting qualitative data from skilled people on the topic not based on their educational knowledge and level but their stake on the topic investigated. For example, if the research is about assessing the effectiveness of a given project, the research should involve people from the government or private institutions who in one way or another were involved in some activities during implementation of the project. When dealing with the key informant interview, the interview guides are the main instruments used in collecting data from experienced people in the field with regard to the study conducted. Through in this method, data will solely be qualitative, challenging to analyse and cannot be generalized. The following is an example of the key informant interview guide for assessing the effectiveness of the project.

Focus group discussion (FGD)

Focus group discussion is concerned with collecting qualitative data from a small sample, often homogeneous group of people within the studied population to explore their ideas on a particular topic based on their life experiences. The group should not be too large to allow everyone to have a chance to participate and should not take long time. The group should also not be very small to allow wide range of ideas from group members. The method is recommended when the researcher aims at not only collecting interesting information, but also identifying issues and themes that are related to the objectives of the research be conducted. Generally, the focus group discussion is impractical in situations where the language barriers cannot be controlled, the researcher has little control over the situation; trust among the participants cannot be established; and free expressions and confidentiality cannot be ensured. In this method, checklist is used in data collection. Checklist is a set of logical pre-designed questions for data collection from focused group members in the field.

Some of the advantages of focus group discussion are as follows: can be conducted relatively quickly and easily; it allows flexibility in modifying the process and questions and it can explore different perspectives from the group participants. Some of its disadvantages include: analysis of the collected data is time consuming and participants are not true representatives of the population from which are drawn. For instance, if drawn from a village they will not represent all villagers. Thus, the data will be biased and some members can be dominated by others. The following is an example of focus group discussion checklist.

Focus group discussion checklist (sample)

1. What are your opinions about the ongoing water project management practices in your village?
2. Are you satisfied with the way village water project management is done?
3. What is going well in village with the project management?
4. What is not going well in the project management that you are dissatisfied with?
5. What kind of things would you like to see happening?
6. How about the issue of transparency among the water committee leader entrusted with overseeing the project and collecting revenue? How about accountability? What do you think about these?
7. Some people have said that one way to improve X is to do Y. Do you agree with this? (Or, how do you feel about that?).
8. Are there other recommendations that you would like to make?
9. Are there any other things you would like to say before we wind up?
    - Can you say more about that? [mention the aspect]
    - Can you give an example?
    - Jane says X. What is your opinion on that?

Interview guide for the key informant (sample)

1. Name of institution .... date.....................
2. What is your current position?
3. Are you a focal person in the climate change adaptation implemented in village X?
4. Based on your participation in the project, what is your opinion on the impact of the project on livelihood and the environment?
5. With respect to your response in question 4, what is the most important factor that motivated people in the project area to participate in the associated activities?
6. Did the project sustainably empower the community? If so, how?
7. In your opinion, what are the main reasons for some villagers to drop the activities in the project?
8. What should be done to sustain the project activities?
9. In your opinion, was the project gender responsive?

Observation method

Observation is a data collection method in which a researcher collects information in the field-based on visualisation. Tools used for data collection are observation guide, recording sheet and field notes. The observation guide can be divided into semi-structured and structured observations guides. Normally, observation method and the associated tools are opted when there is a need for direct information, to understand the ongoing behavior. There is physical evidence, products, activities or outputs that can be observed and need for alternative data in cases other means of data collection seem to be impractical. The following is an example of semi-structured observation guide for forest surveillance activity in a given forest studied;

How does the activity take place in semi-structured observation guide (sample)? For example.

- Who is taking part?
- Number of participants ....
- Nature of activity and forest surveillance ....
- Time and location of the activity.
- How is the activity organised?
- What are the roles of participants and responsibilities?
- Who makes decision and for who?
- Are the resources made available to environmental surveillance team? For example, special equipment, mobile phones and means of transport for surveillance.

Although, observation method is beneficial in collecting direct and real time data still it has some limitations such as it is observer biased, potentially unreliable, interpretation and coding challenges; sampling can be a problem and it can be labour intensive.

Transect walk

Transect walk is a team-based field walk along a defined path (transect) across the community or project area together with the local people often for the sake of collecting geographical data on various aspects by observing, asking, listening, watching and at the end producing a transect map or diagram. The data collection tools in this method include observation guide, recording sheet and field notes. Transect walks are usually preferred when the researcher is interested in collecting direct data by observing people, surroundings and resources in their natural settings. However, this data collection method demands good observation skills.

Activity 2.11

In groups of five students do the following:

1. Select a topic in geography and brainstorm possible objectives of studying that topic then compose the following tools for data collection;
   (a) Questionnaire for household survey.
   (b) Checklist for focus group discussion .
   (c) Observation guide for observation.

Present the work to the class for discussion and make any useful amendments for improving it.

Data analysis and presentation

After the data has been collected, the researcher has to do analysis. The researcher should classify and organise the raw data into some purposeful and usable categories. Data analysis involves recording and storage of data in a computer. For quantitative data will be followed by computing mean, mode, median, range and standard deviation where required. The analysed data are presented in various formats such as tables, graphs, charts and maps, while qualitative data are grouped in themes or topics.

However, in case of qualitative data, this can be analysed through thematic and content analysis. Thematic analysis emphasises on identifying, analyzing and interpreting the pattern of meaning of themes within qualitative data. Content analysis examines patterns in communication in a systematic manner.

The purpose of data presentation is to display the results in a presentable manner to enable easy interpretation and report writing.

Hypothesis testing

In this stage the researcher finds out whether the facts from the field support the formulated hypothesis. Meaning that, research results obtained from the field are used to make decisions whether they support the hypothesis or not. On testing the hypothesis, two possible outcomes are expected, that is, the findings may support or not support the hypothesis. In case the findings do not support the hypothesis, new hypotheses can be formulated, restarted basing on the findings and re-tested. In case the results are supported by the hypothesis you can go directly to generalisation.

Generalizations and Interpretation

If a hypothesis is tested and supported several times, it can increase confidence to the researcher in arriving to generalisation and building a theory. As a matter of fact, the real value of research lies in its ability to arrive at certain generalizations. As researcher who has no hypothesis to test might seek to explain the findings on the basis of some relevant theory or theories that underpinned the study. Finally, the researcher has to prepare the report of the findings.

Revision exercise 2

Answer all questions.

1. Give an account of research methods and methodology.
2. 'There is no need of conducting research in Tanzania.' Comment on the statement.
3. Distinguish between structured and unstructured questionnaire.
4. Give a brief account of the following data collection methods used in field research.
   (a) Household survey
   (b) Interview
   (c) Focus group discussion
5. Distinguish between structured interview and unstructured interview.
6. Discuss the roles of research in daily life.
7. Describe the challenges encountered by a researcher when conducting a research.
8. A research is logical and systematic procedure, state the stages to be used or considered in conducting a research.
9. With examples, explain how you can conduct a field research.
10. In which circumstances would you opt to use,
    (a) Observation method
    (b) Household survey
    (c) Interview
    (d) Focus group discussion

11. Mr Rogwa is an environmentalist from Jozani village in Zanzibar. He receives some claims from his fellow villagers on the rate of deforestation from making charcoal. He decided to conduct a research for his society.
    (a) Suggest type of research which might be used by Mr Rogwa and give the reason.
    (b) Elaborate basic requirements to be considered by Mr Rogwa in conducting this research.
    (c) Explain four objectives for his research.
    (d) Identify three problems that Mr Rogwa may encounter in conducting this research.

Chapter Three

Simple survey and mapping

Introduction

Surveying and mapping have remained important disciplines throughout the history of human beings. In the past, humans used land and astronomic surveys to set important marks of positions on their land or water. However, in the modern era, surveys are used for determining site locations, demarcating boundaries of land parcels, setting out engineering structures, and map making for various land uses. In this chapter you will learn the concept of survey, process in survey, classification of surveys, chain survey, compass survey, plane table survey and levelling survey. The competencies acquired from this chapter will enable you to determine locations of points using different land surveying methods.

Concept of land survey

Since ancient time, land surveying has been used to set important marks on the land. The established marks, also referred to as control points were used to establish position of features. For instance, in ancient Egypt surveyors called *rope stretchers* used the control points and simple geometry to re-establish marks of boundaries swept-off by annual floods of the Nile River. The name rope stretchers originated from a marked rope which was their principal tool of survey, and the today's chain survey originated from this marked rope surveying. It was associated with making linear measurement between the established points or stations. In his work, "*The sea island Mathematical Manual*" published in 263 AD, the ancient Chinese mathematician, Liuhui, described ways of measuring distant objects. The work of Liuhui founded the growth of survey which was later recognized by Romans as a profession.

Thus, land surveying or geomatics as a profession can be defined as the science, art, and technology of determining the relative positions of points or features above, on, or beneath the earth's surface. The determination of such relative position involves measurements of distances, height and angles; which results to graphical or numerical presentation of measured values.

Land surveying supplies data by which accurate space-based plans and maps of the earth's surface or part are made. Survey can aid proper land management and administration in ecumene. The planning of proper layout of streets and water supplying network, division of arable land for farming and other services are significant contributions of land survey.

Influence of technological development in surveying

Land survey is part and parcel of human life and his development. Land surveying aims at establishing boundaries, creating navigation maps, and creating plan and maps for different land uses. To accomplish such tasks, humans have been innovating tools for taking linear, angular, and area measurements.

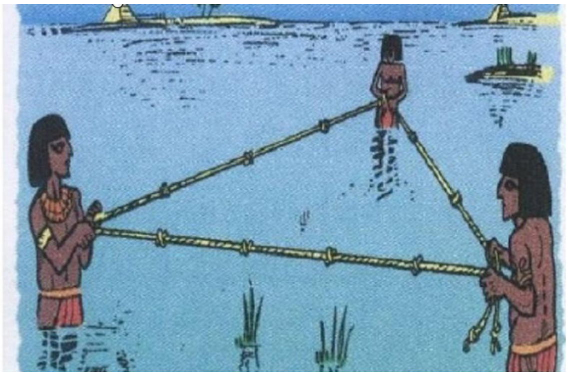


Figure 3.1: *Ancient Egyptian survey*

While the purpose of surveying has remained the same since ancient Egyptian survey (3000 BC) (Figure 3.1), surveying instrument have evolved drastically with technological development. The linear measurement instrument have evolved from chains and Gunter's steel band through steel band and metal tapes to Electronic Distance Measurement (EDM) instruments (Figure 3.2). Subsequently, the Global Positioning Systems (GPS) devices have improved efficiency and greater accuracy of measurement than any other preceding instruments.

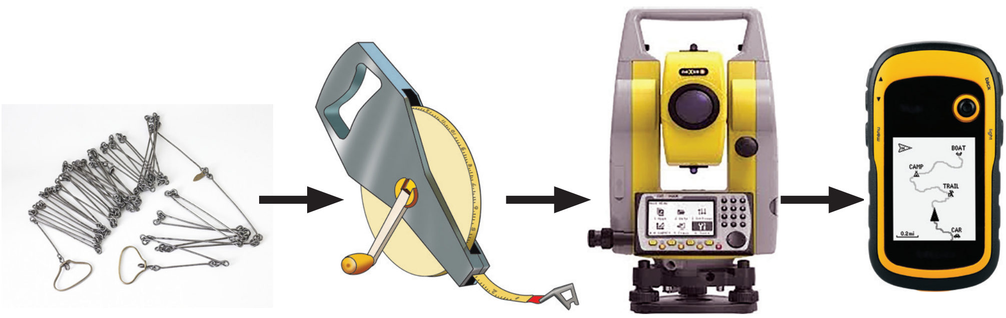


Figure 3. 2: *Evolution of distance measuring instruments*

Just as it was for linear measurements, instruments for angular measurements have also evolved significantly from the Egyptian Groma (which has been perpetuated by the cross-staff and its successor, the optical square) through dioptra to the compass like-instruments called *astrolabe*. The dioptra and astrolabe were followed by sextants, which are more professional and accurate. Evolution of modern angular measurements began with compasses that were followed by Transit, Theodolites and Total stations (Figure 3.3). A total station is a multipurpose surveying instrument that combine the functions of Transit level or Theodolite and electronic distance measurement (EDM) into a single instrument.

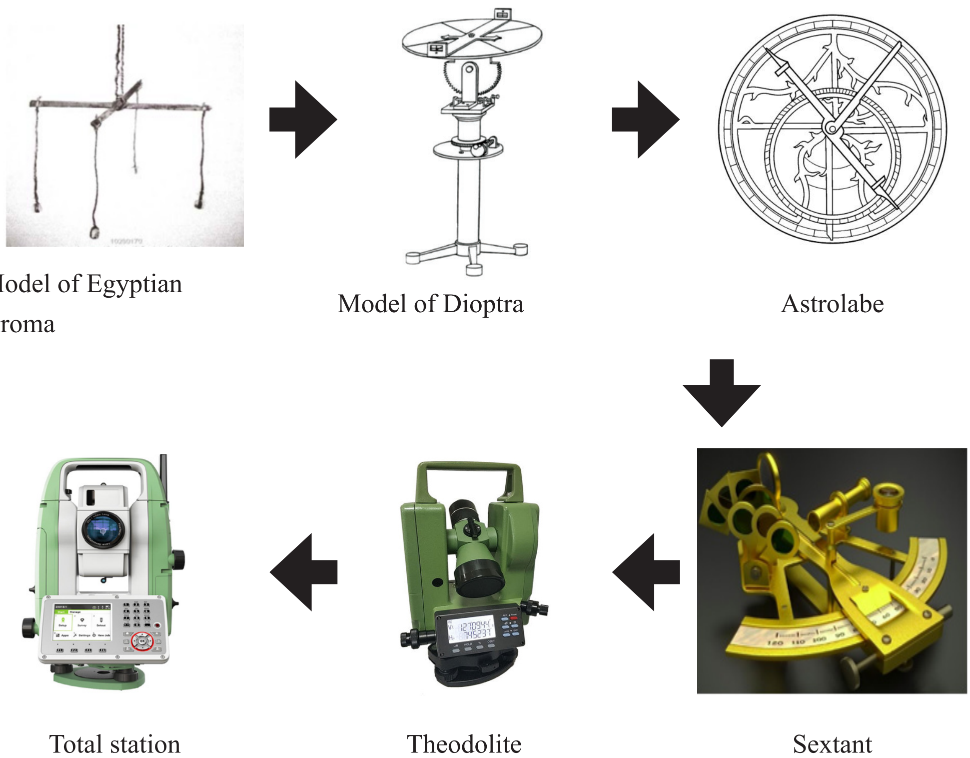


Figure 3. 3: *Evolution of angular measuring instruments*

Modern angular measurement instruments use principles of electronics to calculate angles and distances. Morphologically, there is only a slight difference between Theodolite and Total station. The main difference is on their function and applications. Total station is used to measure both angles and distances while Theodolite is used to measure angles only.

However, in this chapter you will learn basic surveying techniques using basic instruments to understand principles of surveying, which also apply when using modern instruments.

Procedures and process in land surveying

Most of land surveying involves three important processes: reconnaissance, fieldwork and office work. Reconnaissance is the first process in land surveying in which the surveyor gets a general view of the area to be surveyed. In this step, a surveyor gathers information related to the area to be surveyed then for familiarization with its landscape and get an overview of what may be required before the commencement of a fieldwork. This stage helps the surveyor in planning for the execution of the survey project, particularly in identifying appropriate survey methods, instruments, required man power, preparation of budget and time schedule.

Fieldwork is the actual execution of survey work which involves observations and measurements of distances and angles, recording of measurements in a field notebook, preparing field sketches and performing simple calculations.

The office work is the last process which is carried out in the office and involves correction of survey data, reduction of levels, calculation of coordinates, preparation of plans, maps and other graphics, as well as calculation of areas and volumes of Earth quantities.

Classification of land survey

Although land surveying is usually classified on the basis of multitude of criteria, geodetic and plane survey make the general classification in the discipline. The two classes are types of surveys with their differences rooting on the key assumptions they hold. Geodetic land survey assumes the Earth as curved surface (ellipsoid) and that any computation must consider the ellipsoidal nature of the surface, while the plane surveys assume the earth's surface as flat. However, the terms plane surveys and plane table surveying should be treated different. The earlier is a type of surveys, the later represents a technique of plane surveying. Geodetic methods are employed in solving a relatively large land masses, usually over 250 square kilometers at national and continental scale, and widely spaced monuments or features. Plane surveys on the other hand, are used in mapping areas covering less than 250 square kilometers. Contrary to geodetic survey which treats all lines joining stations as arcs, plane surveys consider all lines joining two or more points as straight lines.

A demand of high accurate data in geodetic surveys requires instrument of high precision, accuracy and economy than those employed in plane surveys. Prior to 1970, accurate observation of angles and distances to collect spatial data in geodetic surveys was difficult and pains taking. Angles were measured using precise ground-based Theodolites while distances were measured using special tapes made from metal with low coefficient of thermal expansion. Although these instruments are still used for angles and distances measurement to date, satellite positioning has almost replaced other instruments in geodetic survey. The global positioning system relies upon signals transmitted from satellites for its operation. The entire scope of satellite systems used in positioning is referred to as *global navigation satellite systems* (GNSS) (Figure 3.4).

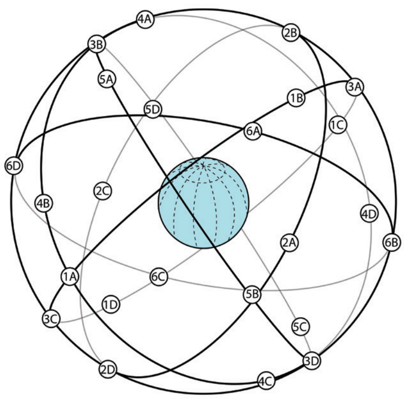


Figure 3. 4: *Global navigation satellite systems*

Receivers that use multiple satelite system like GPS, GLONASS, Galileo, and Beidou are known as global navigation satellites system (GNSS) receivers (Figure 3.5). GNSS receivers use satellites as their reference points. The GPS, GLONASS, Galileo and BeiDou positioning systems are satellites constellations managed by different states or countries. The systems provide precise timing and positioning anywhere on the Earth with high reliability and low cost. The systems operate during day and night, rain or sunshine, and do not require cleared lines of sight between survey stations. Currently, GNSS receivers are used in all forms of surveying including hydrographic, construction and boundary surveying.

Figure 3. 5: *Global navigation satellite systems receiver*

Although (GPS), and 'GNSS' are treated synonymously and used interchangeably by many surveyors, the terms are distinctive and each has its own unique meaning. A term GNSS is an inclusive term that describes satellite navigation systems from any country or region while 'GPS' refers specifically to the NAVSTAR satellite navigation system of the United States. The most common GNSS are GPS (United States), Global Navigation Satellite System - GLONASS (Russia), Galileo (European Union), BeiDou (China) and Quasi - Zenith Satellite System - QZSS (Japan).

Activity 3.1

1. Visit your school library and read survey books, give the types of survey and justify criteria for the classification.
2. Trace the evolution of geodetic survey instrument before and after 1970s in Tanzania and the world.

Specialised types of tape survey

The existence of many types of surveys, named after principal devices, objective and surface surveyed among other criteria implies existence of specialised type of survey in each area. There are many specialised types of surveys including chain or tape survey, compass survey, plane table survey, leveling survey, hydrographic survey, topographic surveys, control surveys, cadastral surveys, mine survey, tacheometric surveying, aerial surveying, photogrammetric surveying and satellite surveying. However, in this chapter the emphasis is put on chain surveying, compass surveying, plane table surveying and levelling surveying.

Chain surveying

Chain surveying also known as tape survey is one of the methods of land surveying in which sides of various triangles are measured directly in the field. It is the simplest but accurate method of land surveying. The method involves measuring a series of straight lines using chain or tape measure. The method is purposely carried out to map flat small areas or near flat terrain and the associated features like foot paths and buildings; to determine the area of surveyed land; to prepare an accurate plan of a plot of land; to restore lost boundary marks; to divide a plot of land into a number of smaller units; to update an existing large scale map, and to set out engineering structures such as roads, railways and dams when implementing engineering projects.

Equipment used in chain survey

Equipment used in chain surveying include chain or tape, ranging rods or pole, plumb bob, wooden or iron pegs, arrow pins, Abney level, clinometer, cross-staff, optical squares, offset rods, drawing and recording materials like pen, pencil,notebook rubber and field sheet or notebook. Modern devices such as Total station, GPS and surveyor band has replaced the chain as basic instrument in chain surveying.

Chain

A chain is primary equipment in chain surveying. It is a tempered steel wire with the length ranging from 20 m to 30 m long. The commonly used chains are composed of 100 or 150 links formed through pieces of galvanised mild steel wire of 4 mm diameter. The ends of every link are looped and connected together through means of three circular or oval shaped wire rings to give flexibility to chain. The length of each link is measured as the distance between the centres of two consecutive middle rings (Figure 3.6). The joints of links are welded to prevent length changes because of stretching. Survey chains are generally grouped into three main types such as the *Gunter's chain which* is 66 ft long, divided into 100 links with each link measuring 0.66 ft; the *Engineer's chain* which is 100 ft long and divided into 100 links and each link measuring 1 ft;and the *metric chain* which is 20 m or 30 m long.

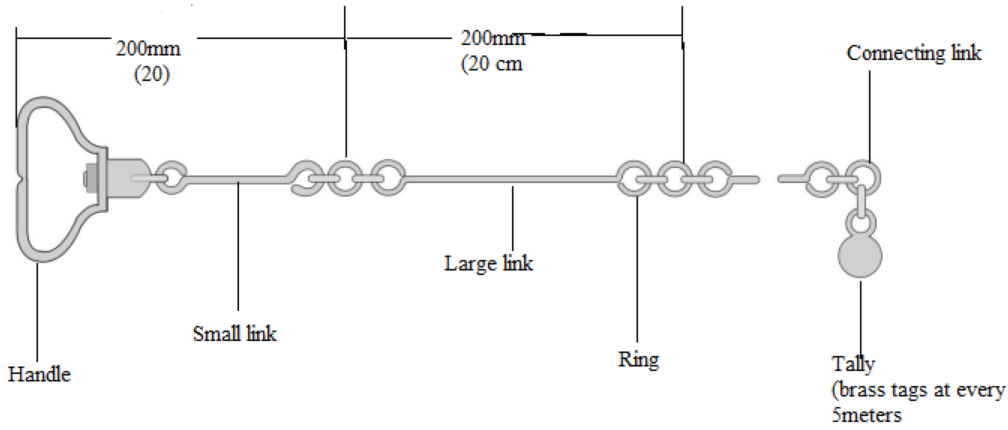


Figure 3.6: *Chain*

Chains are marked with tallies to indicate distances from the handle. Commonly used chains have plastic or brass markers placed at some particular distances. Tallies in a chain are marked at 1 m, 5 m, 10 m, and 15 m. The shape of a tally symbolises a distance it represents wherever placed in the chain. Nowadays, chains are replaced by cheap and readily available measuring tapes, Surveyor band, Total station and GPS.

Tape measure

A tape measure is also a primary equipment in chain/tape surveying. It is used to measure distance. It consists of a ribbon of cloth, plastic fibre or metal strip with linear measurement markings. Surveyor's tape are normally measures in lengths from 50m to over 100m (Figure 3.2).

Cross staff

This is a metal or wooded cross fitted on a short ranging pole with eye slits at right angle (Figure 3.7). It is the simplest instrument used for setting out perpendicular lines from a chain line. Establishment of right angles in chain surveying is the easiest and quickest method though it is not very accurate. If a survey project requires data of great accuracy, survey instruments such as Theodolite or Total stations can be used.

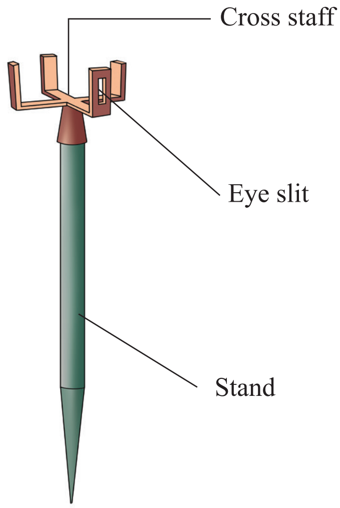


Figure 3.7: *Cross staff*

Ranging pole and ranging rods

The two equipment have always been used interchangeably due to their visual appearance and mode of formation. Ranging rods and poles are wooden, or steel rod made round or rectangular in shape. However, there is a slight difference between ranging rod and a ranging pole. Ranging rods are used for marking temporarily positions of stations while straightening a line. They are made of well-sectioned straight grained timber of teak or deodar and are generally available in 2 m or 3 m length and 3 cm in diameter. A rod is divided into equal parts, each part measuring 0.2 m. Its lower end is provided with a cross shoe of 15 cm length. They are generally painted alternatively red and white, black and white or yellow and white throughout their length to facilitate visibility. On the contrary, ranging poles are similar to a ranging rod except that they are of heavier section of length of 4 m to 6 m long. They are used for ranging very long lines in undulating ground. Figure 3.8 (a) and (b) show ranging pole and ranging rod respectively.

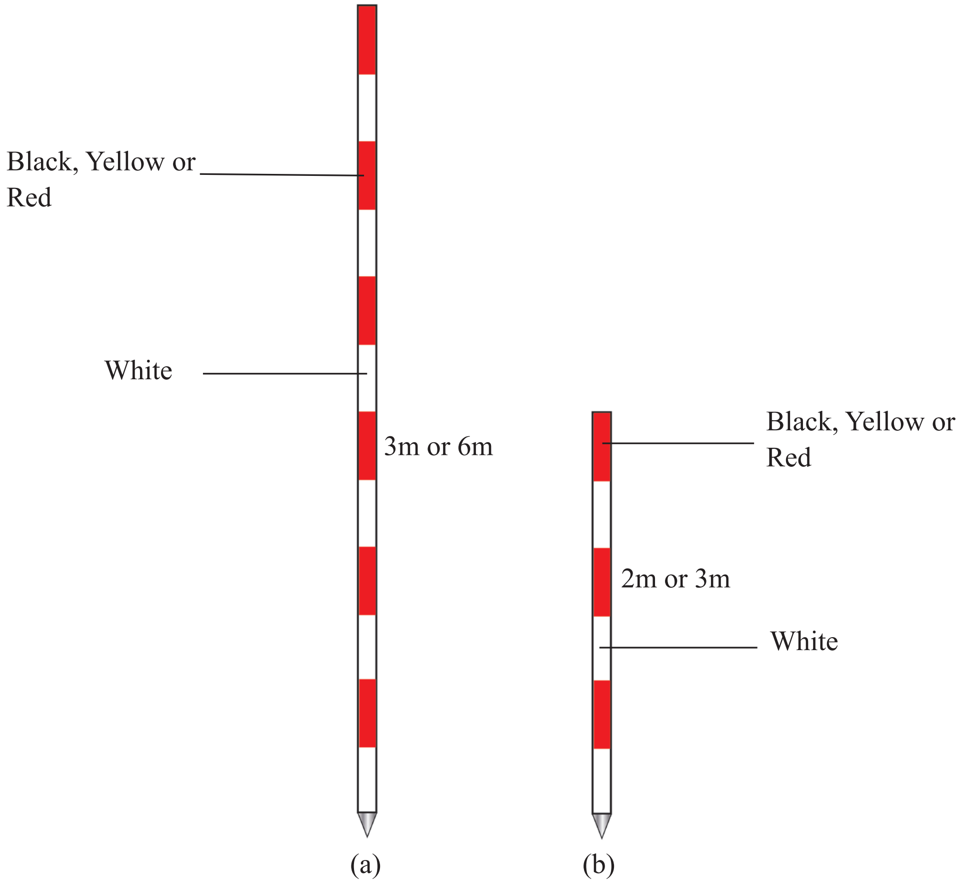


Figure 3. 8: *(a) Ranging pole (b) ranging rod*

Arrows

These are thin steel skewers for marking points on ground temporarily. They are 30 cm to 40 cm long with coloured rag tied to the circular end to make them more visible (Figure 3.9).

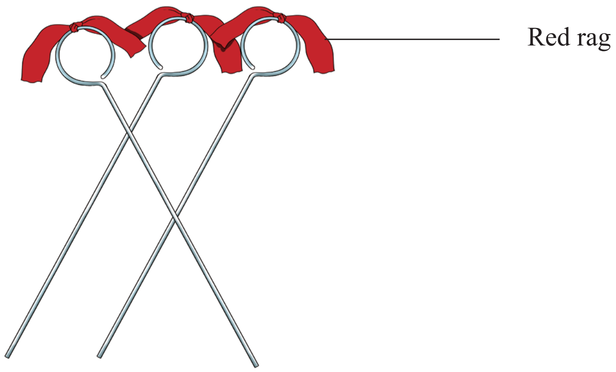


Figure 3.9: *Arrows*

Pegs

Pegs are usually wooden with 40 mm square and 50 cm long. They are used to mark permanent positions of station in the traverse by driving them into the ground by a mallet at the required point. In a very hard ground iron points, nail or a bar made of cement are used to mark position permanently (Figure 3.10).

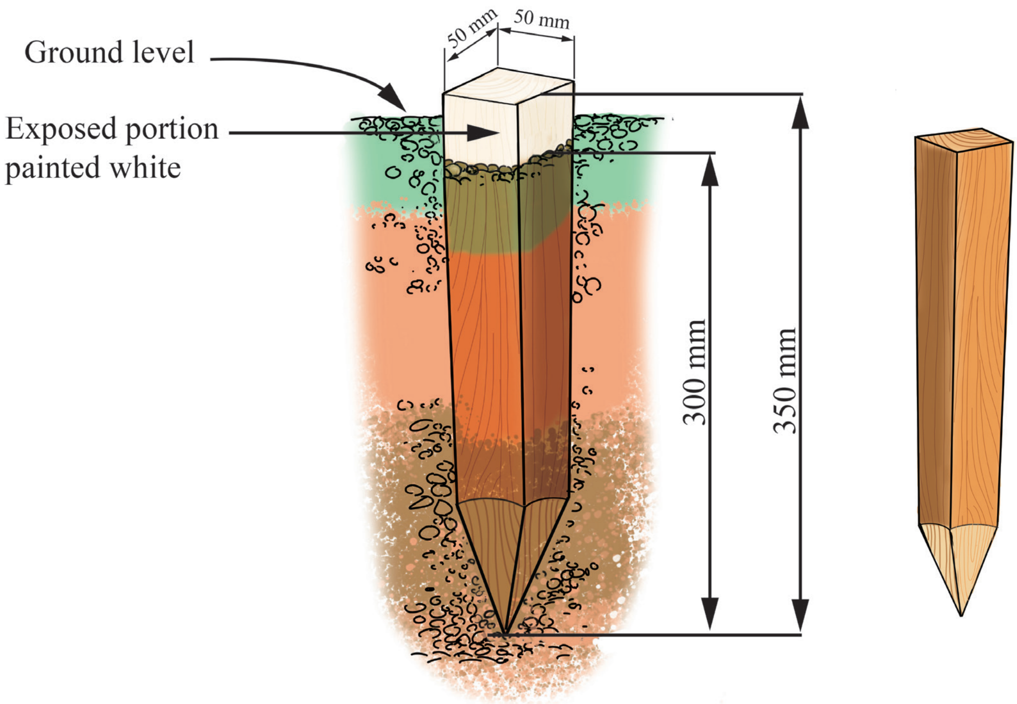


Figure 3.10: *Pegs*

Offset rods

Offset rods are similar to ranging rods. They are usually of 3 m long, divided into equal parts of 0.2 m. Different from ranging rods, offset rods are provided with an open hook at their top to aid for pulling or pushing a chain through obstruction like bushes, rocks, and small water streams (Figure 3.11). Two narrow vertical slots passing through the centre of the section at right angles to one another are provided at the eye level. It is used for aligning the offset over traversing.

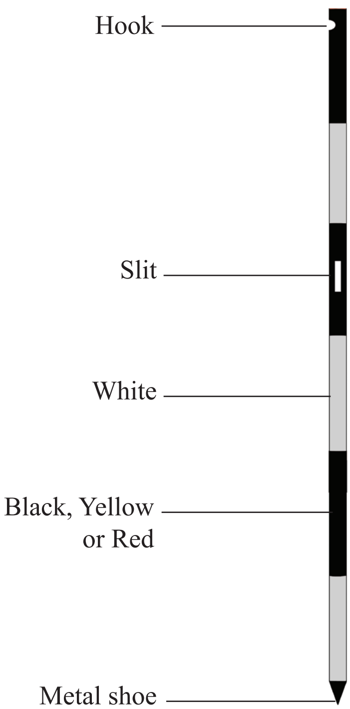


Figure 3. 11: *Offset rods*

Plumb bob

Plumb bob is a metal weight, usually with a pointed tip on the bottom, suspended from a string and used for transferring points vertically from the ground to the tape or chain and vice versa (Figure 3.12).

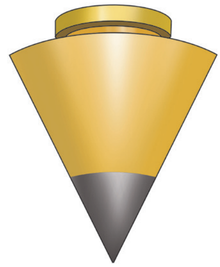
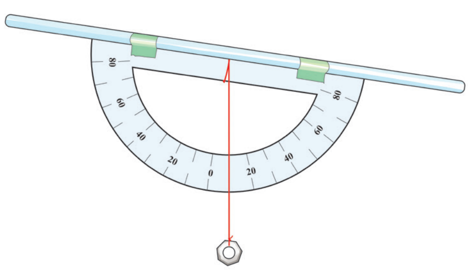


Figure 3. 12: *Plumb bob*

Abney level and clinometer

While Abney level is used for insuring the chain or tape is on horizontal plane when taking measurement. Clinometer is used to measure slope angles for slope reduction (Figure 3.13).

(a) Abney level



(b) Clinometer

Figure 3. 13: *Abney level and clinometer*

Field notebook and recording materials

These are important facilities every surveyor needs for recording all measurements and other information taken in the field (Figure 3.14). It include: notebook, rubber, pen, and pencil, however, with technological development, surveyors also use laptops, and iPad for recording field data.

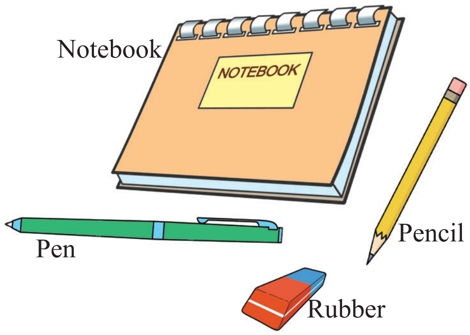


Figure 3. 14: *Notebook, pencil, pen, and rubber*

Other instruments used in chain/tape survey are optical square and surveyors band.

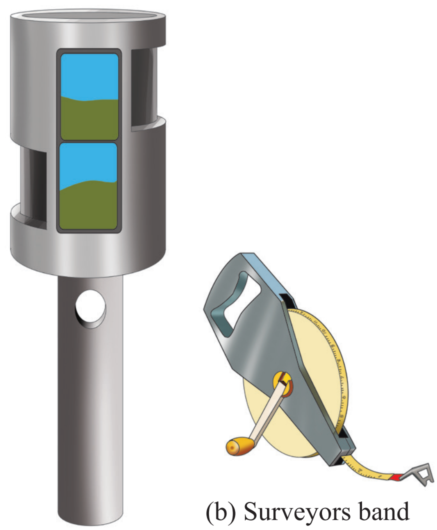


Figure 3. 15: *(a) Optical square and (b) surveyors band*

Terms used in chain/tape surveying

There are several important technical terms used in chain/tape surveying. These terms are; main survey station, subsidiary survey station, main survey lines, check lines and auxiliary or subsidiary or tie lines.

Main survey stations: are points where two sides of a main triangle meet. They are point at either end of a chain line. Main survey stations are usually inter visible from either side of observation.

Subsidiary survey station (or tie station): refers to a station which is selected on the main survey lines for running auxiliary lines.

Main survey lines: are chain lines joining the two main survey stations. In chain surveying, the main survey line is a baseline that surveyors establish to take lateral measurements.

Auxiliary, subsidiary or tie lines: are chain lines joining two subsidiary survey stations. Usually, they are established to locate the interior details which are far away from the main lines.

Check lines: are lines established to check the accuracy of the fieldwork. If the measured length of a check line correspond with the length scaled off the plan, the survey is accurate. Each triangle is generally provided with a check line. The check lines may be laid in such a way that maximum numbers of details are intersected by it. Check lines may also be laid by joining the apex of the main triangle to any point on the opposite side or by joining two points on any two sides of the triangle.

Preparation for field chain/tape survey

Field chain or tape surveying involves several operations. Before field operations, chain surveying involves several activities including testing and adjusting the chain length; preparing the geographical area; working schedule; transport and precaution like first aid.

Testing and adjusting a chain

Prior to executing field chain surveying the chain length is checked whether it is of the correct length as prescribed by the manufacturer. Chain length can be distorted by bents of chain links during its use, or opening up of rings which consequently decreases length of the chain. On the contrary, the length of a chain can increase due to: wearing and tearing of chain rings; over stretching of the links and the joints during chaining and opening out of small rings due to prolonged usage and rough handling. Pulling of a chain through hedges, fences, rocks and thickets is also a cause for the chain damage. Thus, it is necessary to check the length of the chain before and after surveying. If the chain is not tested, the measurements will be unreliable. Before checking a chain, the surveyor should ensure that its links, are not bent, openings are not too wide and there is no mud attached to them, and all connecting rings are circular.

Procedures in testing and adjusting chains

(i) Fix two pegs at the required distance 20m or 30m apart; measured by a standard chain and insert nails into their tops to mark their exact points of 20^{th} or 30^{th} m from peg-tops A and B (Figure 3.16).

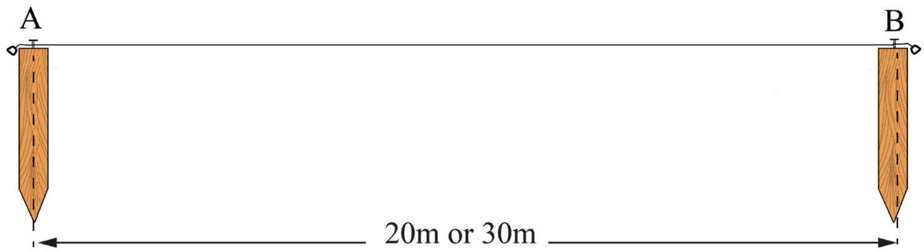


Figure 3. 16: *Distance AB measured by a standard chain*

(ii) Compare the overall length of the chain against the fixed pegs and note down the difference if any. If after comparison, a chain is found to be longer or shorter than its standard, then length may be adjusted. Several ways can help to adjust the discrepancy between the tested lengths and the original manufacture's length. Closing the opened joints of the rings can adjust the chain. However, straightening the bent links; flattening the circular rings; replacing one or more small circular rings by bigger ones and inserting additional circular rings serves the chain from being obsolete.

(iii) If the chain is not adjusted, correction should be done whenever such chain is used to take distance measurements.

Activity 3.2:

1. Fix two pegs with nails on their top at a chain distance apart using a standard chain.
2. Measure the distance between the two pegs using a field tape and compare the measured value with that of a standard chain.

Field procedures in chain surveying

A team of three people that is the leader, follower and the booker or surveyor usually carries out Chain surveying fieldwork. The procedures involved in chain surveying are explained using an example of village Y. Assuming a village Y shown in Figure 3.17 wants to implement a water supply project from a newly constructed water tank, land surveys will be required to locate the route of water supply network and show the longitudinal profile of the located route.

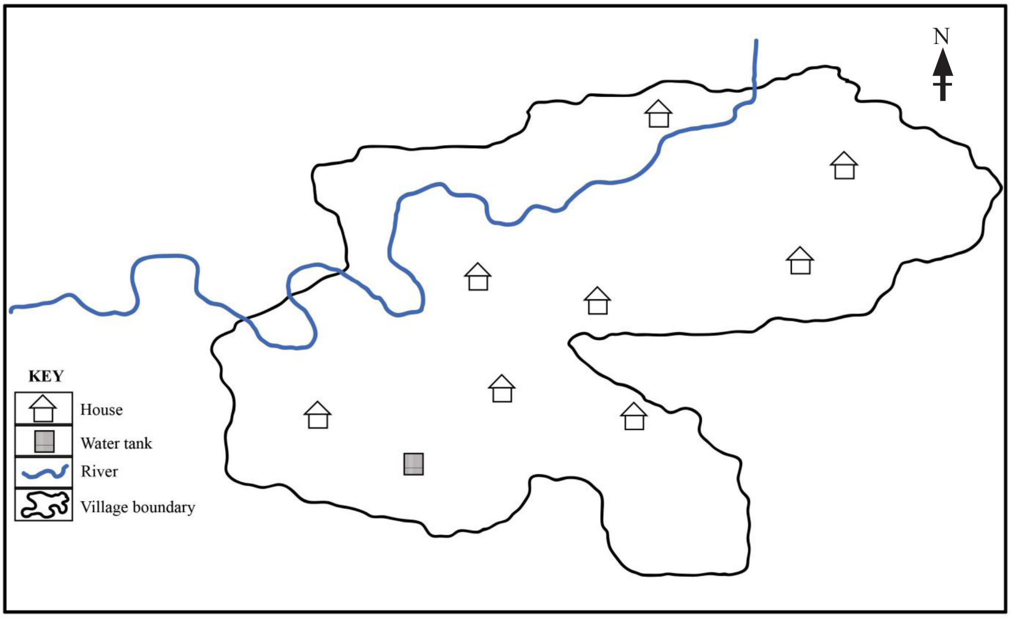


Figure 3. 17: *Sketch map of village Y*

The route of water supply network could be located by chain surveying; compass surveying, plane table surveying or other advanced surveying methods. The longitudinal profile could be prepared after carrying out levelling surveying. Two field procedures; establishment of baseline and point fixation are followed in chain surveying.

Establishment of a baseline

In chain surveying, position of points are fixed relative to a baseline. Thus, before fixing points, a baseline should be established on a level ground for visibility of stations. It is further recommended that, a baseline should be run through the center of the area to be surveyed. Establishment of a baseline involves three activities:

(i) Identifying locations for main stations. Each main station should be located at a place where the preceding and the next main stations are visible and most of target points are visible from a baseline.

(ii) Marking the main stations; the main stations are permanently marked using pegs or iron pins. In Figure 3.18, base stations A, B, and C are permanently marked to define a baseline in a village Y where water supply project is to be implemented.

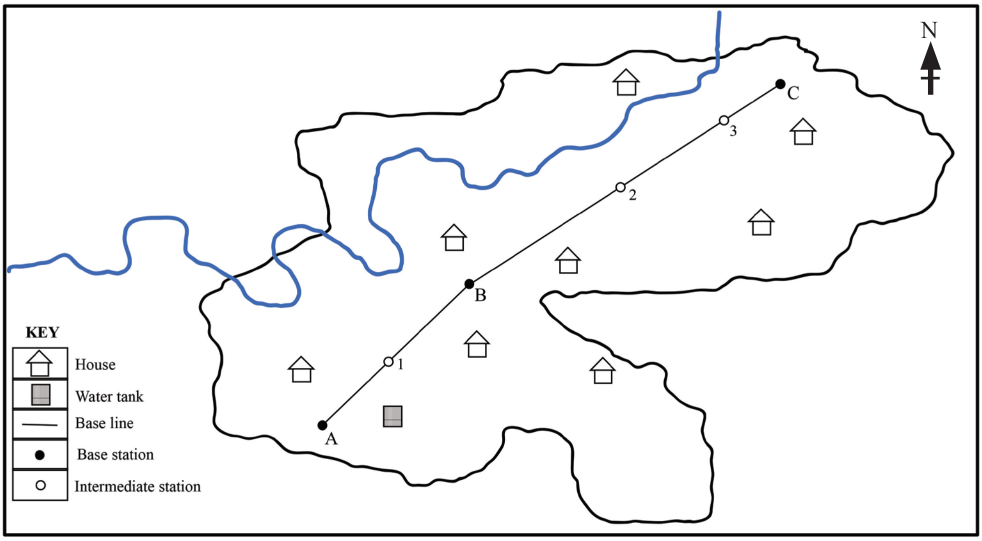


Figure 3. 18: *Baseline establishment for village Y*

(iii) Measuring the length of a baseline; distance between any two adjacent main stations is measured using a chain/tape. To measure a distance, intermediate stations are temporarily marked by arrows along a line connecting two consecutive base (main) stations that are more than chain/tape length apart. For example, if two adjacent base stations are 50 m apart and a field chain/tape is of 30 m, intermediate stations need to be marked. When marking intermediate stations, the leader and the surveyor hold ranging poles at two base stations, while a follower moves with another ranging pole and arrows to mark the intermediate stations. Then, the surveyor directs a follower to move the ranging pole to the right or left until it is aligned with the other two ranging poles. The follower is then signaled to mark a point where the alignment of the ranging pole was achieved. In Figure 3.18, intermediate station 1 is temporary marked between base stations A, and B while intermediate stations 2 and 3 are temporary marked between base stations B and C. To measure distance between stations, a chain/tape is thrown to extend to the marked stations. The follower erects ranging pole at the first base station and places the handle of chain/tape against it. The leader pulls and straightens the chain/tape towards the first intermediate stations and takes the reading at a point where the chain/tape intersects the intermediate stations. The leader reads aloud the observed values and the booker reads back aloud while recording the values to avoid recording errors. The distance should be measured twice, thrice or more times to provide check for errors. Then, the leader moves to the second intermediate station and the follower to the first intermediate station to measure a distance between the two intermediate stations. The same procedures should be followed in measuring distances of other intermediate lines. Thus, the distance between the two main stations is the sum of the lengths observed between the intermediate stations. For example, the length of baseline ABC in Figure 3.18 is the sum of the length between points A and 1, 1 and B, B and 2, 2 and 3 then 3 and C.

Activity 3.3

1. Establish a base line passing through the centre of your school compound.
2. By using a chain or tape. Measure the length of the marked baseline.

Fixing points relative to baseline

In chain surveying, positions of lateral details like culverts, houses and boundaries right or left of the baseline are located with respect to the chain line. The lateral measurement taken right or left of the main chain line are termed as *offsets*. There are two types of offsets in chain surveying; perpendicular offsets and oblique offsets. Their differences lie on the definition implied by their names; the 'oblique' and 'perpendicular.' When a lateral measurement to fix location of a particular detail is made at right angle (90°) to a chain line, the offset is called perpendicular offset or right angled offset. In the Figure 3.19 (a), line EN is a perpendicular offset on the left side of a chain line AB. On the contrary, when a lateral measurement to fix details made at any angle less than (90°) to the chain line, the offsets are referred to as oblique offsets. Offsets DF, and CF in the Figure 3.19 (b) are oblique offsets. In chain surveying, offsets with lengths less than 15 m are short offsets and those with lengths greater than 15 m are referred to as long offsets.

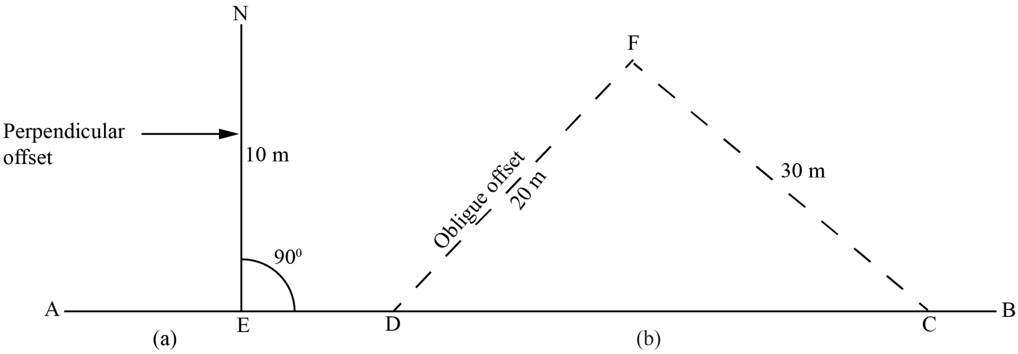


Figure 3.19: *(a) Perpendicular offset EN and (b) oblique offsets DF and CF*

Fixing position of target points relative to a baseline involves three procedures;

(i) Marking tie points; tie points are marked using procedures explained in step (iii) of establishment of a baseline. In Figure 3.20, tie points 1 to 7 are marked where perpendicular offsets to water tank and houses are taken.

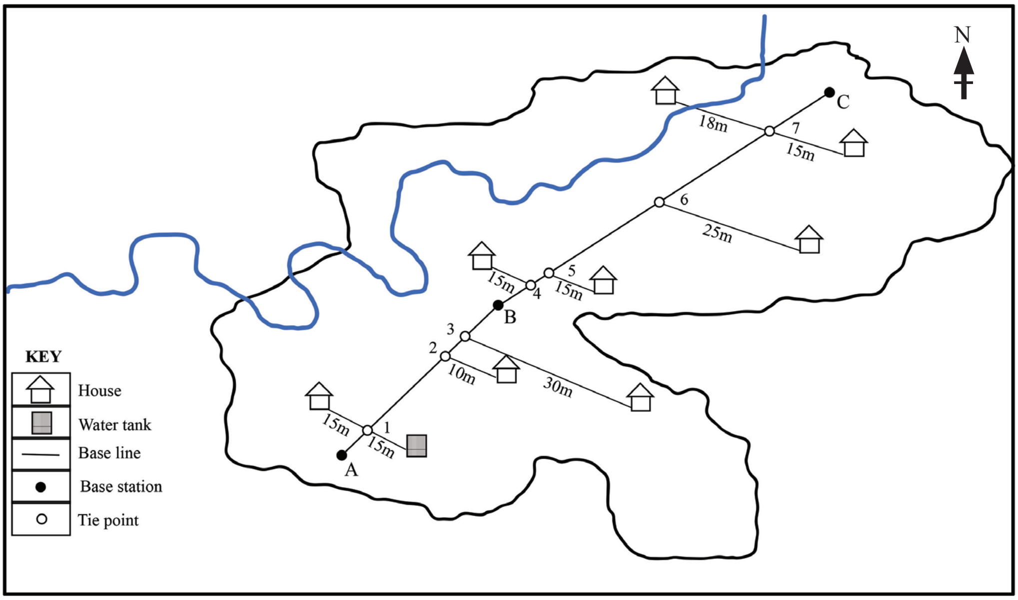


Figure 3.20: *Marked tie points 1 to 7 and the respective perpendicular offsets.*

(ii) Measuring distances from the base points to tie points; distance from main station to each tie points which is also called chainage is measured and recorded in a field notebook as shown in Figure 3.21.

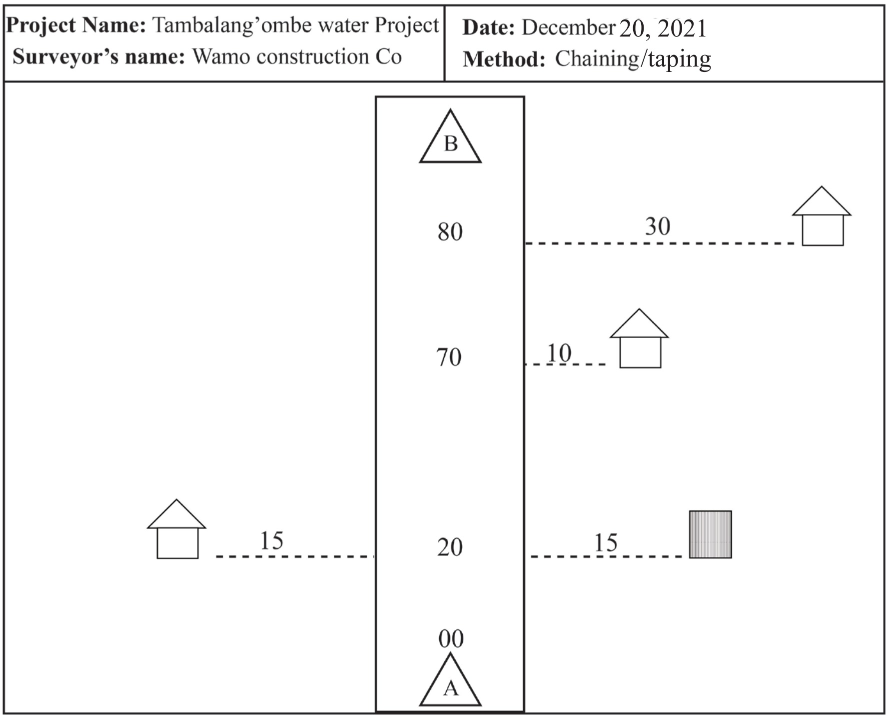
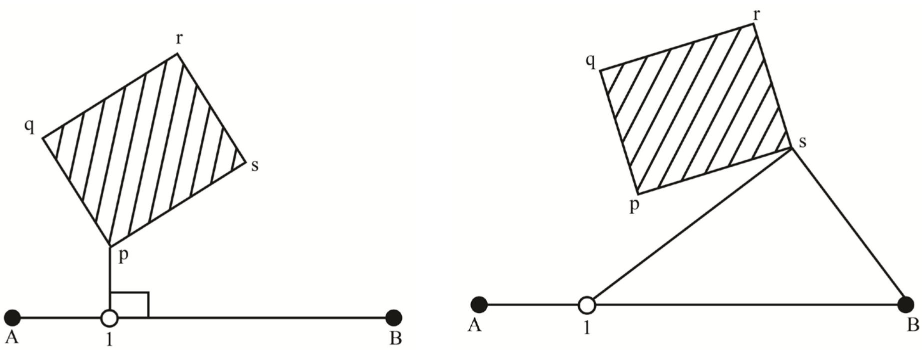


Figure 3.21: *Field note book page for survey line AB*

(iii) Measuring offset distances from tie points to target points; at each tie point, offsets to target points are measured. Measured perpendicular offset to a water tank and houses in Figure 3.20 are recorded in a field notebook shown in Figure 3.21. Two oblique offsets or one perpendicular offset should be measured to fix position of target points as shown in Figure 3.22.



(a) (b)

Figure 3.22: *Fixing target point by (a) perpendicular offset (b) oblique offset*

Oblique offsets should be established at well-conditioned angles between 30˚ and 60˚ for accurate fixation of target points. A check line is measured to check the accuracy of the survey framework. The length of a check line (see Figure 3.23), as measured in the field should correspond with its length on a plotted survey framework.

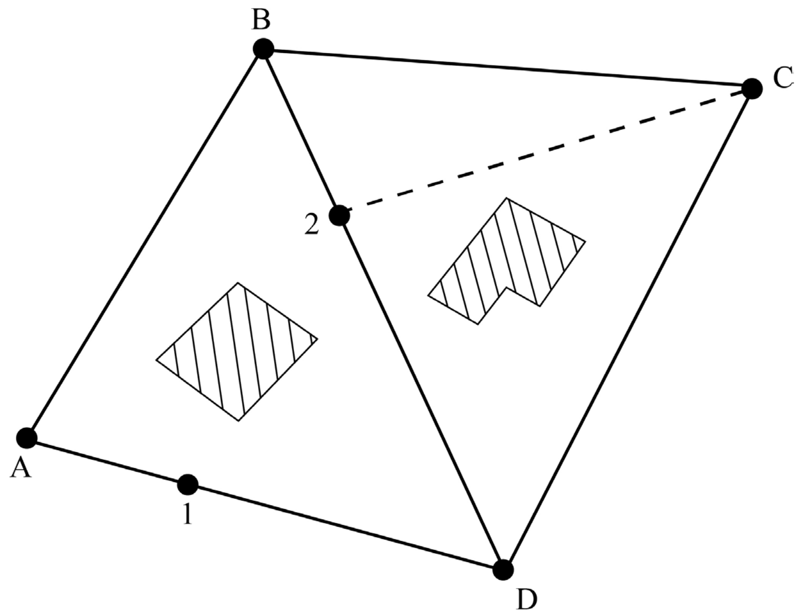


Figure 3.23: *A check line connecting points 2 and c*

In fixing target points as accurately as possible using chain/tape method, a surveyor should observe the following clues: use as few chain/tape lines as possible, avoid steep slopes and major obstacles, select one major line try to maintain triangle between 300 cm and 1200 cm, keep chain line shorter and take accurate measurements to simplify the surveying and minimize errors.

Activity 3.4

1. On a baseline established in your school compaund (in Activity 3.3), mark tie points where offsets to your target points will be taken.
2. Measure and record on field notebook the chainage from the first main station to each tie points.
3. Measure and record on field notebook offsets from tie points to target points.
4. Book the chainage (station) and offsets taken on survey line BC in Figure 3.18.

Folding and unfolding a chain/tape during field operation

In chain surveying, careful handling of equipment including folding and unfolding of chain/tape before and after a day's field work, is a career-based civilization. The practices do not only reduce risks of equipment damage, but also increases the life span of equipment and ensures accuracy and reliability in taking measurements. Unfolding a chain/tape must be done with great care. After removing the leather strap, both the handles should be held in the left hand and the chain should be thrown well forward with the right hand. The leader, then should take one handle of the chain and move forward until the chain is extended to its full length (Figure 3.24). The chain is then examined to see if there are any bent links. After a chain surveying work, the chain is folded into preservable bunch and fastened with a leather strap. To do this, the handles of the chain should be brought together by pulling the chain at the middle. Commencing from the middle, take two pairs of links at a time with the right hand and place them obliquely across the other in the left hand. When the chain is collected in a bundle which some what resembles a bundle of corn, it is tied with a leather strap.

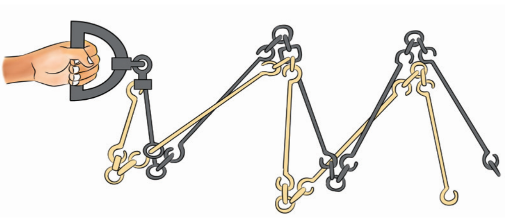


Figure 3.24: *Folding and unfolding of a chain at commencement and end of field chain surveying*

Plotting a chain survey

The presentation of the surveyed data according to their size and shape is termed as plotting. It is a representation of the booked survey details on a paper or suitable flat surface, to a suitable scale. Plotting is done based on survey details recorded in field notebook and it starts after completing a field-work. Transfer of booked chain surveying data into a paper aims at developing a plan or map of the surveyed area. Plotting chain surveying data involves three steps: determination of a suitable scale, plotting survey lines (framework) and plotting offsets.

(i) Determination of a suitable scale: plotting of survey data commences with determination of a suitable scale. The choice of scale depends on variables such as the importance of the work, the extent of survey and the paper size.

(ii) Plotting survey lines (framework): having determined the scale, plotting of survey lines follows. During this phase a base line, is first drawn in the appropriate position on the sheet. The positions of the intermediate survey stations are carefully scaled and marked with fine pencil dots. Other chain lines forming triangles with base line are plotted by describing short intersecting arcs with the lengths of their sides as radii. The accuracy of plotting of these triangles can be checked by fitting in the check lines. The whole framework must be plotted and checked before plotting of the details of chain lines commences.

(iii) Plotting offsets: this activity is done after plotting the main survey lines and may be done in two ways:

In the first method, chainage of perpendicular offsets are marked along the survey lines and their lengths are plotted at right angles. In plotting short offsets, perpendicular offsets may be estimated by eyes, but, for long offsets, pencil lines are drawn perpendicular to survey lines by set squares.

In the second method, a short scale, called an offset scale is used. An ordinary scale is laid parallel to the chain line such that the zero value of the offset scale coincides with the chain line. The chain ages can be read on an ordinary scale. The lengths of offsets are read on offset scale. The offset scale slides along the ordinary scale that is held by weights. The various offset lengths are pricked off rapidly. If the offset scale is graduated such that its zero division is at the centre of its length, the ordinary scale is laid down parallel to the chain line and at a distance equal to half the length of the offset scale so that the zero value of the offset scale coincides with the chain line. The offset scale may then slide to various chain ages. The offsets are marked on both sides of the chain line. Straight or curved lines join the plotted points as the case may be. It must be noted that changes in direction of the boundary occurs only at the end of offsets.

In whatever method one may chose, plotting chain surveying data demands equipment like scale ruler, square ruler protractor, T-square, pair of compasses, drawing board and drawing pins.

Activity 3.5

Plot chain surveying data recorded on a notebook during activity 3.4.

Calculation and correction of errors caused by incorrect chain length

Chains/tapes used in surveying are not manufactured to last forever. They wear-out in everyday of their use. Improper chain handling such as dragging through bushes, rocky surface and rough grounds, causes perturbations of the oval rings and bent of links, which elongates or shortens the chain. Lengths obtained by faulty chain are either too short or too long than the length that could be obtained by using standard chain. This means that, if a chain has its length increased and exceeds the standard length, the measured distance will be less. On the contrary, if the chain is shorter than the standard lengths, the measured distance will be more. The correction for faulty chain can be done through the following formula.

$$\text{True Length of a chainline} = \frac{L'}{L} \times \text{measured length}$$

Where:

L’ = Faulty length of a chain

L = True length of a chain

Example

In a process of chain surveying the school boundaries, a survey line was measured with a 30 m chain, and the total length found was 700.5 m. Unfortunately, when compared with the standard chain, the chain used in the measurement was found to be 0.5 m longer than the standard length. Determine the correct total length of the measured line.

To correct the faulty total chain lengths, the following procedures are followed:

Identification of True length (L) and faulty Length (L’)

L’ = 30 m + 0.5 m = 30.5

L = 30 m

The total measured length of chain line = 700.5

Therefore, the True length of a measured chain line = $\frac{L'}{L} \times$ Measured length of a chain line

$= \frac{30.5}{30} \times 700.5 = 712.175$ m

Therefore, the true length of a measured chain line = 712.175 m.

Sometime, in chain surveying it often happens that at the beginning of measurement, a chain length is correct but is damaged as the chaining process continues. In a scenario similar to that, a surveyor at Tambalang'ombe school had surveyed a distance of 1500 m by using the 30m chain. At the end of measurement, it was noted that the chain length was 0.40 m longer than the standard length. Again, after another 500 m, the surveyor detected that the chain was 0.30m longer than standard chain. To correct the faulty chain length, follow these procedures:

Identify chain length at commencement of 1500 m = 30 m

Identify chain length at the end of 1500 m = 30.40 m

Calculate the mean chain length while measuring

$1500 \text{ m} = \frac{30 + 30.40}{2} = 30.20 \text{ m}$

The True distance for 1500 m =

$\frac{30.2\text{m}}{30\,\text{m}} \times 1500\,\text{m} = 1510 \text{ m}$

Therefore, the true distance for the measured chain line of 1500m is 1510 m

The remaining distance = 500 m

The length of the chain at the end of 1500 m = 30.40 m

The mean length of the chain while measuring

$500 \text{ m} = \frac{30.40 \text{ m} + 30.30 \text{ m}}{2} = 30.35 \text{ m}$

The True distance of a measured chain line for 500 m $= \frac{30.35 \text{ m}}{30 \text{ m}} \times 500 = 505.83$

The exact length of a 2000 m chain line

$= 1510 \text{ m} + 505.83 \text{ m} = 2015.83 \text{ m}$

Activity 3. 6

A distance of 864 m was measured between point A and B using a 20 m chain, which was 0.08 m less than the standard length. Calculate the correct distance between points A and B.

Common errors encountered during chain survey process

There are number of causes of errors in the data obtained from chain surveying. Human source of errors out pace other sources including instrumental and environmental causes. Errors resulting from; improper arrangement of ranging poles, incorrect reading, misplacing decimal points, surveyors' negligence and inexperience leading improper set of instruments, use of incorrect unit of measurement, use of steel tape whose length varies with changes in temperature and use of out dated equipment lead to incorrect data acquisition and loss of resources including funds and time. However, the effects of environmental factors such as land obstacles, weather effects like wind and rainfalls and steep slopes on a land to be surveyed can be overcome.

Obstacles in chaining

It is common to be obstructed by barriers along survey line. These barriers could be of three categories: obstacles to chaining, obstacles to ranging, and obstacle to both ranging and chaining. Obstacles to chaining obstructs chaining but not ranging. That is the follower sees the leader but the distance cannot be measured, for example a pond. Obstacle to ranging obstructs ranging but not chaining, for example a rising groove like hill. Obstacles to both chaining and ranging are like intervening buildings such as a house this means that the ends of the chain are not inter visible and it is not possible to lay out a chain between the two points. Reciprocal ranging as described in the next paragraph, however, can control these barriers.

Avoiding an obstacle to ranging by reciprocal ranging

Reciprocal ranging is done when ends of a survey line are not inter visible due to an intervening hill or ends of survey line are far distance apart. Consider A and B as two survey stations along which chain survey is to be conducted. They are not mutually visible due to high ground between them, yet the measurement has been recorded. Towards making sure the actual distance between the stations which are not inter visible is obtained, a surveyor, first erects a ranging rod tall enough to be seen from another temporary point that is established on the hill or any other barring feature. In Figure 3.25, the chain man established point A and D along the survey line and erected ranging rods on both ends. Then a chain man at point A goes up hill and establishes station B and C. The Point B and C are established in such a way that B can see C and D clearly while C can clearly see B and A.

Having points B and C established, the chain man at B instructs C to shift to C1 so that C1 align straightly with D and that C can see both C1 and D clearly. Then, again C1 instructs B to shift to B1 so that A, B1 and C1 are visibly aligned in one straight line. The practice continues as B1 instructs C1 to shift to C2 so that B1, C2 and D are visibly aligned. C2 then tells B1 to shift to B2 so that C2, B2 and A are aligned. The procedure continues as C2 shifted to C3 so that A, B2, C3 and D are in one line that can easily be measured. The finalisation of this ranging will lead to the establishment of lateral stations A, B2, C3 and D, right or left of the barrier. A chain surveyor then stretches or drag the chain from station A through B2, C3 to D and takes the intended measurement as illustrated in Figure 3.25.

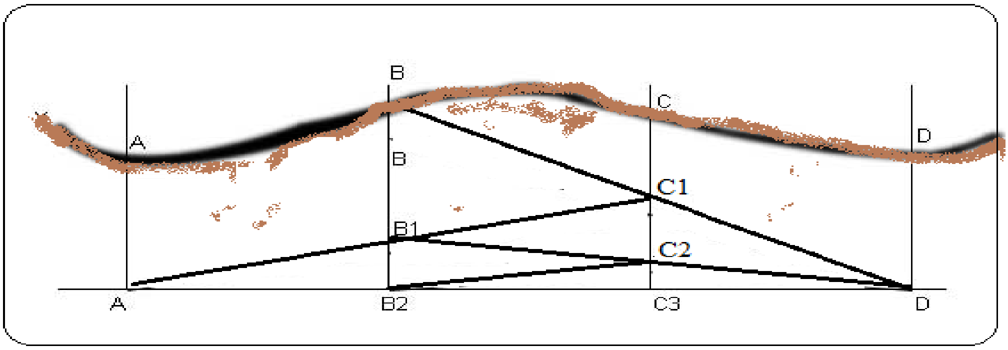


Figure 3.25: *Reciprocal chaining*

Avoiding obstacles to chaining

On either side of obstacles, measurement are required to avoid obstacles to chaining. With the kind of obstacles being at our face towards the chain line, the following two situations usually a rise: (i) It is not possible to chain round the obstacle or (ii) it is possible to chain round the obstacle. In the case when chaining round the obstacle is possible, the nature of the obstacle and the terrain around the obstacle can dictate the type of a method to be employed. Some methods likely to fit include the rectangle method, triangle method specifically right-angled triangle method, and similar triangle method.

Chaining around an obstacle by rectangle method

In rectangle method, a chain man must understand how to establish perpendicular lines with or without ready-made equipment. For example, to determine the distance C to D along the chain line *AB* shown in Figure 3.26, establish two perpendiculars *CE* and *DF* of equal lengths on the same side on either side of the obstruction. Measure the distance between E and F, that equals to the desired length of *CD*. *Thus, distance AB* $(\text{AB}) = \overline{\text{AC}} + \overline{\text{EF}} + \overline{\text{DB}}$.

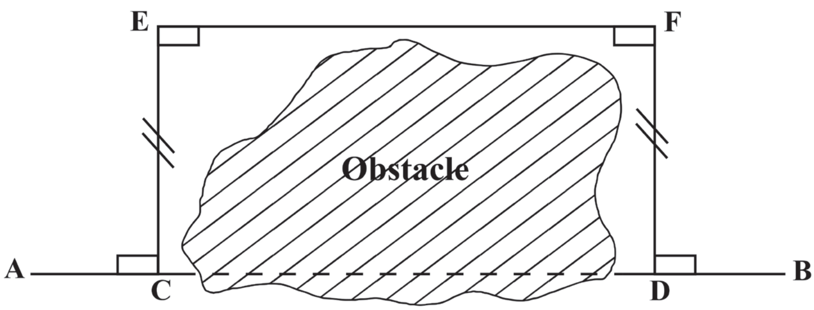


Figure 3.26: *Avoiding an obstacle by rectangle method*

Chaining avoiding obstacle by triangle method

Right-angled triangle method typically applies a Pythagoras theorem. To determine the distance obstructed by an obstacle in figure 3.27, in the first step establish a perpendicular *CE* longer enough to avoid the obstruction. Make sure $A\hat{C}E$ is an accurately measured right angle. Measure both *CE* and *BE* accurately (Figure 3.27).

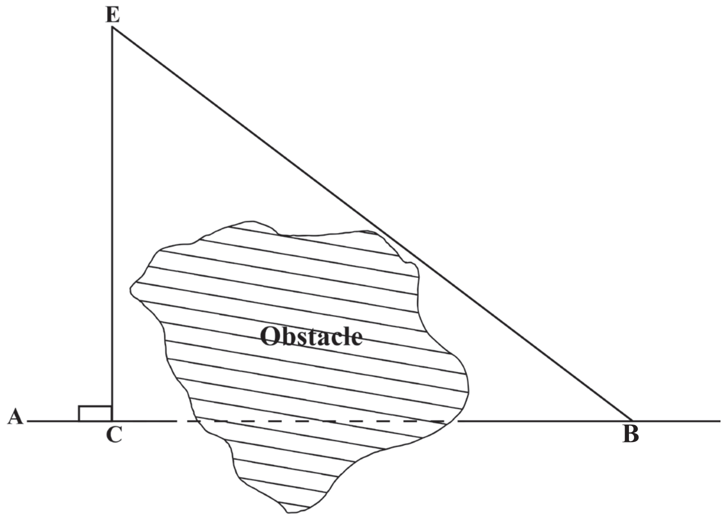


Figure 3.27: *Avoiding obstacles and triangle methods*

Similarly, the same obstacle can be avoided by taking right angle triangle of 90° at another position. You should note that, using a right-angle construction method in avoiding obstacles, a chain surveyor can establish a right angle at point C or E see figure 3.27). On either side of the obstacle, for example at point E (see figure 3.28) as it may be found convenient.

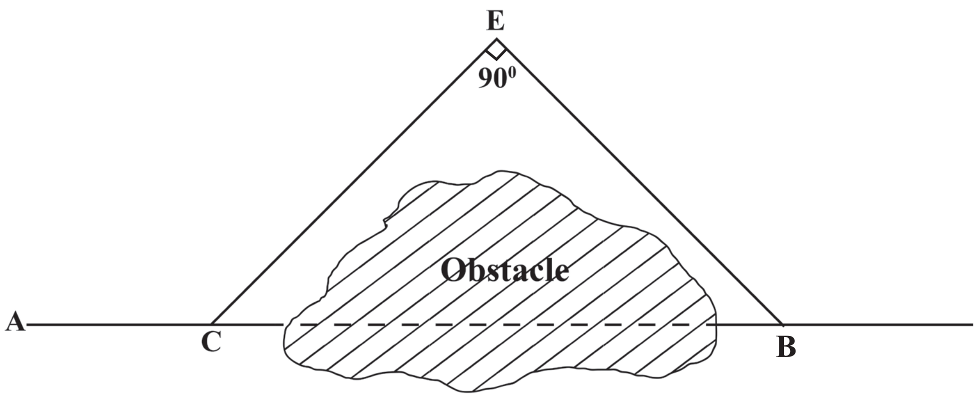


Figure 3.28: *Avoiding an obstacle by triangle method with right angle on either side of the obstacle*

After establishing point E on either side of the obstacle, measure distance $\overline{CE}$ and $\overline{EB}$. Using pythagoras theorem, distance $\overline{CB} = \sqrt{\overline{CE}^2 + \overline{EB}^2}$. Thus, distance $\overline{AB} = \overline{AC} + \overline{CB}$

Chaining across the obstacle by similar triangle method

Consider a river obstacle shown in Figure 3.29. The chain line *AB* is crossing a river. A surveyor can overcome river obstruction by, first establishing stations C and D as shown in Figure 3.29. Then, the surveyor fixes poles at C and D and sets out the right angle at C. From the established point C, a surveyor establishes a convenient perpendicular line to station E and measures distance CO and EO.

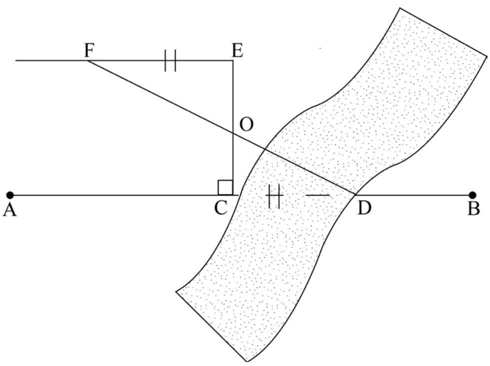


Figure 3. 29: *Avoiding obstacles by similar triangle method*

A chain surveyor should then establish a line joining station E and F, which is perpendicular to line CE and parallel to line AB. Point F is at a position such that a line joining it with point D crosses point O. A distance between station E and F is then measured. Since EF is parallel to line AB and lines CD and FD are shared by triangle COD and OEF in figure 3.29, the two triangles are similar. Thus distance CD is calculated as CD = CO/EO x EF.

Avoiding obstacle to both chaining and ranging

When both chaining and ranging are obstructed, a rectangle method, also refered to as "parallel diversion" method explained in Figure 3.26 may be adopted.

Exercise 3.1

1. What is chain surveying?
2. Explain the procedures to check if the chain contains errors.
3. A distance of 250 m was measured between location P and Q using a chain of 0.05 m longer than the standard length of 30 m. Calculate the distance between the two locations.
4. What is a baseline?
5. With the aid of the diagram, describe perpendicular and oblique offsets.
6. Distinguish between the following terms as applied in surveying;

(a) Baseline and check line

(b) Main station and tie station

(c) Geodetic survey and plane table survey

4. State the function(s) of the following instruments; (a) Chain/ tape (b) Ranging rod (c) Cross staff (d) Arrow.

5. Show how you would use the right angled, rectangle and similar triangle chaining methods to avoid obstacle during chaining.

Compass surveying

The compass surveying involves fixing of an object's position in the field by measuring the angles of bearings between the line of magnetic North (0°) and the line of sight to the object (Figure 3.30). This section exposes readers into concepts related to compass survey. Geography students especially of survey class must adopt some important personalities necessary for theoretical and practical studies through learning to check for the equipment's condition, handling them with care and wearing proper field-dress. Concepts covered in this section are history of compass surveying, types of compass, compass bearing, compass traversing, local attraction, closing error adjustments, intersection method, and resection method.

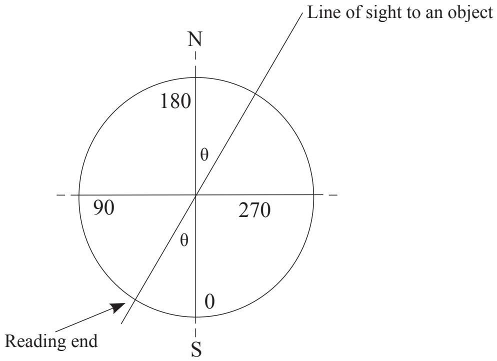


Figure 3.30: *Measuring angle by compass*

Concept of compass surveying

Compass surveying is commonly employed when the land area to be surveyed is comparatively larger than area covered in chain surveying. Compared to chain, compass surveying is suitable for rough landscapes. Compasses for land surveying originated from a Chinese 'iron-attracting mineral (lodestone) and have been in use since 400 years BC (Figure 3.31). Ancient Chinese suspended the lodestone with their hands or on boats and other navigation facilities to help them point 'south'. The use of lodestone as a compass to point to the south gave birth to its names such as "***South-governor***" and "***South-pointing-fish***". Swinging of the lodestone, the south governor, or the *south-pointing fish* as they called it to point the south, then became the origin of the today's compass used in survey.

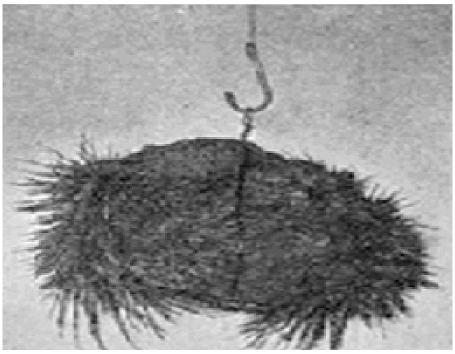


Figure 3.31: *Lodestone*

Types of compass survey

There are two major types of compass surveys which are the prismatic and surveyor's compasses. The compasses are differentiated by key features including; their body size, the bearing system they use to designate readings, and their mode of formation.

Surveyor's compass

A surveyor's compass is an old form of compass used by surveyors which is similar to the prismatic compass but with few modifications. It is used to determine the magnetic bearing of a given line. The instrument has commonly been referred to as the *Circumferentor*. Surveyor's compass is larger and more accurate than prismatic compasses and designated to read bearings in quadrant bearing system (QBS) as shown in Figure 3.32.

Figure 3.32: *Surveyor's compass*

Prismatic compass

This is a non-magnetic metal case with a graduated ring and glass top used for determining angles, bearings and direction to objects of surveyor's interest. It is a small, hand-held device in a circular box of about 100 mm in diameter used in fixing objects in the field and from which the angle of bearing is measured between the line of magnetic north and the line of sight to the object. It is usually used for surveying works that do not require very high accuracy. For example preliminary survey for minerals exploration.

The morphology of prismatic compass can be identified by its elements. Its cylindrical metal box, lifting pin and lifting lever, magnetic needle, graduated circle or ring, prism, object vane, eye vane, glass cover, sunglasses, reflecting mirror, and spring brake pin. Prismatic compass is a cylindrical metal box with a graduated ring supported by pivot at its center. Provided just below the sight vane is lifting pin and lifting lever which assist in pressing the lifting pin when a sight vane is folded. The lifting pin with the help of lifting lever lifts the magnetic needle out of pivot point to prevent damage to the pivot head. The magnetic needle of a prismatic compass is a core part of the instrument. It is attached to the graduated aluminum ring marked in degrees from 0˚ to 360˚. It measures bearings of lines from magnetic meridian. The needle that always points towards north-south pole at its two ends when freely suspended (Figure 3.33) measures angles to the objects.

Figure 3.33: *Prismatic compass*

Another important element in the prismatic compass is prism. This is why the technique is termed as prismatic compass. A prism assists surveyors to read graduations on graduated compass ring and to take the exact degree values. The prism is made up of a hole called prism hole. The prism hole is protected by prism cap to protect it from dust and moisture. The eye vane provided with an eye hole and the top glass to protect the ring, complements the operations of other compass parts such as sun glasses, reflecting mirror and spring brake.

Designation of compass bearing

There are two types of bearing designations. They include Quadrant Bearing System (QBS) and Whole Circle Bearing system (WCB). In QBS, the bearing of survey lines is measured from either north line or south line whichever is the nearest to the given survey line. The bearing readings can be done clockwise or anti-clockwise. Bearings in QBS range from 0° to 90°. The NORTH and SOUTH poles are designated by 0° while WEST and EAST are designated by 90°. In QBS, the angular value is preceded by a prefix N or S and followed by a suffix E or W based on its quadrant. For example, an angle of 45° magnitude measured from North towards East, which is in first quadrant is written as N 45° E. In WCB designation, bearings are measured clockwise from North direction and range from 0° to 360°. Bearing in QBS are WCB are also refered to as bearing and azimuth, respectively.

Compass survey by traverse method

The term traverse is used to refer to a series of connected lines of known lengths related to one another by known angles. There are two types of traverses namely; the *open traverse* and *closed traverse*. When a series of connected lines forms a closed circuit, it is called ‘closed traverse. In closed traverse, reading and taking of bearings or azimuth starts and ends at the same station as shown in Figure 3.34(a). On the contrary, when the survey lines start from one point and end at another point which is not the starting point, this is known as open traverse as shown the Figure 3.34(b).

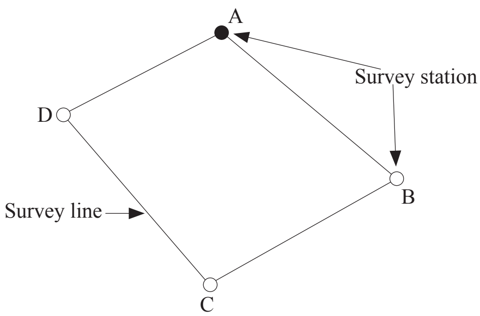


Figure 3. 34 *(a) closed traverse*

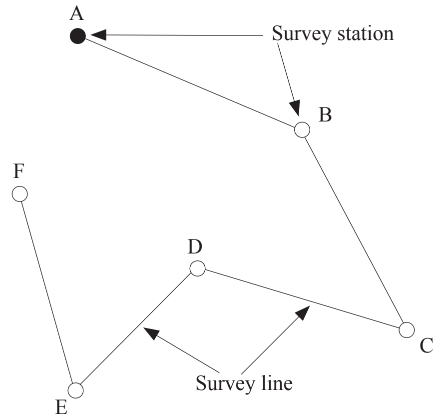


Figure 3.34 *(b) open traverse*

Reference meridians

A bearing is horizontal angle which is made with reference to a particular line called meridian to line of sight. Basing on the meridian, a surveyor chooses the reference. There are four types of meridians; the true meridian; magnetic meridian, grid meridian and arbitrary meridians. True bearing of a line is the horizontal angle between the true meridian and the line of sight. It is also defined as the line along the earth's surface connecting the North and south poles. The true North is also called geodetic north, the true meridian or North as frequently referred to by geographers, is different from the magnetic north which is the direction pointed by the compass, and it is different from the grid north which is in the direction along the grid lines towards the north. The true bearing is measured from the true north in the clockwise direction (Figure 3.35).

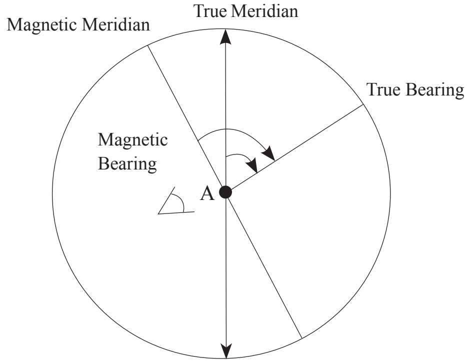


Figure 3.35: *Magnetic variations*

The magnetic bearing on the other hand refers to the horizontal angle which the line of sight meets with the magnetic north. It is the direction which is pointed by the compass needle in response to the earth's magnetic field. The deviation between the true north and the magnetic north varies from place to place as the earth's magnetic poles are not fixed with respect to its axis. The earth's magnetic poles are not aligned to the actual geographic north and south poles. Instead, the magnetic South Pole is in Canada which is in the north while the magnetic north pole lies in Antarctica which is in the south. The magnetic poles are inclined by about 10 degrees to the earth's rotational axis (Figure 3.36).

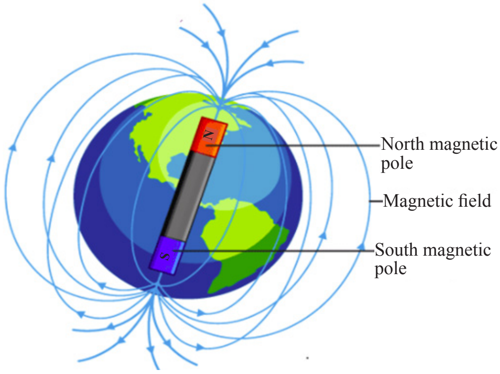


Figure 3.36: *Distribution of earth's magnetism*

Grid bearing means horizontal angle and the line of sight AB to an object meets with the grid meridian. An arbitrary bearing is the horizontal angle between the line of sight AB and any arbitrary meridian established. An arbitrary meridian serves as temporary north whose magnetic or true bearing could later be determined. The meridians, also termed as Norths that is, *Magnetic North, True North, Arbitrary North* and *Grid North*, are major reference points in compass surveying.

Back and forward bearing

In prismatic compass survey, a survey line can be defined by two bearings, the forward bearing which is taken from one station to the other in the direction of a survey and back bearing which is taken in the opposite direction of the survey direction. Both bearings are expressed in whole circle bearing (WCB). The forward and back bearing in WCB differs by 180°. That is, the bearing (α) of the line *AB* in the survey direction from *A* to *B* is a forward bearing whereas the bearing (B) of the line *AB* in opposite to the survey direction from B to A, is a back bearing (β) (Figure 3.37).

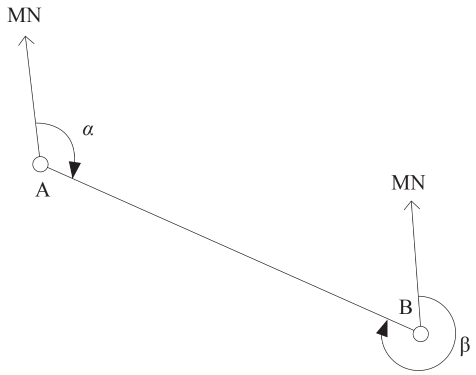


Figure 3.37: *Forward (α) and back (β)bearing*

This means, if the forward bearing is greater than 180°, then subtract 180° to get back bearing and when the forward bearing (FB) is less than 180^0, add 180^0 to get back bearing (BB). However, it must be noted that, this can only be meaningful when checking the accuracy of the data collected from the field. In the field, the FB and BB must be measured for each survey line.

By the formula:

$$FB = BB \pm 180^0$$

$$\text{and } BB = FB \pm 180^0$$

Field procedures for compass survey by traverse method

1. Prepare all necessary equipment for the prismatic compass survey. Important equipment includes: Prismatic compass, chain or tape, ranging rod or poles, tripod stand

if available, field note book and other drawing materials like rubber and pencils. Do not dress or carry metal material during the compass surveying. Iron materials like a bunch of keys, ear and finger rings, watch, metal frame or rimmed eyes glasses can interfere with the compass readings and there after provide incorrect readings.

2. Establish stations through which your traverse will be carried out. For example, in Figure 3.38 stations A, B, C, D, and F are established at farm corner points.

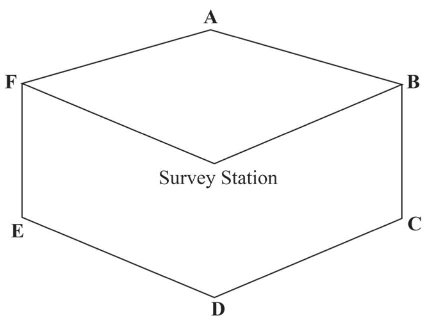


Figure 3.38: *Corner points of a farm to be surveyed*

Prismatic compass surveying has important preliminary procedures to be considered before the actual field practice is carried out. Any attempt to ignore them can lead to erroneous reading of the bearings. Therefore, adjustment of a prismatic compass before any activity is conducted is necessary. Two types of adjustment can be done; Temporary and permanent adjustments.

a) *Temporary adjustment*

A prismatic compass needs to be adjusted at every station. The adjustments of an instrument required to be made at every set up of the instrument are known as *temporary* or *Station Adjustment.* On the contrary, adjustments which are made only if the fundamental relations between the various parts of a compass, are disturbed due to careless handling or otherwise, are called *permanent adjustments.* Temporary adjustments include the following operations:

(i) *Centering the compass;* this is a setting of a compass at its center over the ground station mark. It involves making the pivot exactly vertical over the ground station mark. A station mark can be a boundary beacon or a brick established for that purpose. Centering is done by adjusting the legs of the tripod. To ensure a compass is on top of the starting point, a plumb bob is hunged from the centre of the circular box, to define a vertical line. If no plumb bob is provided, the centering may be judged by dropping a small pebble freely from the centre of the bottom of the circular box. If the compass is centred perfectly, the pebble will fall exactly over the ground station mark.

(ii) *Levelling;* is the other adjustment which involves the setting of the compass horizontally such that its graduated ring swings freely. Levelling of a compass can be done by the level specially made for that purpose or estimated by eye. Generally, the compass is provided with a *ball and socket* arrangement attached to

the tripod for achieving quick levelling of the instrument. In surveyor's compass two plate levels at right angles to each other, are sometimes provided. The ball and socket arrangement is adjusted till the two bubbles remain central in both plate levels.

(iii) *Focusing the prism:* The process of moving up or down the prism for obtaining the figures and graduations sharply and clearly, is called *focusing the prism*. This adjustment is for prismatic compass only.

(b) Permanent adjustments: on the other hand, are the permanent setups of instrument damaged or its parts disturbed by surveyors' careless handling or unfortunate dropping. It involves adjusting the plate level, sight vane, magnetic needle and pivot.

Other survey methods for fixing objects and lines during prismatic survey

Fixing object or line of survey in prismatic compass survey can be done by methods other than traversing. A detail in prismatic survey can be positioned by *intersection* and *resection* methods. Just bear in mind that the intention of the whole process in surveying is to tell the where-about of some geographical features. One way of identifying location of the intended objects in relation to other nearby permanent objects is through prismatic compass survey.

3. Set a compass over station **A** perform temporary adjustment and take a forward bearing to B. Then, shift the instrument to station B and read the back bearing to A to check for angular error. Then measure a distance between the station **A** and **B** and record all measurement in the field note book.
4. Continue taking forward and back bearings and measuring distances for all remaining stations (Figure 3.39).

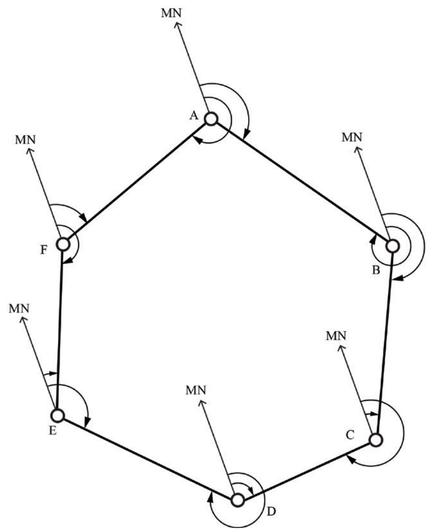


Figure 3.39: *Clockwise reading of forward (blue arrows)and back bearing (black arrows)*

5. Correct the observed field data for any error. Correction for the error can be done in two ways: graphically and mathematically. However, in this chapter the focus will be on the graphical methods. In the graphical method, the data should be plotted and if there are some errors, the traverse will not close. That is, the last survey line will not join the station where a survey started (Figure 3.40).

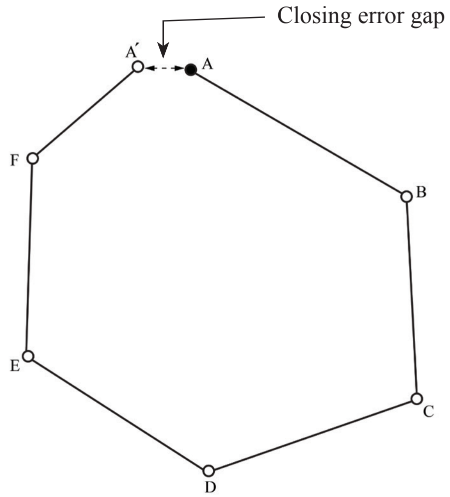


Figure 3.40: *Traverse closing error gap between A' and A*

Graphical correction of traverse closing error

Commonly, the north end of a freely suspended magnetic needle of compass always points to the magnetic north, if it is not influenced by any other external forces except the earth's magnetic field. Sometimes, the magnetic needle gets deflected from its normal position, if a compass survey is carried near magnetic rocks, iron ores, cables carrying current or iron electric poles. Those forces disturbing compass needle are called '*Local attraction*'. Prismatic compass is therefore not reliable in areas with these characteristics, unless these are checked against the presence of local attraction at each station and their elimination.

The presence of local attraction at any station may be detected by calculating forward and back bearings of the line to see if the difference between them is 180°. If checked and found that the difference between forward and back bearings is 180°, then both end stations are free from local attraction. If not, the discrepancy maybe due to;

(i) An error in observation of either forward or back bearings or both for example, not holding the comps steadily at 180^0 when taking bearings.

(ii) Presence of local attraction at either station or around.

(iii) Presence of local attraction at both stations.

(iv) Slugging pivot or needle.

Local attraction at any station affects all the magnetic bearings by an equal amount and therefore, the included angles deduced from the affected bearings are always correct. In case, the forward and back bearings of lines of traverse differ by the permissible error of reading, the mean value of the bearings of the line least affected, may be accepted. The correction to other stations may be made according to the following methods: graphical method based on local attraction are graphical method based on Bowditch rule.

Graphical method based on local attraction

Graphical method based on local attraction involves calculation of error due to local attraction at each station while graphical method based on Bowditch rule does not involve calculations. The procedures for correcting errors due to local attraction are illustrated based on traverse data presented in Table 3.1

(i) Plot a traverse framework from uncorrected data presented in Table 3.1 (Figure 3.41).

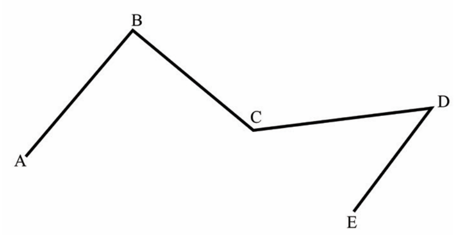


Figure 3.41: *Uncorrected traverse ABCDE*

(ii) Correct the forward and back bearings observed in traverse ABCDE shown in Table 3.1.

In correcting data provided in Table 3.1, use the formula FB = BB ± 180º to check for bearing error in each line. For example, in line AB, BB −180° = 226° −180° = 46° which is greater than the measured FB by 1°. Thus, 1° is the bearing error due to local attraction in line AB. Continue determining errors in the remaining lines. Then, choose a leg not affected or least affected and investigate from there a leg or legs which are affected by local attraction causing the discrepancy. Then correct each affected leg by adding or subtracting the error. If the observed bearing of a line is more greater than the calculated bearing, the error is subtracted and vice versa.

Table 3. 1: *Errors due to local attraction in open traverse ABCDE*

Station	Length (m)	Observed FB	Observed BB	Calculated FB	Error
AB	30	45°	226°	46°	+1°
BC	55	135°	316°	136°	+1°
CD	50	90°	270°	90°	0
DE	75	225°	45°	225°	0

In this example, the difference between the forward and back bearings for lines CD and DE is 0, which means lines CD and DE are not affected by local attraction. Thus, the correction is done for forward and back bearing observed at stations D and E. Since point C is free from local attraction, errors in line BC are due to local attraction at point B.

Table 3. 2: *Corrected forward and back bearing in traverse ABCDE.*

Line	Length (m)	Observe bearing		Error	Corrected bearings	
		FB	BB		FB	BB
AB	30	45°	226°	+1°	46°	226°
BC	55	135°	316°	+1°	136°	316°
CD	50	90°	270°	0°	90°	270°
DE	75	225°	45°	0°	225°	45°

(iii) Then on the first plot of uncorrected angle, plot the traverse using the corrected bearing and observed distance from Table 3.2 using a protractor and a ruler. For example, line 'bc' is drawn from point C using corrected back bearing and length of line BC. Line ab is drawn from point B using the corrected back bearing and length of line AB. Thus, the correct plot of a traverse is the one presented with lower case letters from 'a' to 'e'. Lines 'cd' and 'de' coincide with lines CD and DE, respectively, as points C, D and E are free from local attraction (Figure 3.42).

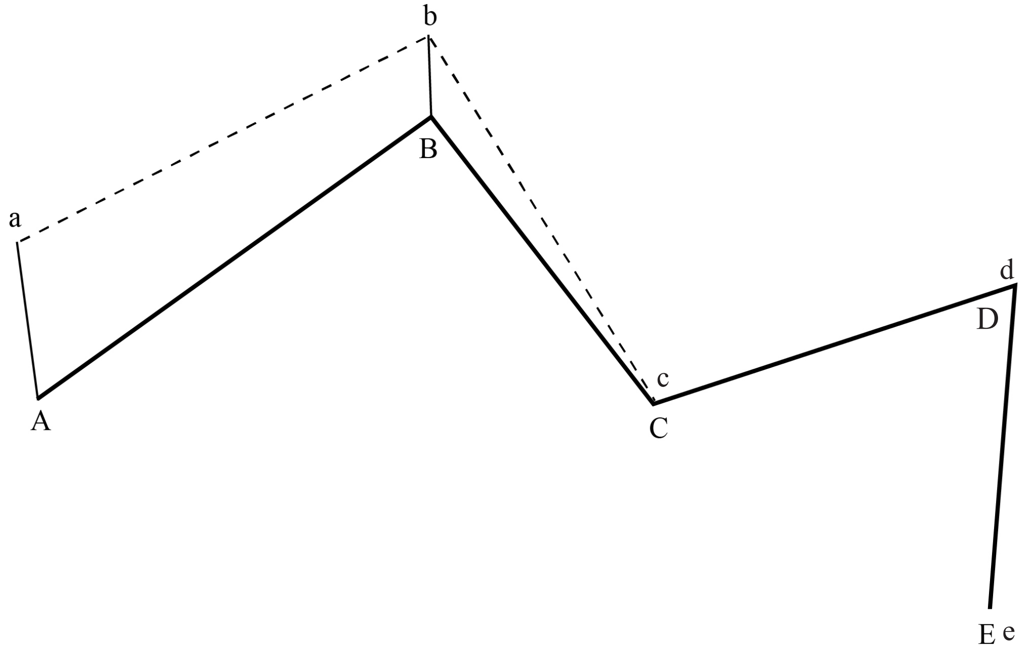


Figure 3.42: *Error correction in open traverse ABCDE based on local attraction*

Activity 3.7

Correct the forward and back bearings provided in Table 3.3 for open traverse PQRST.

Observed bearings in open traverse PQRST

Bearing/Traverse line	PQ	QR	RS	ST
FB	60°	115°	45°	78°
BB	241°	295°	226°	260°

Graphical method based on Bowditch rule

Is at the same level as graphical method by local attraction. In case of a closed traverse ABCDEA in Figure 3.43, the following procedures could be followed after plotting the traverse using the observed bearings and distances.

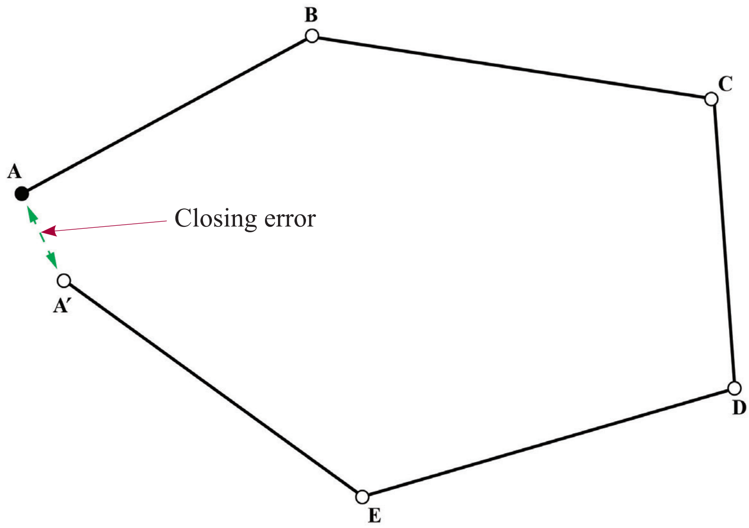


Figure 3.43: *Closing error in traverse ABCDEA*

1. First measure the misclosure of a traverse by ruler and record. Let's assume the gap is 1.5cm.

2. Draw a horizontal line (AA') of a length, which equals to the total length of the traverse and mark the position of traverse stations B, C, D, E, A' to scale. Assuming the length of line AB = 40 m, BC = 60 m, CD = 50 m DE = 60 m and EA = 30 m, at a scale of 1:10, the position of stations B, C, D, E, and A' are at 4 cm, 10 cm, 15 cm, 21 cm, and 23 cm from station A, respectively (Figure 3.43).

3. At point A' on the horizontal line draw a vertical line to point 'a' at a distance which equals the measured misclosure, the 1.5 cm to a scale used to plot the uncorrected traverse in Figure 3.44. Then draw a line connecting station A on horizontal line AA' and on vertical line A'a . At stations B, C, D, and E, draw vertical lines connecting points b, c, d, and e on line Aa, respectively (Figure 3.44).

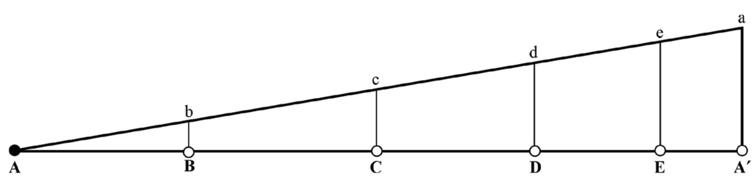


Figure 3.44: *Horizontal line AA' and vertical lines Bb, Cc, Dd, Ee and A'a.*

4. Measure the lengths of vertical lines Aa; Bb; Cc, Dd and Ee. Then, on a plotted uncorrected traverse draw a line parallel to line A'A at station B and mark the position of station 'b' along that line. Do the same at stations C, D, and E. Finally draw a dotted line connecting points A, b, c, d, e and A to show the corrected traverse (Figure 3.45).

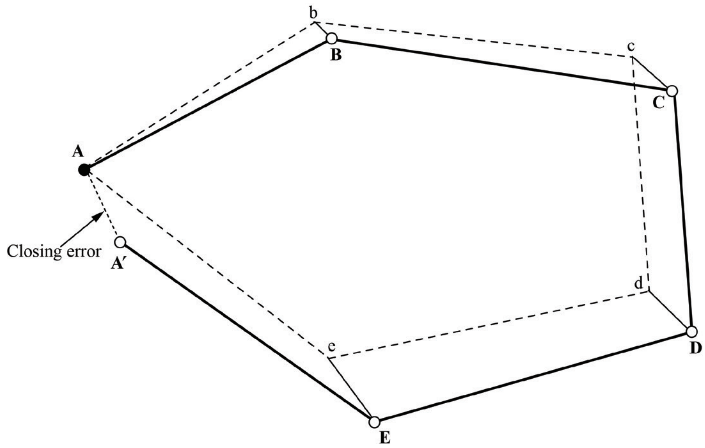


Figure 3.45: *Original traverse ABCDA' and corrected traverse A b c d e A.*

Compass survey by intersection method

In intersection method, a point where two lines meet is determined. Thus, intersection is a method of fixing the position of object relative to two or more points of known positions. It is a method that locate points of intersection by taking forward bearing from two or more fixed points. The procedure followed in intersection methods are:

(i) From two known points, say C and D, for instance, take forward bearing to point X that you want to locate on a map (Figure 3.46).

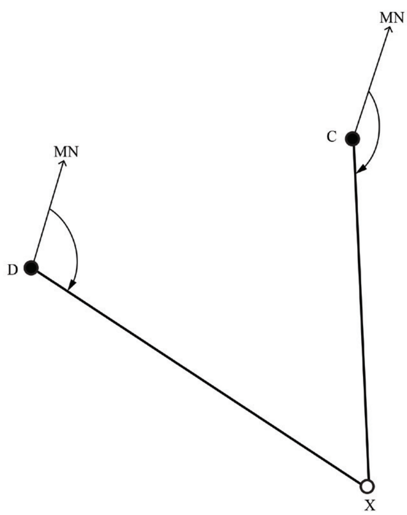


Figure 3.46: *Fixing objects by intersection*

(ii) Check the accuracy of the forward bearing from points C and D to point X by taking forward and back bearing of line CD;

(iii) Lastly convert all magnetic bearings to true bearing; and

(iv) On a map, draw a line parallel to true north at point C and D. Then, using a protractor mark the direction (basing) of lines CX and DX, and extend these lines until they cross to work position of point X.

Compass survey by resection method

Resection differs from intersection since, instead of setting a compass at known points, you set the compass at the unknown points, for example station Y. Thus, forward bearing are read from station Y to points or features of known map locations (Figure 3.47).

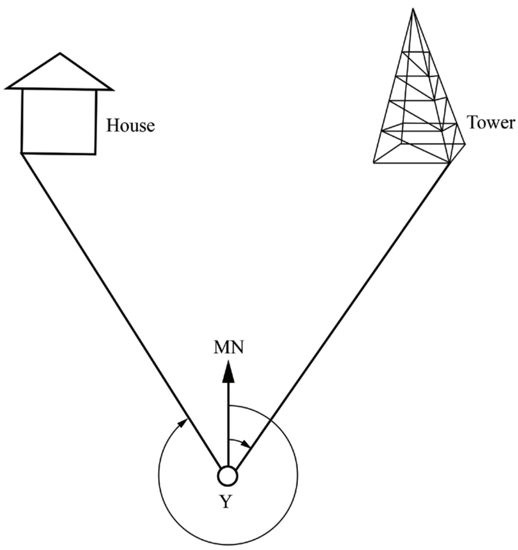


Figure 3.47: *Fixing objects by resection method*

Procedures for resection are:

(i) Set a compass at unknown station Y and perform all temporary adjustment;

(ii) Take forward bearings from point Y to two or more known points. Do not record a car or animal as an object to fix your point (tower and house). Animals and cars are mobile and therefore cannot be shown on the map;

(iii) Then convert all magnetic bearing to the fixed point you have chosen into true bearing;

(iv) To fix point Y on a map, calculate the back bearings from the forward bearing obtained in step (ii) above. Then, on a map where the location of a house and mobile tower in Figure 3.45, draw a fine pencil line parallel to true north at the chosen objects, in this case, a house and a mobile tower; and

(v) Measure the respective true back bearing calculated in step (iii) at the two chosen objects and extend these lines until they cross each other to mark the position of point Y.

Plotting of prismatic compass field data

Field surveying of all types targets at extracting important information that can be communicated in a manner that every user can understand. Information obtained in compass surveying is recorded in field note books. Notebooks contain information which is not easy to be understood by common users. They are short hand, sometimes roughly written and peculiar to the surveyor only, (Figure 3.48).

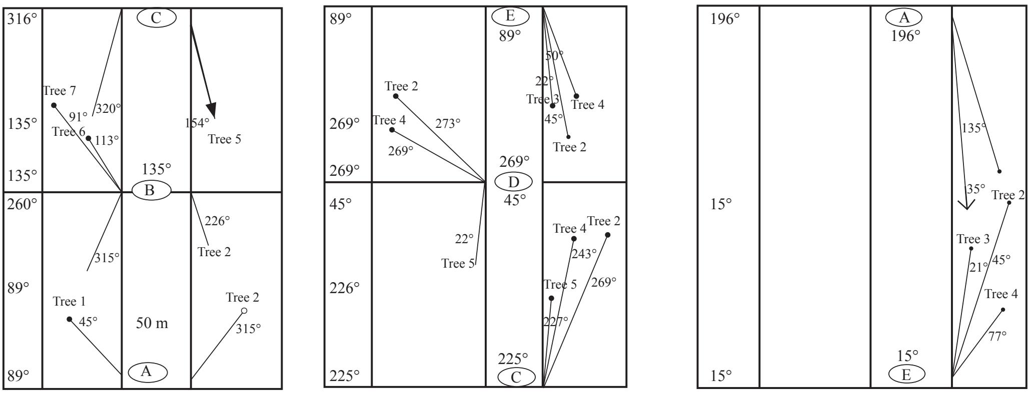


Figure 3.48: *Compass survey data recorded on field notebook.*

From the field, surveyors collected data and booked as seen in Figure 3.48. After the collection and booking of survey data, plotting follows. Plotting is therefore a transferring of the data from the field notebooks into graphical representation that can easily be understood and implemented. In plotting compass data, the following procedures are followed:

(i) Prepare necessary materials for drawing a ruler, pencil, eraser and protractor are important facilities in plotting.

(ii) Check whether the observed bearings are correct or not. If any attraction is detected correct them.

(iii) Convert all magnetic bearing into true bearings.

(iv) Plot the true forward bearings and measured distance to scale of your choice.

After the work, the surveyor produces a plan as shown in Figure 3.49.

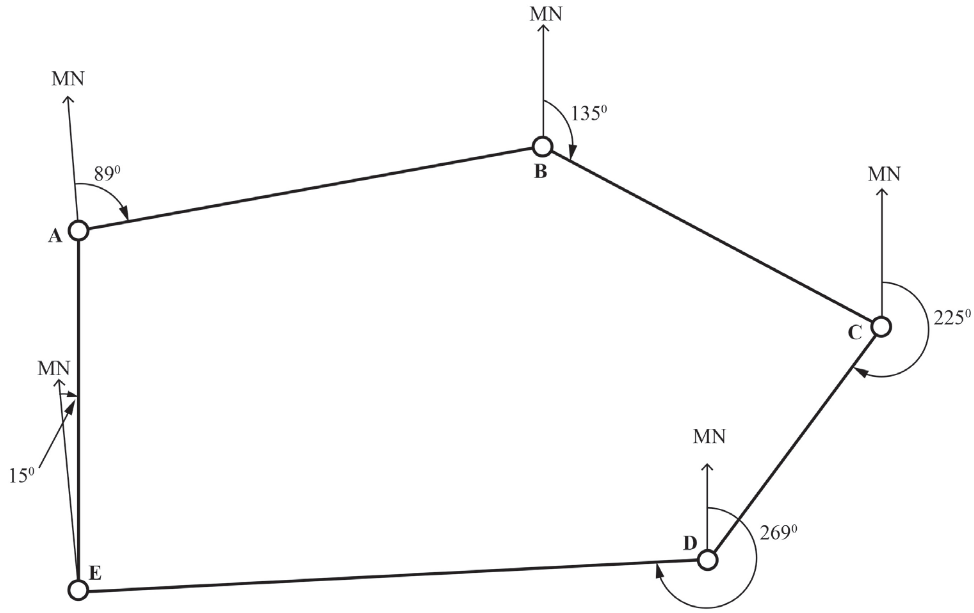


Figure 3.49: *Plot of field data*

Activity 3.8

1. Use the following back and forward bearings obtained for different framework lines ABCDE to answer the following question;

   (a) Identify traverse station with discrepancies.

   (b) Correct error if any discrepancy is observed.

   (c) Plot traverse ABCDE from the observed and corrected bearings

Bearings of a traverse ABCDE

Line	Distance (m)	FB	BB
AB	40 m	60°	240°
BC	60 m	120°	300°
CD	100 m	210°	30°
DE	140 m	317°	135°

2. Carefully study the data of a traverse ABCDEA presented and answer the questions that follows:

   Bearings of a traverse ABCDEA

Line	Distance (m)	FB	BB
AB	900	265°	085°
BC	700	350°	173°
CD	700	070°	250°
DE	900	110°	290°
EA	800	250°	070°

(a) Identify stations with errors in taking bearings and suggested associated causes.

(b) Plot the traverse using measured bearings at a suitable scale on A_4 paper.

(c) Correct errors using graphical method.

Earth's magnetic field

Earth's magnetism is a result of the convection currents of molten iron and nickel in the earth's core. These currents carry streams of charged particles and generate magnetic fields. These magnetic fields deflect ionising charged particles from the sun (called solar wind) and prevent them from entering our atmosphere. Without preventing this magnetic shield, the solar wind could have slowly destroyed our life on earth. Mars does not have a strong atmosphere that can sustain life because it does not have a magnetic field protecting it. The earth's magnetic field has three components that govern its magnitude and direction; namely: magnetic declination, magnetic inclination or the angle of dip and the horizontal component.

Magnetic declination

Geography students must understand that the horizontal angle between true north and magnetic north at a place and at a time of observation is what we term as *magnetic declination.* The angle of convergence between the true north and magnetic north at any place does not remain constant. It depends on the direction of the magnetic meridian at the time of observation. If the magnetic meridian is on the eastern side of true meridian, the angle of declination is called the *eastern declination* or *positive declination.* On the other hand, if the magnetic meridian is on western side, the declination angle is called the *western declination* or *negative declination.* When both true North and magnetic meridians coincide, magnetic declination is zero.

The imaginary lines joining the places of equal declination either positive or negative, on the surface of the earth, are called *"Isogonic lines"*. As the earth magnetism is not regular and the intensity of its magnetic field also varies, the isogonic lines do not form complete circles but these follow irregular paths. The isogonic lines with zero declination, are known as "*Agonic lines*".

Determination of magnetic declination/ variation

True meridians and compass observations are important inputs in determining magnetic declination of any place. True meridians in many places are determined by making astronomical observations, especially to stars. Compass observations are made by sighting of the true meridians at the places. The angle of inclination between the true meridian and the magnetic meridian given by a compass reading is the desired magnetic declination that can be determined as the difference between the true bearing and the magnetic bearing. Therefore; magnetic declination = True bearing - Magnetic bearing. For instance, if the true and magnetic bearings of a line are 78° 45' and 75° 30' respectively. Use negative sign for eastern declination and positive sign for western declination. As shown in Figure 3.50, therefore the Magnetic Declination (MD) = 78°45' − 75°30' = 3°15'. Having determined the magnetic bearing of a line and the magnetic declination at that place, true bearing of the line, may be calculated from the formula: true bearing = magnetic bearing ± magnetic declination. Similarly, to calculate magnetic bearing, we must be sure that we have calculated true bearing of a line and magnetic declination of that place. This formula can therefore be used:

Magnetic bearing = True bearing ± Magnetic declination

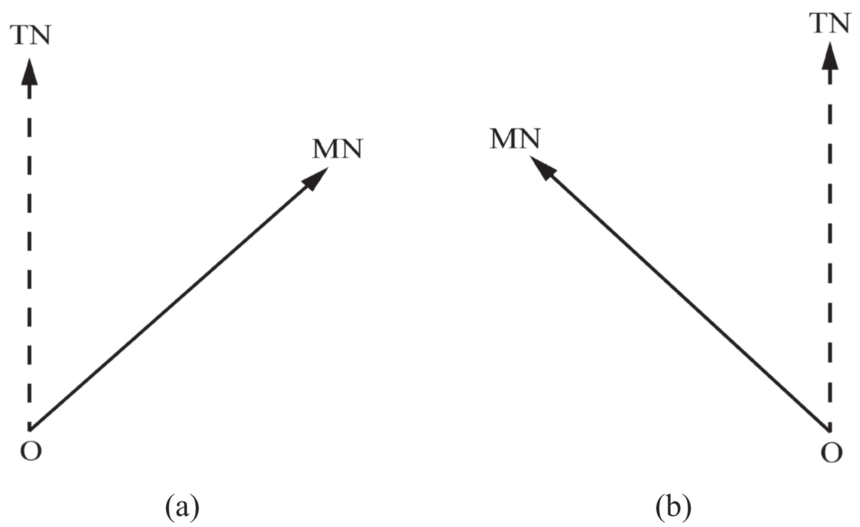


Figure 3.50: *(a) East declination and (b) west declination*

Variation of declination

The magnetic declination at any place does not remain constant but keeps on changing from time to time therefore it may increase or decrease. We classify the changes into four subheadings as secular variation, annual variation, diurnal variation, and irregular variation.

a) *Secular variation.*

The continual changing of the magnetic meridian relative to geographical poles affects the declination of a place. Secular variation is a slow continuous change in declination of places. It alters the declination more frequently and in a less regular manner from year to year. Due to its greatness, secular variation is considered the most important for land surveyors. It appears to be of periodic character and follows a sine curve.

The swing of declination at a place over a period of centuries, may be compared to a simple harmonic motion. A secular change from year to year is also not uniform for any given place. It is also different for different places. To convert magnetic bearings into true bearings, an accurate amount of declination is essentially required. As such it is very important for a surveyor to know the exact amount of declination. When observations for the declination are made in different years of a century, it is revealed that magnetic meridian moves from one side of true meridian to the other. The change produced annually by secular variation at different places amounts from 0.02 minute to 12 minutes. The variation depends on the geographical position of different places. The annual secular change is the greatest near the middle point of meridians and the last at its extreme limits.

b) *Annual variation*

This is the change in declination at a place over a period of one year. It is observed at different places over a period of 12 months. Annual variation is about 1 minute to 2 minutes, depending upon their geographical positions.

c) *Diurnal variation*

The departure of declination from its mean value during a period of 24 hours at any place is called *diurnal variation.* The diurnal variation is a variation of the following variables:

(i) The geographical position of the place. Diurnal variation is the greatest for the places in higher latitudes and lesser near the equator.

(ii) Season of the year. Diurnal variation is comparatively more in summer than in winter at the same place.

(iii) The time at the place. It is more during the day and less at night.

(iv) The year of the cycle. It is different in different years in the complete cycle of secular variation.

d) *Irregular variation*

Abrupt changes of declinations at places due to magnetic storms, earthquakes and other solar influences, are called *irregular variations*. These disturbances may occur at any time and place and cannot be predicted. The displacement of a needle may vary in extent from 1° to 2°.

Magnetic dip

The magnetic dip is defined as the angle made with the horizontal by the earth's magnetic field lines. It is also known as dip angle or magnetic inclination and was discovered by George Hartman in the year 1544. When the inclination is positive, it indicates that the earth's magnetic lines are pointing downward to the Northern Hemisphere and when the inclination is negative it indicates that the earth's magnetic lines are pointing upward to the Southern Hemisphere.

In the year 1581, Robert Norman discovered a dip circle which is a method used to measure the dip angle. The other terms used are *isoclinic* lines (when the dip of the earth's magnetic field is the same along the line) and *aclinic* lines (when the locus of the points has zero dips).

Avoidance of errors in compass survey

To reduce possible errors during a compass survey, the following are very crucial. Check the accuracy of the compass by comparing it with an accurate compass or with location of magnetic north (MN) for the year of the survey with updated MN correction adjustment for field readings. Always check every reading with a back bearing and adjustment by adding or subtracting the mean of the error. Hold the compasses steady at 180° and ensure accuracy of all chain or tape measurements between ends of legs and to points of observation on legs.

Check that all conversions from magnetic bearing to true bearing are accurate and all scaled conversions are accurate. Ensure the booker takes down reading accurately by asking him to repeat where necessary. Avoid areas where there are deposits of metalliferous ores steel structures, metal gates, railway lines and others, which would influence reading. Avoid wearing metal rimmed spectacles, metal bangles or steel watches when using the compass.

Advantages of compass survey

First, fairly rapid method in the field, compared to other old survey methods, like simple chain survey. Secondly, a check can be made on all compass bearing, simply by calculating the forward and back bearing. Thirdly, cumulative error is reduced and can be easily rectified, with the help of advanced devices used. Fourthly, near and distant objects can be pin-pointed with accuracy by using various instruments which are able to accommodate the distance of object. Fifthly, the method can be combined with other methods such as chain levelling and plane table, and in fact the prismatic compass is sometimes needed for mapping.

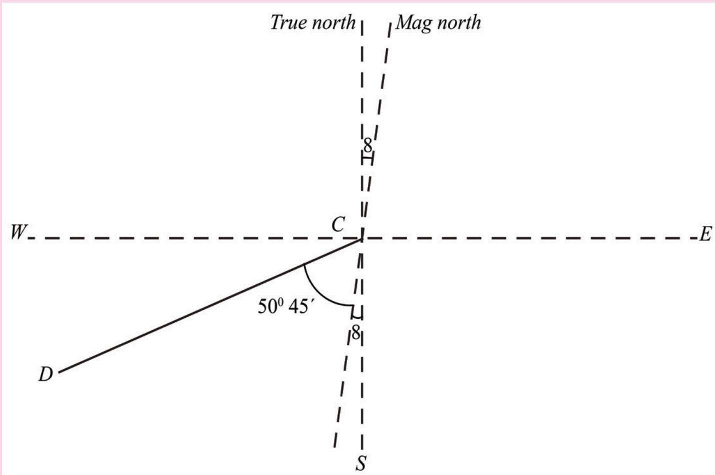
Disadvantages of compass survey

In elementary survey, compass observations over long distance object cannot be checked by back bearings unless transport is provided. Human error is involved in taking as it is difficult to hold the compass absolutely steady;

taking the mean of the difference between forward and back bearing reduces error but does not entirely eliminate it. The presence of ore bodies may not be known to the surveyor and this would affect readings. It is always better to consult the geological map or geologist first but the presence of iron ores in large quantity would necessitate using another method.

Exercise 3.2

1. Calculate the true bearing of a line CD if its magnetic bearing is S 50° 45' W and the declination is 3° 45' E.



2. In an old map, a survey line was drawn with a magnetic bearing of 202° when the declination was 2° W. Find the magnetic bearing of the line at a time when magnetic declination was 2° E.

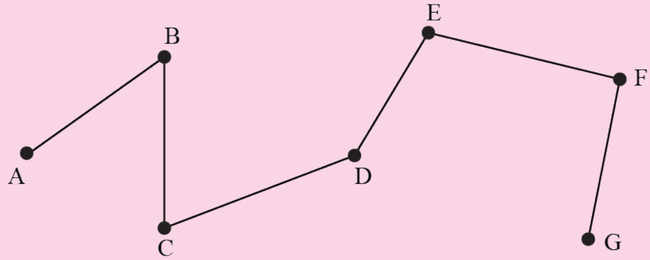
3. In 1935, a certain line had a magnetic bearing of S 67° 30′ E and then the magnetic declination at that place was 8° E. In 1977, the magnetic declination was 4° W. Find the magnetic bearing of the line in 1977.

4. Discuss how diurnal variation affects magnetic declination of the Earth.

5. Explain procedures for converting closing error in compass traverse using graphical method.

6. Convert the following bearing observed in whole circle bearing (WCB) system to quadrant bearing system (QBS): (a) 65° 40' (b) 135° (c) 265° 25' (d) 305° 45'.

7. An open compass traverse was run from station A through B, C, D, E, F, and G as it is shown in Traverse ABCDEFG.



The observed forward and backward bearings in traverse ABCDEFG are shown in the following table with the observed bearings.

Observed bearings in traverse ABCDEFG

Line	FB	BB
AB	45° 00'	225° 30'
BC	178° 50'	359° 00'
CD	82° 00'	263° 00'
DE	45° 00'	225° 00'
EF	100° 30'	280° 50'
FG	205° 45'	25° 55'

Use data (observed bearings) to:

i. Identify a traverse line which is free from local attraction.

ii. Correct bearings of all traverse lines starting from the line which is free from local attraction.

8. By using the observed magnetic bearings and distances in a closed traverse ABCDEA do the following ;

   a. Plot a traverse and measure the closing error.

   b. Correct the traverse by graphical method.

Magnetic bearing and distance in a closed traverse ABCDEA.

Line	FB	BB	Distance (m)
AB	45° 00'	225° 20'	40
BC	100° 00'	280° 30'	50
CD	160° 30'	340° 30'	40
DE	250° 00'	70° 10'	51
EA	312° 00'	132° 00'	57

Plane table survey

Plane table surveying is a graphical method of survey in which the field observation and plotting are done simultaneously. It is a graphical construction of straight lines, angles, and triangles for plotting the ground detail points. This method of land surveying is simple and cheaper than theodolite survey and only suitable on small areas. The plan is drawn by the surveyor in the field while the area to be surveyed is in front of his eyes. Therefore, there is low possibility of omitting the necessary measurements. Hence, the method has very low chances for committing errors. Just as it is for the case of compass and chain surveying, plane table surveying is named after the principal instrument used, the plane table. The earliest mention and account of a plane table and plane table survey dates back to 1551 by Abel Foullon's in his work *"Usage et description de l'holomètre", which* was published in Paris. Prior to 1830, the method was called *plane table* (Figure 3.51).

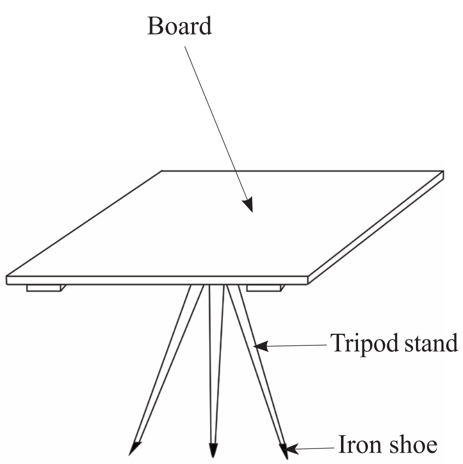


Figure 3.51: *Plane table*

Plane table are available in 750 mm × 600 mm in dimension and the legs of the tripod are usually 1200 mm long. They are made entirely of well-seasoned wood except for the metal plate, bolts, nuts and screws, which are made of brass and the shoes of the legs, which are made of iron.

Principles of plane table survey

The plane table technique operates on the principle that every established ray to various details must pass through the survey station. This principle is called *parallelism* which means that, all the lines drawn through various details should pass through the survey station. This principle can be best understood by considering the graphical reduction of a triangle to the given dimensions. The base of the triangle is plotted on the desired scale and the base angles are plotted directly by turning the alidade at each end. In plain table survey, the position of plane table at each station, must be maintained identical, that is, at each survey station the table must be oriented by magnetic north.

Equipment used in plane table survey

In plane tabling equipment can be grouped into basic equipment and accessories. Equipment includes a plane table; tripod stand and alidade. While accessories include trough compass, plumbing fork, plumb bob,chain or tape and ranging poles spirit level, U-fork, water proof cover, drawing paper, pins, pencil and eraser. The later supporting instruments are what this book is referring to as accessories.

Plane table this is the principal equipment in plane table surveying. It is a board from which rays to the target objects are established, measured and located. Drawing board for plane tabling is made up of well-seasoned wood with its upper surface exactly plane. Plane tables are in a number of sizes. The common dimensions of plane tables are those rectangular in shape with size 75 cm X 60 cm. Plane table comes with wooden or aluminum tripod stand to mount on during the surveying process. They are provided with clamps to fix it in any direction. The table can revolve around its vertical axis and can be clamped in any position when necessary. The plane table is mounted on a tripod stand (see Figure 3.52(b)).

Tripod stand is provided with three-foot screws at its top for levelling and adjustable legs for adjusting the height of the plane table. The height of the tripod stand is normally 120 cm (Figure 3.52(a)).

Figure 3.52(a): *Tripod stand*

Figure 3.52(b): *Tripod stand with plane table*

Alidade is multi-task purpose equipment useful throughout plane table surveying in assisting as a ruler and a sighting instrument. It is a straight edged ruler, attached with a sighting device. One edge of the ruler is beveled and graduated. Usually, the graduated edge is used for drawing lines of sight to objects from the plane table station. There are two types of alidades available for plane tabling; the *simple alidade* and *telescopic alidade*.

Simple alidade is used for ordinary work. It consists of gun-metal or wooden ruler with two vertical vanes at the ends. The eye-vane is provided with a narrow slit while the object vane is open and carries a horse hair. Both the slits, provide a definite line of sight which can be made to pass through the object to be sighted. To draw the rays, one of the edges of alidade is beveled and its perfectly smooth working edge is known as the fiducial edge. The fiducial edge is graduated to facilitate the plotting of distances to a scale (Figure 3.53).

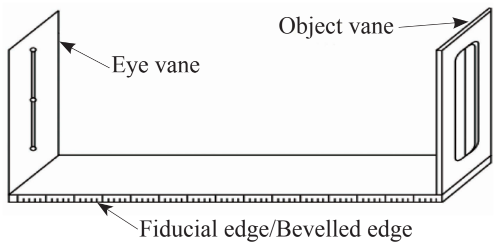


Figure 3.53: *Simple alidade*

Telescopic alidade: is used when it is required to take inclined sights. It essentially consists of a small telescope with a level tube and graduated arc mounted on horizontal axis. It gives higher accuracy and more range of sight (Figure 3.54).

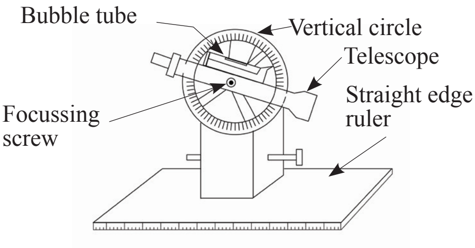


Figure 3.54: *Telescopic alidade*

Trough compass is a thin narrow wooden box containing a magnetic needle about 120 mm long. The box is moved around on plane table surface so that when the needle points to the magnetic North, it is parallel to the sides of the box. It is required for drawing the line showing magnetic meridian on the paper. It is used to orient the table to the magnetic meridian (Figure 3.55).

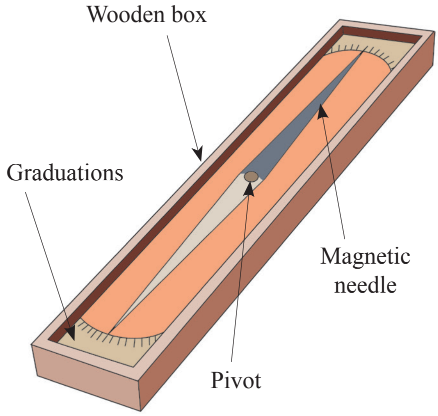


Figure 3.55: *Trough compass*

Spirit levels are common and cheaply available for masonries. They are flat-based aluminum or woody bar fitted with bubble tube and are used for levelling in brick laying. In plane table surveying, spirit levels are used to level the plane table during surveying or ascertaining if the table is properly leveled. Board's levelling is done by placing the level on the board in two positions at right angles and getting the bubble at the center of bubble tube. To ensure that a plane table is perfectly leveled, a bubble of spirit level must be at the center of the bubble tube and checked with its positions in any two mutually perpendicular directions as indicated in Figure 3.56.

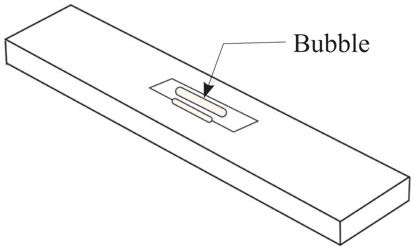


Figure 3.56: *Spirit level*

Apart from the instruments for the plane table, there are also accessories which include the following;

U-fork with plumb bob is used for centering the table over the survey station. U-fork is also called a U-frame. It is attached on the plane table during the field plotting and fixed with a plumb to point on a station when the plotted position of that point is already on the sheet. In the beginning of the work the U-fork with its plumb bob is used to transfer the ground point onto the sheet as indicated in Figure 3.57.

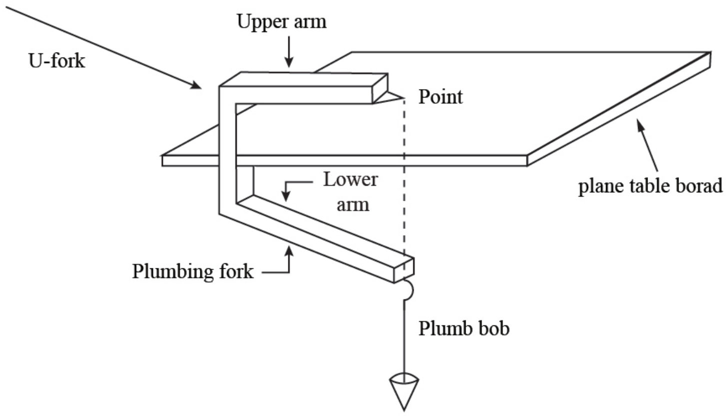


Figure 3.57: *U-fork with plumb bob*

Note that, u-forks appears in different shapes as indicated in Figure 3.58 (a, b, and c).

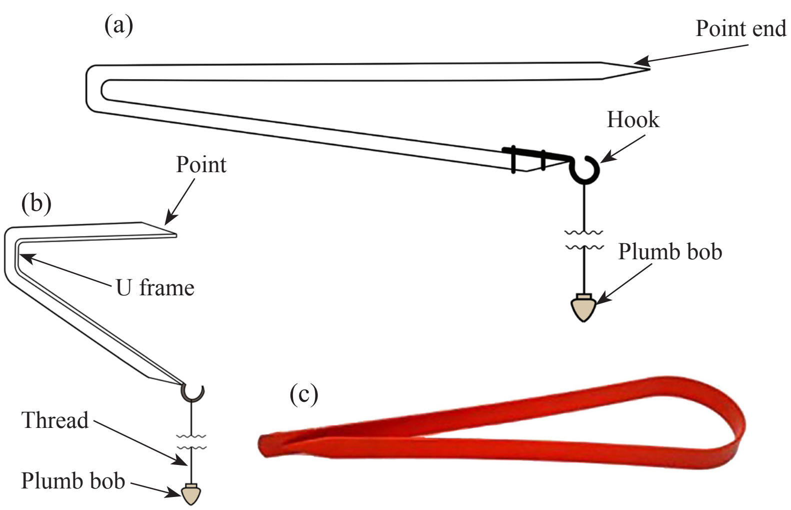


Figure 3.58: *Different shapes of u-forks*

Field practical operations

Form five, and six geography students should note that proper handling of plane table equipment and its accessories and performing surveying activities diligently and in accordance with the practice and rules which ultimately build a foundation for obtain reliable, and accurate field data is very important. In performing plane table surveying, two main steps are involved: Setting *up a plane table* and *locating the position of points or features* as required.

a) Setting up the plane table over the chosen station

Setting up a plane table involves three operations. Centering, levelling and orienting. Centering the plane table means putting the table exactly over the starting point you have chosen. The procedure involves setting up of tripod by fixing them firmly and properly spread on the ground and mounting a plane table board on a tripod at a convenient height. The table should be approximately leveled by tripod legs by judging by the eyes. Then the operation of centering is carried out by means of u-frame and plumb bob.

It is a preliminary stage to plane tabling, after mounting the board, then a point on the ground is transferred to a paper sheet, spread on top of the board (Figure 3.59).

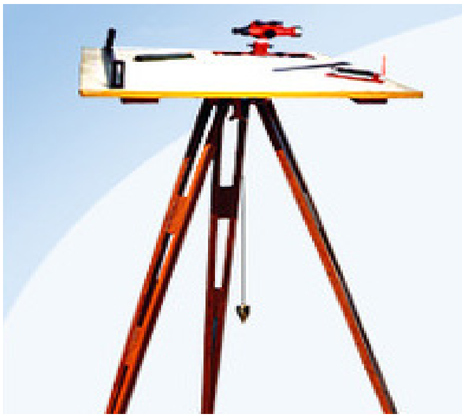


Figure 3.59: *Plane table on ground beacon station*

The table then is leveled using the spirit level (Figure 3.60). The board is considered level when a spirit level bubble is at the center. After mounting a plane table on tripod stand, the process of making a plane table perfectly horizontal is what we phrase in this book as *plane table levelling*. The spirit level is placed parallel to the two perpendicular sides of a plane table at each corner. Then, its bubble is brought to the center by either turning the three foot-screws or adjusting the three legs of a tripod stand.

Figure 3.60: *Spirit level*

Orienting the table is another equally important and necessary process for setting up of a plane table before any measurement is taken. It is a process of aligning setting up a plane table in such a way that, all the lines plotted on a sheet are parallel to corresponding lines on the ground. The procedure and processes of making lines drawn on sheet of paper on the board parallel to the corresponding lines on ground, are refered to as *orientation of plane table*. The accuracy of plane table survey mainly depends upon the accuracy of plane table orientation at each station point. The orientation of a plane table can be achieved by either trough compass or back-sighting method. Therefore, orientation here means assuring that the plane table is strictly oriented towards the magnetic meridian.

In orienting by trough compass, a line representing a meridian is drawn on a drawing sheet to orient a plane table. A trough compass is then placed along this line, and a table is turned until the trough compass points towards the north-south direction. At this position, the plane table is clamped. This method is quick but unsuitable in areas with metal ferric ores which affect the direction of magnetic needle due to local attractions. Consider ABCD and E step by step using radiation method (see Figure 3.61).

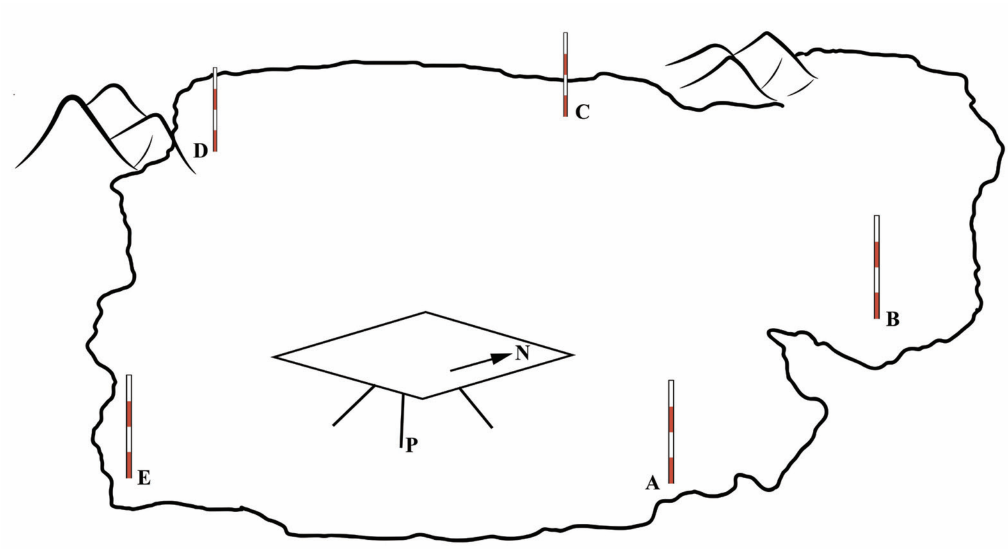


Figure 3.61: *Plane tabling the farm ABCDE*

Procedures:

(i) Set the plane table at P and perform centering and levelling using spirit level as described in the preceding paragraphs. Put a mark on paper sheet at a point above point P. The point **P** is transferred to *p* on the sheet paper by using U-fork and plumb bob;

(ii) Then using a trough compass, establish north direction somewhere on the right-hand side on the sheet of paper. To indicate north direction, place a trough compass where you would like to draw it and keep twisting to make sure a compass arrow points to the North. Then draw a line towards the meridian as shown by a compass to indicate north direction as shown in Figure 3.61. After fixing the north direction, then the direction to orient a plane table is ready and all lines will be drawn parallel to it; and

(iii) Then start taking measurement from the table to the established stations.

The orientation by back-sighting is a common method used in plane table surveying. After finishing surveying from the plane table at A, if the table is to be shifted to station B, a line is drawn from the plotted position of station A towards station B. Then distance AB is measured, scaled-down and plotted position of station B is obtained. Then the table is shifted to station B, centered and levelled. Keeping alidade along line BA, the table is turned to sight station A and clamped. Thus, the orientation of the table is achieved by the back sighting. Orientation may be checked by observing already plotted objects.

Therefore, the orientation procedures in plane table survey aim at making sure that the plane table at each station, is parallel to all other successive station, hence the emergence of the principle of *parallelism*.

b) Locating position of points or features

All surveys exist to accomplish one important objective, which is locating or positioning of both natural and man-made features. Plane table survey is not different from this objective. It may aim at updating information in a school map by locating the new infrastructure established recently or it may aim at demarcating land parcels for housing, farming and others. In plane table, position of points or features is determined by scaling down the measured distances and plotting them on a drawing sheet. There are three common methods used to determine the position of points or features in a plane table which are; *radiation, intersection or triangulation; traverse and resection.*

Plane table survey by radiation method

For form five secondary students, a word *radiation* should be taking you back to the radiation topics where you generally made association of radiation and the sun. You may apply your knowledge in this topic too. Radiation is a method in which all measurements starts from one point on the plane table out widely to the object or details intended. Radiation method is only effective when the entire area can be surveyed from one single station. The plane table will be set up at one station from where all the other points that need to be fixed are visible. For example, positions of points A, B, C, D, and E in a farm, which are visible from station P, can be fixed using the radiation method through the following procedure:

(i) Set up a Plane table at point P where all other points to be fixed (that is, A, B, C, D, E) are easily seen. Then decide a scale for the measurement that you are going to make, let's say, *1cm represents 10 metres*. However, preliminary set up of plane table must be conducted as outlined in a setting up plane table section above;

(ii) Put the alidade on point 'P' marked on the drawing paper vertically above point 'P', and the first point, say A is sighted from it . A ground distance from P to A is measured and presented on the sheet the line of sight connecting points P and A is drawn (Figure 3.62) ;

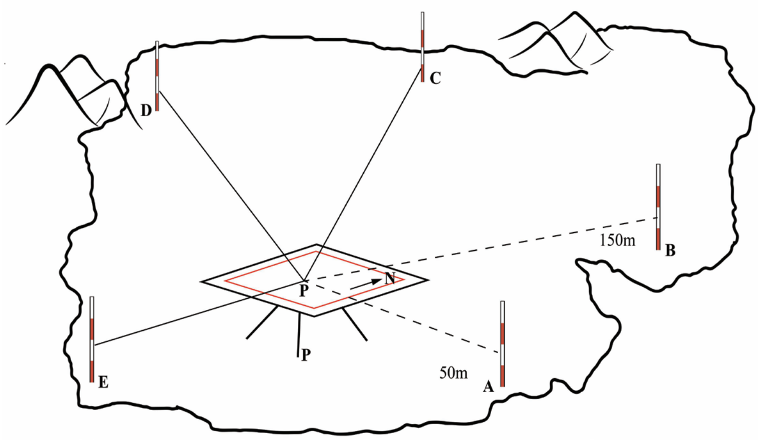


Figure 3.62: *Plane tabling setup and procedures*

Continue measuring all other stations using the alidade to sight to points B, C, D, and E and present their distances on the paper as shown on the board as '*b*', '*c*', '*d*', and '*e*' (see Figure 3.63).

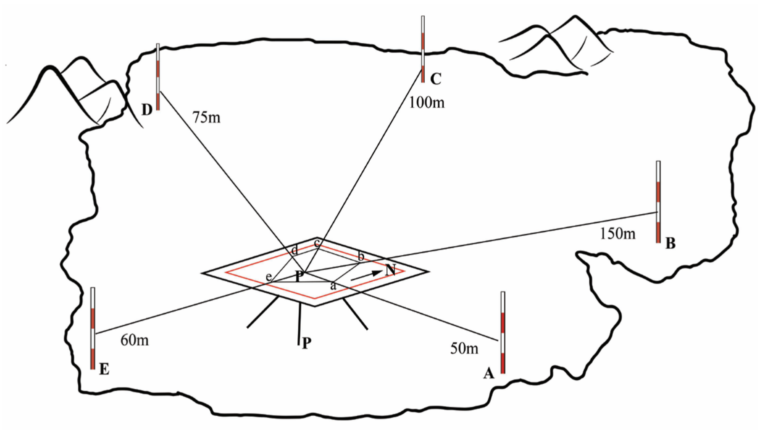


Figure 3.63: *Farm ABCDE*

(iii) Then join the Points 'a', 'b', 'c', 'd', and 'e' as shown in Figure 3.63; and

(iv) Finally, produce a plan of a farm surveyed. However, it should be remembered that, point 'P' must be located in such a way that a surveyor is not there and the plan is found, any other person can determine its location.

Generally, the points that the surveyor wants to locate are boundary point A, B, C, D and E. In this case point 'P' is just a reference point from which the stations A, B, C, D and E can be identified. It should be remembered that A, B, C, D, and E, can also be used to locate 'P'. It must be remember that, radiation method, fixes location or position of details from a single point.

Plane table survey by intersection method

Different from radiation method, where a line of sight is defined and the distance to a fixed point is measured, in intersection method, only a line of sight is defined. This means that in order for a point or feature, such as a building, a water well and others to be fixed, two lines of sight are defined from two different points towards a point to be fixed. For example, two corners, A and B of one side of a building, are fixed using the intersection method from two points, S1 and S2.

For instance, in the Figure 3.64 if the interest is to locate a form two class building from point S2 near water tank and point near S1 the headmaster's house, a plane table survey through intersection method can go through the following procedures:

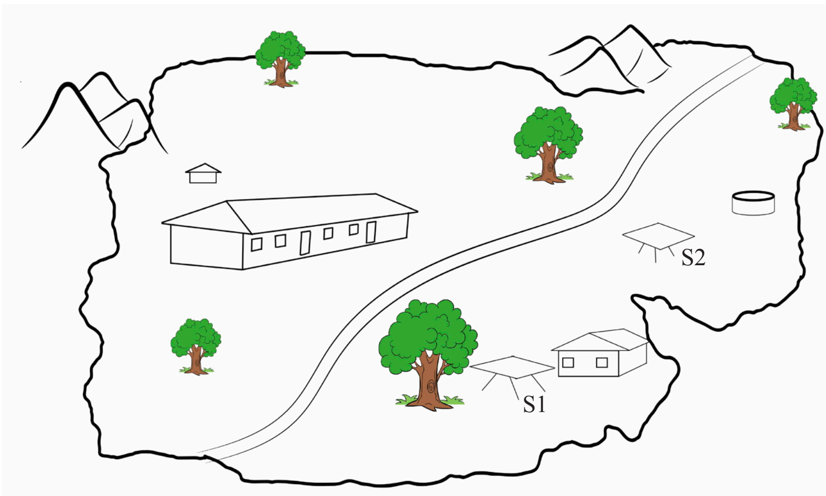


Figure 3.64: *Plane table setting at stations S1 and S2*

(i) Firstly, set up a plane table at stations where points A and B can easily be seen. In Figure 3.64, we establish stations **S1** and **S2.**

(ii) Secondly, the alidade is put on point S1 marked on the drawing paper vertically above point S1 and A is sighted from S1. The line of sight connecting points S1 and A is drawn. The same is done to S1 and B which are also drawn on a drawing paper.

(iii) Thirdly, a baseline connecting stations 'S1' and S2 is defined by measuring the distance between stations S1 and S2 on the ground and plotting it to a suitable scale on the drawing sheet between points S1 and S2 (Figure 3.65).

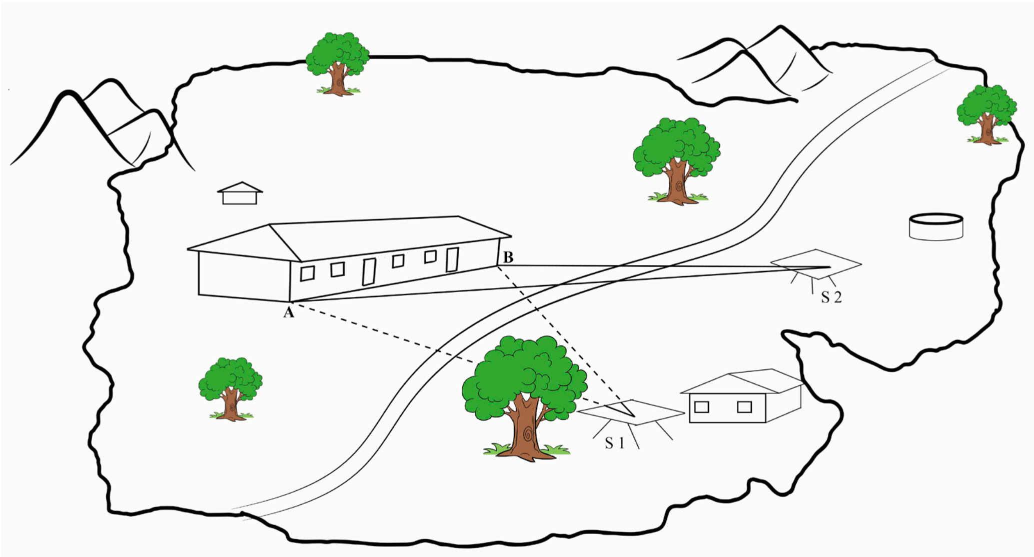


Figure 3.65: *Intersection of points A and B from survey stations S1 and S2*

(iv) In the fourth step, a plane table is moved to station S2 and set up such that S2 is vertically above point S2. Then, the alidade is put along a line connecting points S2 and S1. A plane table is turned horizontally about a vertical axis until the alidade bisects a ranging pole held at station S1 and the table is clamped.

(v) Finally, the alidade is put on point S2, turned to bisect stations A and B to define their respective lines of sight on a drawing paper. A point where lines of sight for station A from stations S1 and S2 intersect is a position of point A, marked as a on the drawing paper. Similarly, a point where lines of sight for station B' from stations S1 and S2 intersect is a position of point B, marked as b on the drawing paper.

Plane table survey by traverse method

This method has been used in previous lessons. It has been used in chain and prismatic surveying. Traverse involve establishing a series of connected lines whose positions are to be determined. A traverse method in plane table surveying is different from traverse in chain and prismatic surveying. In plane table survey, plotting is done instantly in the field. Plane table is also used in fixing survey lines between stations of a closed or open traverse. Through traverse method, a plane table is set up at each traverse station. For example, a traverse method is used to fix five corners A, B, C, D and E of a farm (Figure 3.66).

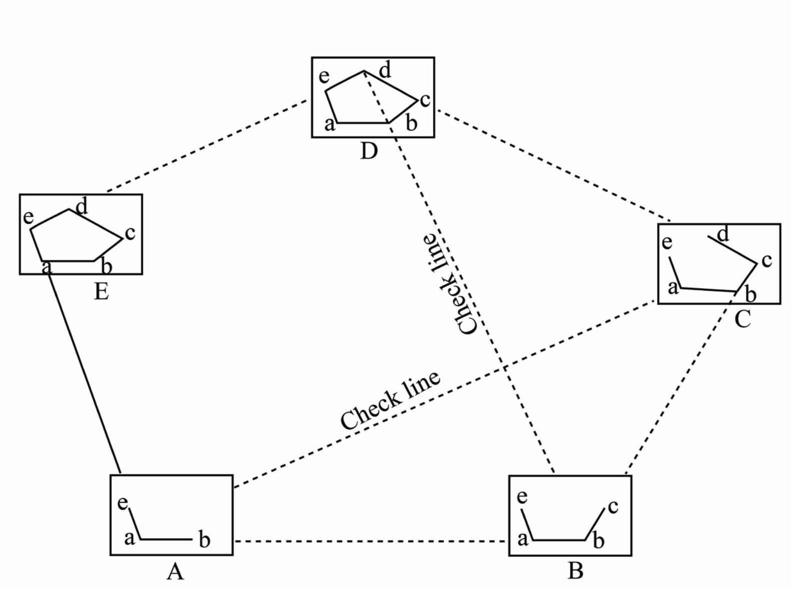


Figure 3.66: *Fixing positions of five corners A, B, C, D, and E of a farm using traverse methods of plane table surveying.*

The following procedures are followed to fix position of points using traverse method of plane table survey:

(i) A plane table is set up at one of the corner points, say corner point 'A', where the next corner point, say 'B', is easily seen. The setting-up involves the procedures discussed.

(ii) From point 'A', a sight is taken towards B and the distance AB is measured and plotted to a suitable scale as '**ab**' on the drawing sheet.

(iii) The plane table is moved to station 'B' and set up such that 'b' is vertically above 'B'. Then, the alidade is put along a line connecting points 'b' and 'a'. A plane table is turned horizontally about a vertical axis until the alidade bisects a ranging pole held at station 'A', then the table is clamped.

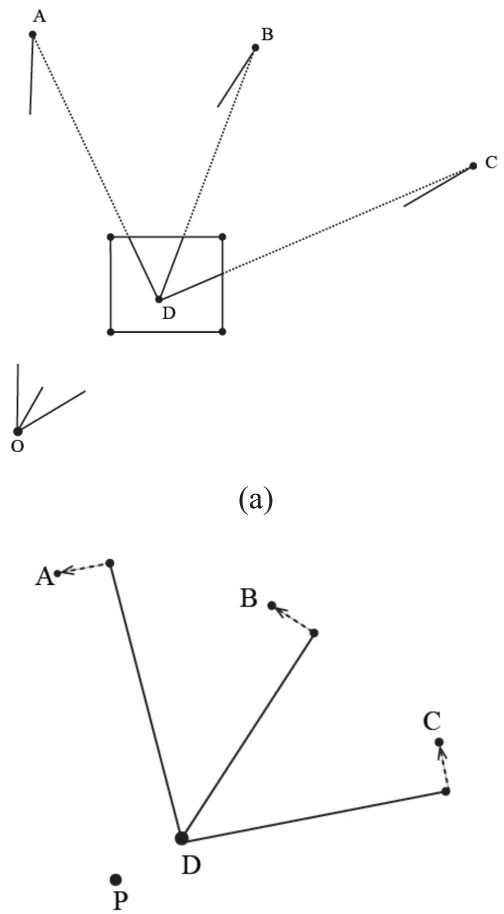
(iv) The alidade is put on point 'b', turned to sight a ranging rod held at C, then the line of sight connecting points B and C is drawn on a drawing sheet. A distance BC is measured and plotted to a suitable scale.

(v) Steps (iii) and (iv) are repeated for traverse stations C, D, and E.

Plane table survey by resection method

Resection is the method used in determining a location of an unknown point in relation to known points. The plane table is fixed at an unknown point to allow sighting of points of known positions. The method is usually applied when some objects may be difficult to see them from the base line stations.

To do this, the board is moved to the position of the object position, oriented by trough compass and clamped. Rays are drawn on a tracing paper from three objects in the field A, B, and C as shown in Figure 3.67. If the board is correctly oriented, the rays will intersect at unknown point D. If the positions of rays A, B, and C coincide with their positions on the map, the position of D can then be established on the map.



(a)

(b)

Figure 3.67: *Fixing position of object by plane table resection method.*

However, due to incorrect orientation, the rays may form a small triangle with D either within or outside the triangle. This is referred to as the triangle of error. The error can be fixed through the following procedure;

Case 1

(i) If the position of D is within the triangle of error, it can be found by drawing short lines within the triangle, each line vertically from the ray line and proportional to the length of their respective rays. If they are properly drawn with a compass they should intersect at D's position as shown in Figure 3.68.

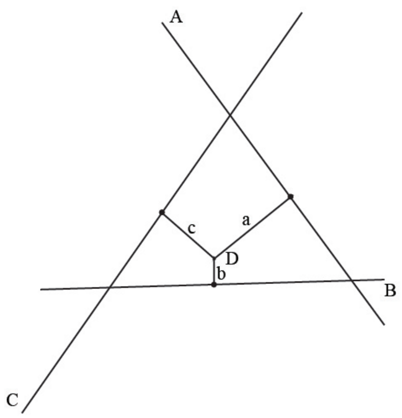


Figure 3.68: *Correcting error when point D is within the triangle.*

(ii) To check the new position of D, lay the alidade on D, turn the board slightly until A and D are aligned and draw a new ray. Do the same for B and C. The new rays should meet at point D, if they do not, repeat the process.

Case 2

(i) If the position of D lies outside the triangle of error, point A, B, and C being in front of the observer, D may be on the right or left of the triangle of error. The board may be moved slightly to the right to orient it correctly with A, B, and C. Thus, the position of D will be to the left. To fix D use vertical lines from rays proportional to the length of the rays as shown in Figure 3.69.

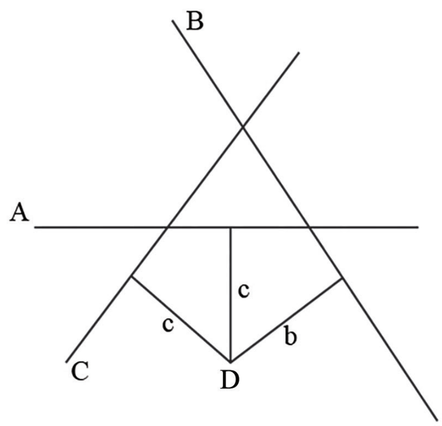


Figure 3.69: *Correcting error when point D is outside the triangle.*

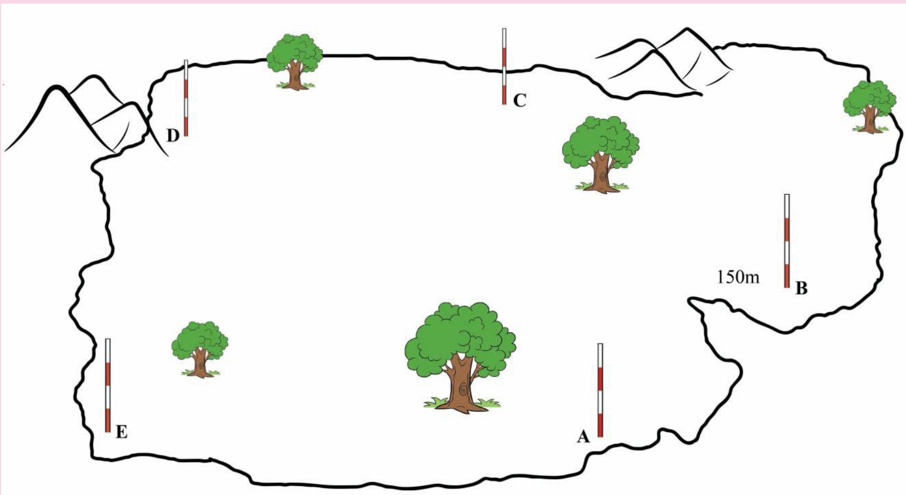
Source of errors in plane table

Plane tabling like other survey methods, is not free from errors. Errors in plane table survey could fall into three categories, mainly instrumental errors, errors in manipulation and sighting and errors in plotting. Instrumental errors include instability of the table due to the shrinking of the paper, thickness of the pencil and faults related with poor or failure of proper setting of the plane table at the start. Some faults from human error include: improper setting of the drawing board; improper setting of the fixing clamp and alidade being not parallel with the line of sight. Errors from manipulation include those resulting from defective levelling, sighting, orientation, and centering. Consistently, defective scale of a map and wrongly intersecting the rays drawn from two different stations contribute highly to production of faulty survey data.

Significantly, plane table surveying is a simple and rapid method for survey work of small land areas where by a map or plain can be produced. But, the methods provide little room for surveyors to omit necessary measurement in the field. The fact that, the land area surveyed is in front of the surveyors' eyes, surveyors are able to compare feature sizes easily. It demands fairly simple skills. It is being more field based, the possibility of making mistakes is minimized. Despite advantages mentioned, plane table surveying has some weakness such as; the method cannot be used in rainy and windy conditions. The plane table equipment is heavy to carry so this may require the use of a car which adds expenses. A single error in the ground base line measurement can throw out all angle measurement. The table uses a lot of equipment and accessories which are easier to forget while in the field. Lastly, the method cannot be used for a large scale survey.

Exercise 3.3

1. Describe resection in plane table survey.
2. (a) Explain advantages of plane table survey.
   (b) Write short notes on the importance of centering in the plane table survey.
   (c) Describe two problem in plane table survey.
3. What do you understand by the term 'orientation' as used in plane table survey?
4. Show the effect of bad orientation on traverse.
5. Describe how you would carry out plane table survey by traverse method of the area provided in the following figure.



6. With the aid of diagrams, describe radiation method as applied in the plane table survey.
7. Compare and contrast the following surveying methods:
   (a) Compass traversing and plane table traversing
   (b) Radiation and intersection methods
8. (a) What is meant by triangle of error and how can one deal with it in setting a plane table?
   (b) Illustrate the intersection in plane table surveys.
9. (a) What is a plane table survey?
   (b) What are the possible sources of error in plane table survey?
10. Describe five (5) equipments used in plane table survey.

Levelling survey

Levelling is a method of land survey that focus on determining the heights of given points above or below a datum line or determining difference in elevation between points. Datum is the point or the surface with respect to which levels of other points are calculated.

Most of survey methods have their names derived from the main survey equipment employed or the activity that is carried out, the technique used or the survey objective. Levelling survey derives its name from the survey objective, levelling, and its principal equipment level. Mentioning a word "level" may seem new to some students but it has been used quite often in our daily activities. A spirit level shown in Figure 3.70 is the most common level that is used in masonry works, especially, maintaining perfect wall horizontality and verticality during brick laying.

Figure 3.70: *Spirit level*

Levelling survey uses the same principles used by masons to maintain the horizontality and verticality during brick laying. Levelling survey has been very useful in contouring mapping, preparing land cross section and longitudinal section. Levelling survey provides data helpful for construction works of narrow sections of the earth such as sewers, pipelines, roads and railways.

Common terms in levelling survey

There are many special and non-special terms commonly used in levelling. Some of these are highlighted in this section without emphasis and detailed explanation. Other terms will be explained in each section they appear. These terms are;

Instrument station: is the point where instrument is set up for observations.

Station: is the point where levelling staff is held. It is the point whose elevation is to be determined or the point that is to be established at a given elevation.

Height of instrument (HI): is the elevation of the line of sight with respect to the assumed datum. It is also referred to as *height of collimation (HC)*. In levelling it does not mean the height of the telescope above the ground level where the level is set up.

Back sight (BS): is the first sight taken on a levelling staff held at point of known elevation. It ascertains the amount by which the line of sight is above or below the elevation of the point. Back sight enables the surveyor to obtain the height of the instrument.

Fore sight (F.S): is the sight taken on a levelling staff held at a point of unknown elevation to ascertain the amount by which the point is above or below the line of sight. Fore sight enables the surveyor to obtain the elevation of the point. It is also generally known as *minus sight* as the foresight reading is always subtracted from the height of the instrument (except when the staff is held inverted) to obtain the elevation.

Change point (CP): is a point on which both the fore sight and back sight are taken during the operation of levelling. Two sights are taken from two different instrument stations, a fore sight to ascertain the elevation of the point while a back sight is taken on the same point to establish the height of the instrument of the new setting of the level.

Intermediate sight (IS): is the fore sight taken on a levelling staff held at a point between two change points or a benchmark and a change point, to determine the elevation of that point. It may be noted that are stations sighted between BS and FS.

Bench mark (BM): refers to a relatively permanent and fixed reference point of known elevation above the assumed datum.

Line of collimation (LC): refers to the line passing through the optical centre of the objective and the point of intersection of the cross hairs stretched in front of the eye piece and its continuation.

Line of sight (LS): refers to a line passing through the optical centre of the objective, traversing the eye-piece and entering the eye.

Vertical datum: refers to any level surface to which elevations are referenced. Means sea level is one of the vertical datum assigned on elevation or reduced level of zero.

Mean sea level datum (M.S.L): is a mean sea level obtained by making hourly observations of the tides at any place over a period of 19 years. The $M.S.L$ datum adopted by the survey of India for determining the elevations of different points in India is that of Mumbai. In East Africa, the datum line is situated in Mombasa, while in Nigeria it is in Lagos and for South Africa it is in Cape Town.

Reduced Level (R.L): is the height or depth of a point above or below the assumed datum. It is also known as elevation of the point. Elevations of the points below the datum surface are known as *negative elevations*.

Vertical line: is a line that follows the local direction of gravity as indicated by a plumb line.

Level surface: is a curved surface that at every point is perpendicular to the local plumb line (i.e., the direction in which gravity acts)

Level line: is a curved line on a level surface

Horizontal place: is a plane perpendicular to the local direction of gravity and tangential to the level surface.

Horizontal line: is a line on a horizontal which is perpendicular to the vertical line.

Vertical control: is a series of benchmarks or other points of known elevation established throughout an area.

Equipment used in levelling survey

Traditional levelling survey requires three major equipments for its operations. The equipments includes; a level, tripod stand and a levelling staff.

A level is an instrument with a telescope and bubble tube and levelling head used for sighting targets, particularly, levelling staff (see Figure 3.71). A telescope is an optical instrument mounted on levels to magnify and view distant objects. It provides a line of sight. A bubble tube is used together with the levelling head to make the line of sight horizontal by bringing the bubble to the center of its run.

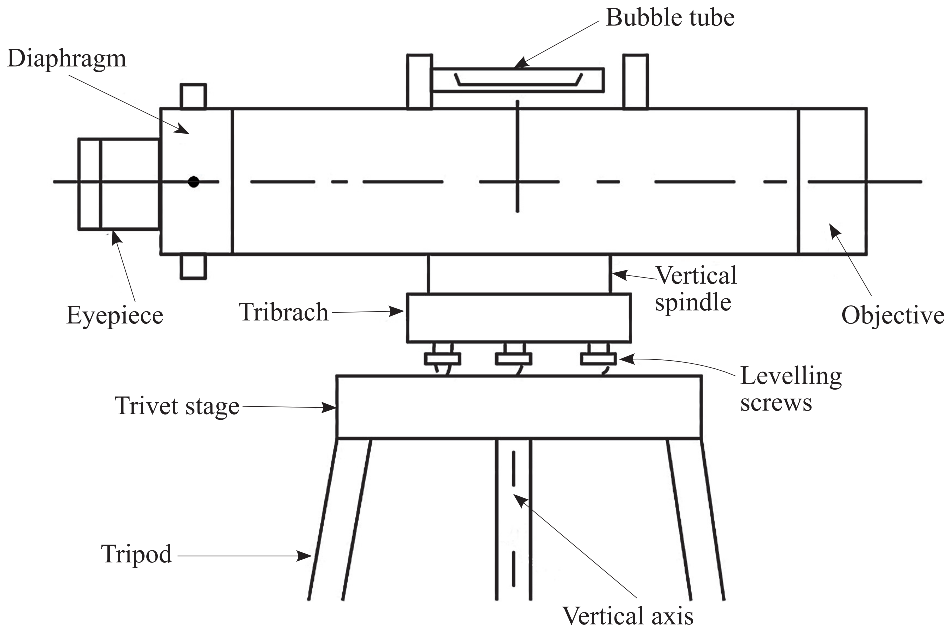


Figure 3.71: *Components of a level instrument*

There are three basic types of level instruments, namely: *Dumpy levels, engineers' or tilting levels and automatic levels*. The first two are spirit bubble levels. The dumpy level is a very simple basic instrument, while the tilting level has certain modifications which give it greater convenience of operation and a possibility of greater clarity. However, the most often used and "quick set" level is a tilting level without foot-screws. The automatic type of levels which gives a horizontal line of sight automatically, are the most favorable to use, but they are relatively expensive.

(a) *Dumpy level:* is characterized by their telescope being rigidly attached to the vertical spindle (see Figure 3.72). The levelling of the instrument is done by means of three-foot screws separating their two plates. The upper plate with the vertical spindle on which the telescope and bubble tube are mounted has to be levelled with the foot screws.

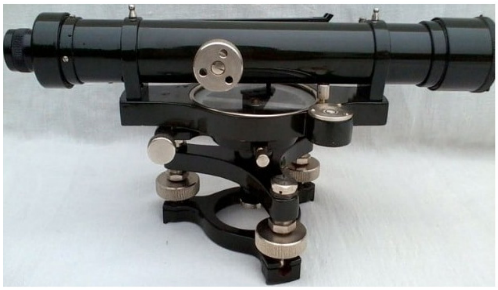


Figure 3.72: *Dumpy level*

(b) *The engineer's level:* also known as tilting level has a telescope which is not rigidly fixed to the vertical spindle (Figure 3.73). Instead, the telescope is capable of tilting slightly in the vertical plane about a point just below the telescope. This vertical movement of the telescope is made by rotating a tilting screw below the eyepiece. They have two bubbles, *circular bubble* on the upper plate is used to achieve approximate levelling by means of the three foot screws and *telescope bubble* (tube bubble) to be levelled for each sighting by the tilting screw only. This type of levels exists in two features, the "quickest" and normal tilt levels. Contrary to the "normal" tilting level the "quickset" level does not have foot screws in the levelling head. A ball-and-socket joint is provided to level the instrument quickly, but only approximately. Accurate levelling of the instrument must be completed with the tilting screw for each sighting.

Figure 3.73: *Engineer's level*

(c) *The automatic level:* automatic levels are fairly advanced than dumpy and tilting levels. They are provided with either foot screws or a ball-and-socket joint (Figure 3.74). However, they do not have a bubble tube for precise levelling, instead they use compensators to automatically to make the line of sight horizontal once an approximate levelling has been achieved. Setting up and approximate levelling is done with the circular bubble in the same way as for a tilting level.

Figure 3.74: *Automatic level*

(d) *Tripod stand:* is an important component in any levelling process for it carries a level instrument during levelling survey. The level is mounted on a tripod stand which consists of three solid wooden or aluminum framed legs. At the lower ends, the legs are provided with pointed iron shoes for driving them on the ground during the levelling process (Figure 3.75).

Figure 3.75: *Tripod stand*

(e) *Levelling staffs:* are wooden or metallic rods, graduated into metre or feet and further smaller divisions of 10 mm intervals and marked in red, black and white for easy reading (Figure 3.76). The staffs are available in 3 m to 5 m long. The bottom of the levelling staff represents the zero reading. The reading given by the line of sight on a levelling staff held vertically is the vertical distance above the point on which the staff is held. Levelling staffs may be grouped into two classes; self-reading staffs and target staffs.

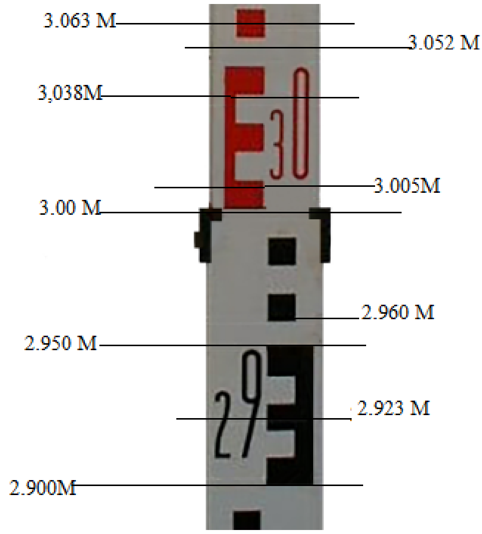


Figure 3.76: *Reading on a levelling staffs*

(i) *Self-reading staff:* are those in which the readings are directly obtained by the observer through the telescope. In self-reading staff any ordinary man can hold the staff and keep it in plumb. Self-reading staffs are of three types: the solid staff, the folding or hinged staff and the telescopic staff. *The Solid staff* are usually available in 3 m long in one length. The absence of hinge or socket on these staffs, makes them more accurate in reading compared to hinged ones. However, the staffs are inconvenient to carry in the field. Use of a solid staff is generally restricted to only precise levelling work. *Folding or hinged staff* are made of well-seasoned timber with 4 m long. They consist of two portions, each being 2 m hinged together. The width and thickness of the staff, is kept 75 mm and 18 mm respectively. *Telescopic or Sopwitch type of staff* consists of three pieces;

Top piece is solid 1.25 m long whereas central piece 1.25 m and lower piece 1.5 m are hollow. The top portion slides into the central portion telescopically. When fully extended, total length of the staff is 4 m. The upper two pieces are held by brass spring catches.

(ii) *Target staff:* is a class which consists of two ordinary rods, the upper rod 6 ft. in length and which slides into lower one which is 7 ft. in length. A target which can be moved up and down is attached to the staff. The rod is graduated in feet, and its tenths and hundreds. For taking readings the level man directs the staff man to raise or lower the target till it is bisected by the line of sight. The staff man clamps the target and takes the reading. This means that the duties of a target staff-man are as important as those of the observer and demand the services of a trained man.

(f) *Theodolite and total station:* although levels are still highly in use, it is not because they are the only equipment that can be used for levelling. Technological development has provided options to other advanced and sophisticated equipment like Theodolites and Total stations (Figure 3.77).

Figure 3.77: *(a) Electronic theodolite*

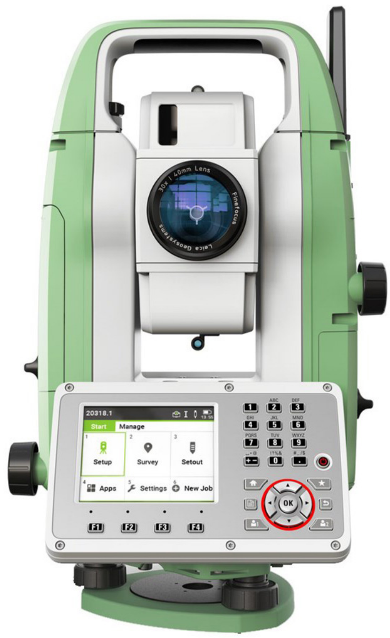


Figure 3.77: *(b) Total station*

Theodolite is an optical or electronic equipment for measuring horizontal and vertical angles or distances. Total station is an electronic instrument for measuring both horizontal and vertical angles and distances. The two equipment are used in a trigonometric levelling. Trigonometric levelling applies trigonometric relationship to determine elevation of points from measured vertical angles and measured horizontal or slope distances.

Types of levelling

Different books classify levelling differently based on different perspectives and context. All levelling practice can be divided into direct levelling which involves all methods which take vertical distances direct from the field and indirect levelling in which vertical distances are not measured directly in the field. Direct levelling is of two types namely *differential levelling and profile levelling.*

Differential levelling

Differential levelling is carried out to determine the elevation of a distant point that cannot be determined with a single set up of the instrument. It involves setting up a level several times to take reading along the route between the benchmark and the distant point. At each instrument set up, only two staff readings, a back sight and a fore sight are observed (Figure 3.78).

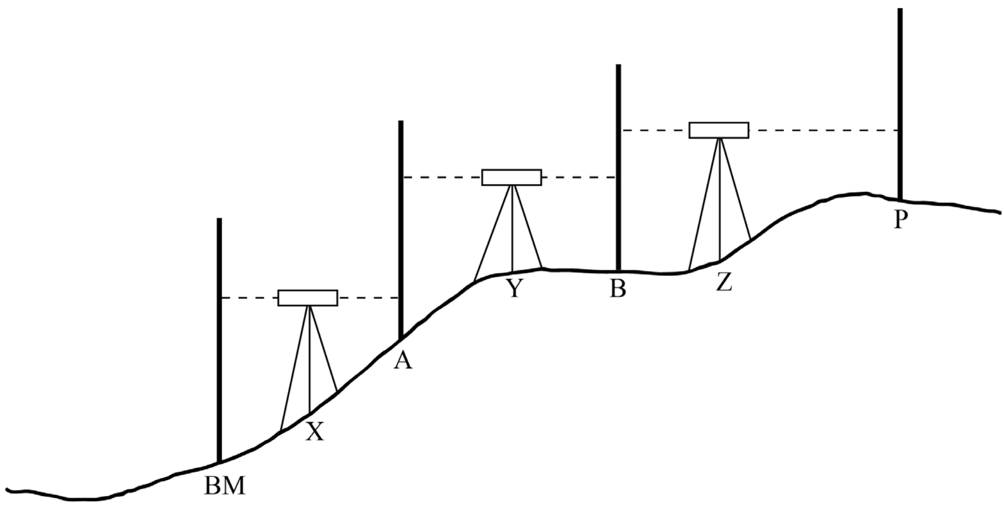


Figure 3.78: *Differential levelling*

(a) Profile levelling

Profile levelling is another category of direct levelling which determines elevations of a series of points along a line before shifting a level to another station. In this type of levelling, an instrument can determine elevation of several points between a back sight and fore sight. As such a back sight, a fore sight and as many intermediate sights as possible are taken in profile levelling (Figure 3.79). Profile levelling is particularly considered important in drainage and terrace layout.

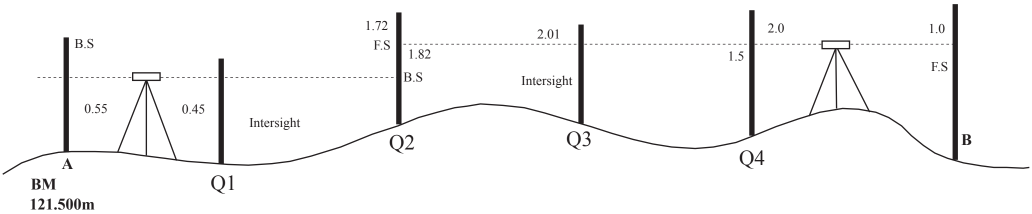


Figure 3.79: *Profile levelling*

Levelling procedures

The execution of levelling starts with the adjustments of the level instrument and followed by leveled observation and record observed levels in level sheets.

Instrument adjustment

The instrument adjustment done in levelling is categorized into temporary adjustment and permanent adjustment.

(a) *Temporary adjustment*

These are adjustments performed at each instrument station where a level is set-up before taking any observation. Temporary adjustment involves setting up a level, levelling and eliminating parallax. The following procedures are carried out:

(i) Setting up the level: this operation includes fixing the instrument on the tripod and levelling the instrument approximately by leg adjustment. The tripod legs are so adjusted that the telescope is at a convenient height and the machine (tribrach) is approximately levelled. To fix the instrument on tripod stand, tripod legs are well spread on the ground to place a tripod's head nearly level and at convenient height, a level is mounted and fixed on the tripod. Then adjust the tripod's legs and bring all the foot screws of the level in the centre of their run. Modern levels such as automatic levels, are provided with a small circular bubble on the tribrach for achieving approximate levelling of the instrument.

(ii) Levelling is done with the help of foot screws and bubbles. The purpose of levelling is to make the vertical axis truly vertical. The method of levelling depends upon whether there are three-foot screws or four-foot screws. In all modern instruments three-foot screws are provided and only procedures for levelling instruments with three-foot screws are explained. In the first step, a tubular bubble is aligned parallel to any two-foot screw which are then simultaneously turned inward or outward to bring the bubble to the centre. Then, the tubular bubble is aligned perpendicular to these two foot screws and a third screw is turned to bring the bubble to the centre. The tubular bubble is turned to different positions to check whether the bubble remains central. When the bubble is central, the level is levelled, otherwise permanent adjustment is required.

(iii) Elimination of parallax involves two operations, focusing on the eye piece and focusing on the objective. To *focus on the eye-piece*, first direct the telescope either towards the sky or hold a sheet of white paper in front of the objective. Then move the eye piece in or out till the cross hairs appear distinct and very dark. In some levels, the eye-piece is graduated and numbered. Once the eye-piece is focused, the observer may note this position to save much of his time at other settings.

The objective is focused to adjust the visibility of a staff through a telescope. To focus on the objective, direct the telescope towards the levelling staff to see the staff. If the staff is not seen from the telescopic level, turn the focusing screw till the staff image appears clear and sharp. The image of the staff should be formed on the plane of cross hairs.

(b) *Permanent adjustment*

Contrary to temporary adjustment, permanent adjustment can be carried when the device has major technical problem. Two types of permanent adjustment are usually carried out in levelling: adjustment of bubble tube error and collimation error. The bubble tube error happens when the vertical axis of a level is not truly vertical after bringing the bubble to the centre. The collimation error happens when the line of sight is not horizontal after bringing the bubble to the centre.

Field procedures and field data booking

Field levelling procedures involve setting up the instrument as described in temporary adjustment, reading vertical distances on the levelling staff and recording them on field note books.

Reading vertical distances

To take the staff readings the following procedure are carried out:

(i) The level is set up at a convenient position, such as X and the level staff is placed over the benchmark (BM), such as the BM of a reduced level of 100 m (Figure 3.80). Then, the first reading, called back sight (BS) is taken at the BM. Let its value be 1.82 m.

(ii) The staff is now moved to points A and B in turn and readings, called intermediate sights (IS) are taken. Let their values be 1.0 m and 0.6 m. The staff is moved from station B to C and the last reading let its value be 0.25 m, called foresight (FS) is taken with the first set up of the instrument.

(iii) After taking the last reading in the first set up of the instrument, the level is moved to the second position, say Y. Then, the staff held at station C is turned towards station Y and a back sight reading is taken at it. Let its value be 1.94 m (Figure 3.80). The staff is moved from station C to D and the last reading, called foresight (FS) is taken before the instrument is shifted again, or the levelling observation stops. In Figure 3.80, BM is a benchmark, A and B are intermediate sights and E is the last station while X, Y, and Z are instruments stations.

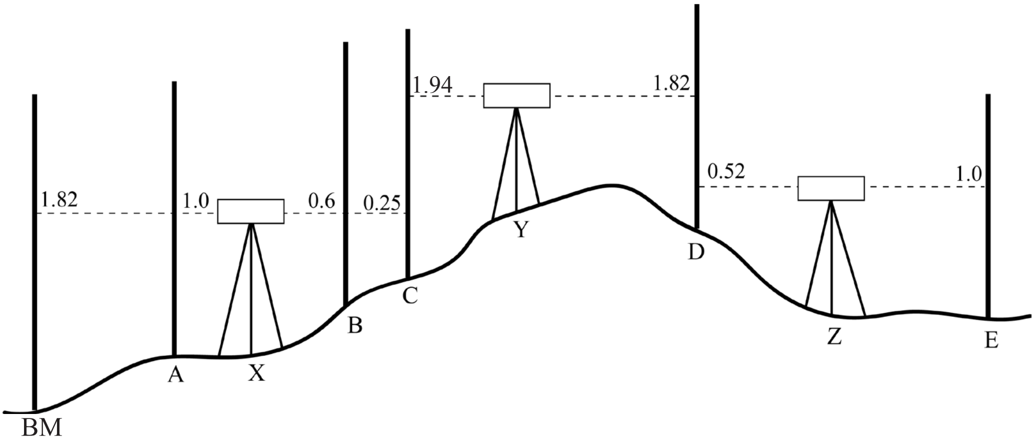


Figure 3.80: *Levelling procedures*

Recording staff reading

The staff readings are then recorded on a field note book and reduced using the rise and fall method or the height of collimation method.

Rise and fall method

In rise and fall method, the amount which a point is above or below another point is determined by subtracting each staff reading, the IS or FS from the preceding staff reading, which could be the BS or IS. The method uses a table of eight columns, namely, Station, BS, IS, FS, Rise, Fall, RL and Remarks. At each row, staff readings and reduced level at a particular station are recorded. The following procedures are followed in Rise and Fall method:

(i) In the first row, record reading taken at the first station, BM. The station identifier is recorded in the first column, the BS in the second column and the RL in the seventh column. In the last column a remark is provided (Table 3.3).

(ii) In the second row, record the station identifier, A and the IS in the third column.

(iii) Subtract staff reading at A (IS) from sight reading at BM (BS). If the difference is positive, point A is relatively above BM, meaning there is a rise in ground surface from BM to A. Record the difference in the fifth column called Rise. If the difference is negative, point A is relatively below BM, meaning there is a fall in ground surface from BM to A. Thus, the difference should be recorded in the sixth column, called Fall. The negative sign should be ignored when recording Fall values, that is only magnitude values should be recorded.

(iv) Calculate the RL of station A by adding the Rise to or subtracting the Fall from the RL of the BM. In this case, a Rise at A is added to the RL of the BM and recorded in the seventh column. Repeat the procedures (i) to (iv) for stations B, C, D and E (see Table 3.3).

(v) At the end of the table arithmetic check must be shown. The check is given by:

$\Sigma BS - \Sigma FS = \Sigma(Rises) - \Sigma(Falls) = RL_{LAST} - RL_{FIRST}$

Table 3.3: *Rise and fall method*

Station	BS (m)	IS (m)	FS (m)	Rise (m)	Fall (m)	RL (m)	Remarks
BM	1.82					100.00	Benchmark
A		1.00		0.82		100.82	
B		0.60		0.40		101.22	
C	1.94		0.25	0.35		101.57	Change point
D	0.52		1.82	0.12		101.69	Change point
E			1.00		0.48	101.21	Last station

$\sum BS = 4.28\ m$

$\sum FS = 3.07\ m$

$\sum (Rises) = 1.69\ m$

$\sum (Falls) = 0.48\ m$

RL of the last station (RL_{LAST}) = 101.21 m

RL of the first station (RL_{FIRST}) = 100.00 m

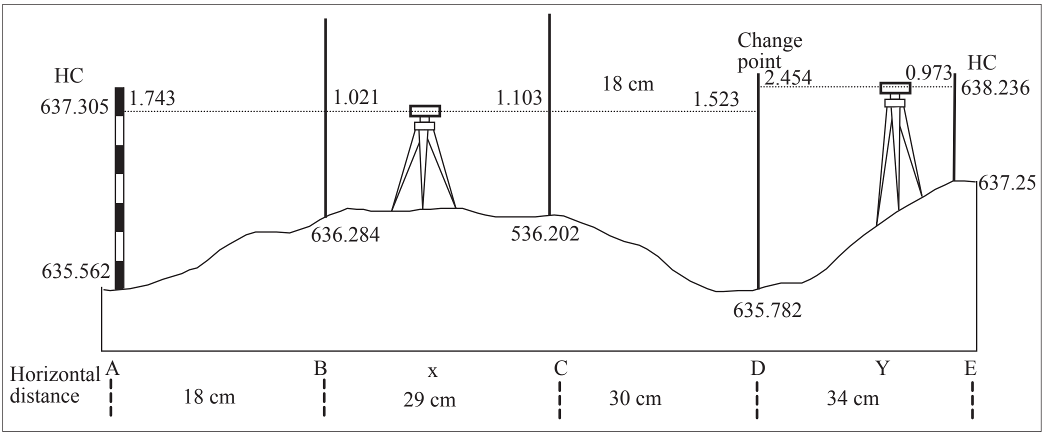
Since $\Sigma BS - \Sigma FS = \Sigma(Rises) - \Sigma(Falls) = RL_{LAST} - RL_{FIRST}$

4.28m − 3.07 = 1.21m, 1.69m − 0.48m = 1.21m, 101.21m − 100.00m = 1.21m

Therefore, recording and reduction of levelling was correctly done.

Example

Record and reduce levelling data using Rise and Fall method.



The staff reading in Figure 3.80 are recorded and reduced as shown in Table 3.4.

Table 3.4: *Rise and Fall method for a profile levelling in Figure 3.76*

Station	BS	IS	FS	Rise	Fall	RL	Remark
A	1.743					635.562	Benchmark
B		1.021		0.722		636.284	B
C		1.103			0.082	636.202	C
D	2.454		1.523		0.42	635.782	Change point
E			0.973	1.481		637.263	Last station

$\Sigma BS = 4.197$ m

$\Sigma FS = 2.496$ m

$\Sigma BS - \Sigma FS = 4.197 \text{ m} - 2.496 \text{ m} = 1.701$ m

$\Sigma(\text{Rises}) = 2.203$ m

$\Sigma(\text{Falls}) = 0.502$ m

$\Sigma(\text{Rises}) - \Sigma(\text{Falls}) = 2.203 \text{ m} - 0.502 \text{ m} = 1.701$ m

RL of last station (RL_{LAST}) = 637. 263 m

RL of the first station (RL_{FIRST}) = 635.562 m.

$RL_{LAST} - RL_{FIRST} = 637.263 \text{ m} - 635.562 \text{ m} = 1.701$ m

Since $\Sigma BS - \Sigma FS = \Sigma(\text{Rises}) - \Sigma(\text{Falls}) = RL_{LAST} - RL_{FIRST} = 1.701$,

Therefore, the recording and reduction of levelling was correctly done.

Height of collimation method

In height of collimation method, the height of collimation (HC) is determined at each instrument set up by adding the BS to the respective RL. The method uses a table of seven columns, namely, Station, BS, IS, FS, HC, RL and Remarks. At each row, staff readings and reduced level at a particular station are recorded.

The following procedures are followed for height of collimation method:

(i) In the first row, record reading taken at the first station, say BM. The station identifier is recorded in the first column, the BS in the second column and the RL in the seventh column. Add a staff reading at BM (BS) to the RL of the BM to get the height of collimation (HC) at the first instrument set up, and record it in the fifth column. In the last column a remark is provided (see Table 3.5) that uses data from Figure 3.78.

HC at first set up = BS at BM + RL of station BM

(ii) In the second row, record a staff reading taken at A (IS) in the third column. Then, subtract staff reading at A (IS) from HC of the first setup of instrument to get the RL of station A and record it in the sixth column. Continue determining and recording RL at all stations observed in the first set up (see Table 3.5).

RL at A = HC at first set up – IS at A

RL at B = HC at first set up – FS at B

(iii) Add a BS reading taken at B in the second set up of the instrument to the RL of station B to get the second height of collimation (HC) and record it in the fifth column as shown in Table 3.5.

HC at second set up = BS at B + RL of station B

(iv) In the fourth, fifth and sixth rows, subtract staff reading taken at stations C, D and E from the HC of the second set up of instrument to get their respective RL and record them in the sixth column.

RL at C = HC at second set up – IS at C

RL at D = HC at second set up – IS at D

RL at E = HC at second set up – IS at E

(v) Repeat the procedures (iii) to (iv) for any instrument set up that follows.

(vi) At the end of the table, arithmetic check must be shown. The check for height of collimation method is given as:

$\Sigma BS - \Sigma FS = RL_{LAST} - RL_{FIRST}$.

Table 3.5: *Height of Collimation method for a profile levelling*

Station	BS (m)	IS (m)	FS (m)	HC (m)	RL (m)	Remark
BM	0.55			122.05	121.50	Benchmark
A		0.45			121.60	
B	1.82		1.72	122.15	120.33	Change point
C		2.01			120.14	
D		1.50			120.65	
E			1.00		121.15	Last station

$\Sigma BS = 2.37$ m

$\Sigma FS = 2.72$ m

$\Sigma BS - \Sigma FS = -0.35$ m

RL of last station (RL_{LAST}) = 121.15 m

RL of the first station (RL_{FIRST}) = 121.05 m.

$RL_{LAST} - RL_{FIRST} = -0.35$ m

Since $\Sigma BS - \Sigma FS = RL_{LAST} - RL_{FIRST} = -0.35$ m,

Therefore, the recording and reduction of levelling was correctly done.

Remember:

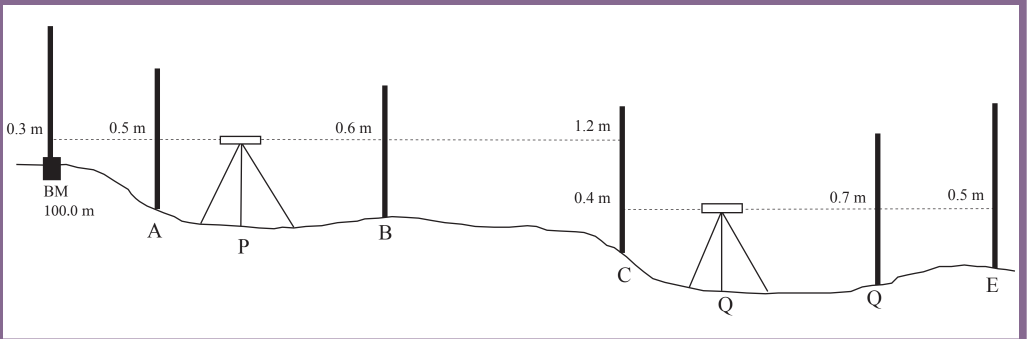
(i) Only, one staff reading is recorded in each row, except at a change point. In Table 3.5 for instance, one staff reading is recorded at the first, second, fourth and fifth rows, while two staff readings (BS and FS) taken at change point (CP) B are recorded in the third row.

(ii) In Height of Instrument or Height of Collimation, the HC is recorded at a BM and every change point. In Table 3.5 for instance, HC is recorded at BM change point (CP) B.

(iii) In rise and fall method, only magnitude values of rise and fall are recorded, their associated algebraic signs are not written.

Activity 3.9

1. Identify intermediate stations and change points in a profile levelling shown in given figure.
2. In the following figure, record and reduce the following staff reading at station A to E using; (a) rise and fall method (b) height of collimation method.



Staff reading along a profile levellin

Application of levelling

Levelling skills and knowledge are of great demand in our daily life. Apart from the general problem of determining the difference in levels between two points, the main applications of levelling are in contouring, preparation of longitudinal and cross-sectional profiles and setting out of levels in construction works.

Contouring

Contouring is the process of creating contours. Contours are imaginary lines connecting points of equal elevation. Contouring can be done using direct method or indirect method.

Direct method of contouring

In the direct method of contouring, points defining a contour line are pegged out on the ground and their horizontal positions determined. The contouring method involves the following procedure:

(i) A level is set at a convenient position in the area and a BS reading is taken at an appropriate bench mark.

(ii) The height of collimation is found and the required staff reading for a contour line is calculated. The required staff reading is determined by subtracting a contour on the height of collimation staff reading (IS or FS) = HC – contour value.

(iii) The instrument man asks staff man to move up and down in the area till the required staff reading is found. In Figure 3.81, a staff reading of 1.3 m is needed to mark a contour of 101.5 m. The staff was first held at point 1 and its reading was higher than 1.3 m, thus it was moved to points of higher elevations until a staff reading of 1.3 m was taken.

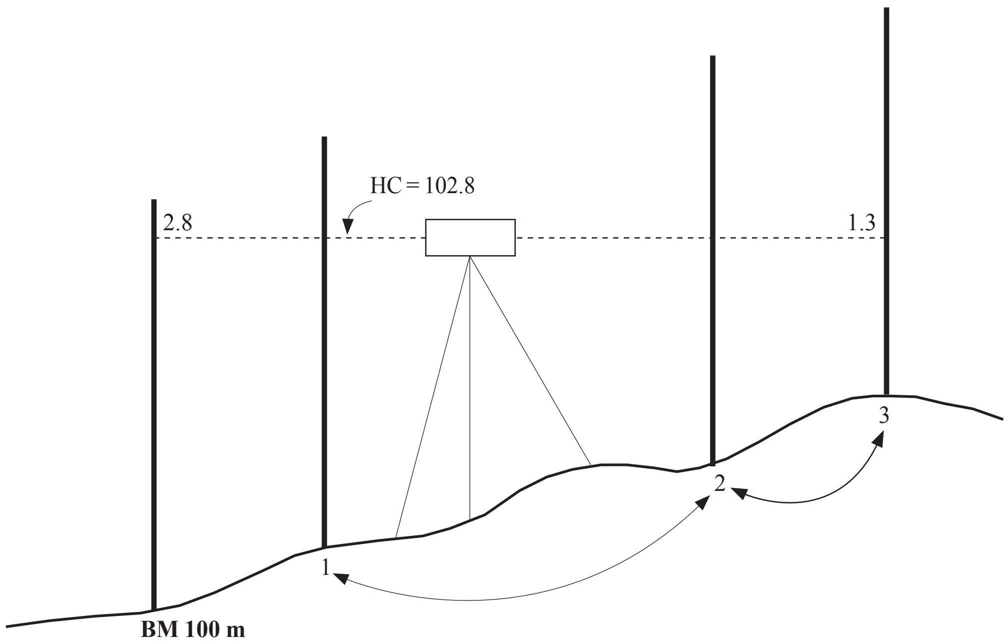


Figure 3.81: *Direct contouring*

Then, a surveyor determines the horizontal coordinates of that point using chain surveying, compass surveying, plane table surveying or other advanced surveying. The method is very accurate but, slow and tedious.

Activity 3.10

A contour line connecting points of elevation of 105 m is to be established by direct method from a benchmark of 103.625 m. Determine the staff reading at points where the contour line passes.

Indirect contouring

In the indirect contouring method, staff readings are taken at some selected points and their levels are reduced. That is the horizontal position is established first and then the levels of those points are found. After locating the points on the plan, reduced levels are marked and contour lines are interpolated between the selected points. During the interpolation it is assumed that the ground is uniform between any two spot heights. The indirect method is further classified into grid and radiation methods based on the approach used to select points for staff reading.

Grid method

Grid method is best suited to gently sloping undulating land and fairly small areas. In this method the area to be surveyed is divided into grid or series of squares. The grid corners are marked on the ground and their spot heights are determined through levelling. The grid is plotted to the scale and the spot heights of grid corners are entered. The contours of desired values are then located by interpolation as shown in Figure 3.82.

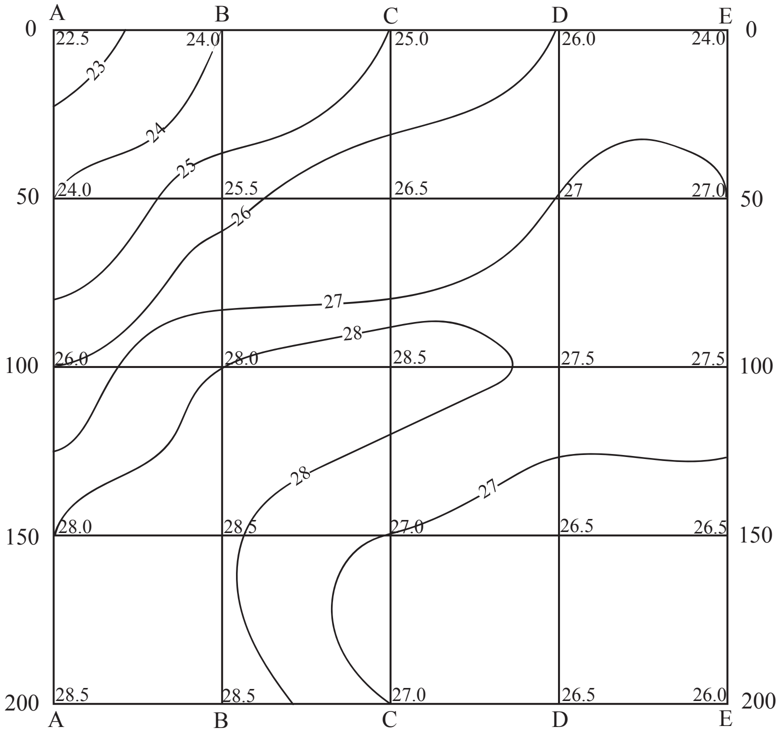


Figure 3.82: *Grid method of indirect contouring*

Radiation method

Radiation method is useful for areas located in small hills. The method establishes a central position on a hill and set out radiating lines using the prismatic compass, theodolite or total station. Points are then marked on ground at a regular interval along the radiating line and their spot heights are determined through levelling. The radiating lines and the marked points are plotted to scale and the spot heights of the marked stations are entered. The contours of the desired values are then located by interpolation as shown in Figure 3.83.

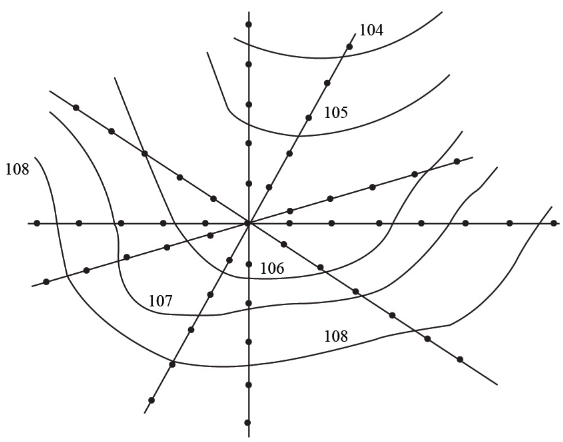


Figure 3.83: *Radiation method of indirect contouring*

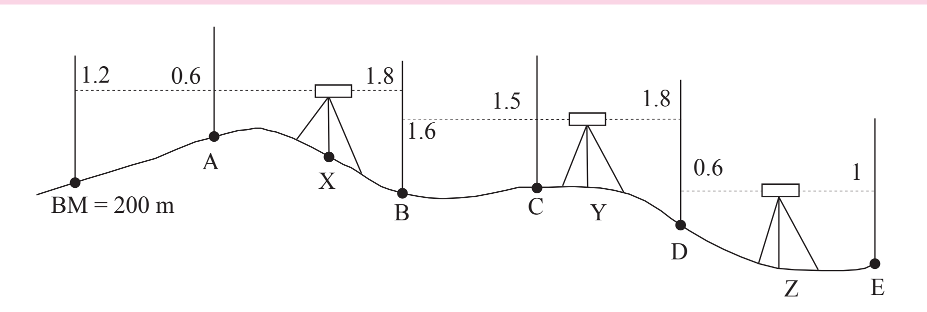
Errors in levelling

The fact that surveyors' personalities and ability to adhere to ethical guides of survey to be unavoidable. Just as may be the case with other surveying methods, errors in levelling exist and can be grouped into Personal errors (due to natural causes) and instrumental errors. Personal errors can include those resulting from sighting problems, manipulation errors, error in reading the staff, those from recording and computation. Sighting errors can be a result of visual impairment or failure of a tool's cross hair to coincide with the staff graduations. The later could be a result of either due to long sights or due to coarseness of the cross hairs and the staff. In some cases, natural changes of atmospheric conditions during the practice, such as the presence of mist or fog can impair visibility of the staff from the instrument man, hence errors. This category of errors can be accidental and compensative.

Manipulation errors are mistakes or blunders as other surveyor's call. In most cases, they originate from failed adherence to surveying ethics. They may be caused by careless setting up of a level; the presence of parallax (the imperfect focusing on eyepiece and objective) and imperfect levelling of an instrument. Too much trust over your experiences or assumptions and instrument's verticality cause an error of no-verticality of the staff. The absence of a staff bubble plate attached to a staff causes difficulty in holding of the staff verticality. Other equally defective causes for errors are incorrect reading, recording and computation of the staff reading.

Exercise 3.4

1. Mention components of a level machine.
2. A profile levelling was carried out to determine elevations of stations A, B, C, D, and E as shown in the following figure indicating profile levelling through stations A, B, C, D, and E.



(a) Identify intermediate stations (IS) and change points (CP).

(b) Record staff readings and determine the reduced levels of stations A, B, C, D, and E using;

(i) Rise and fall method.

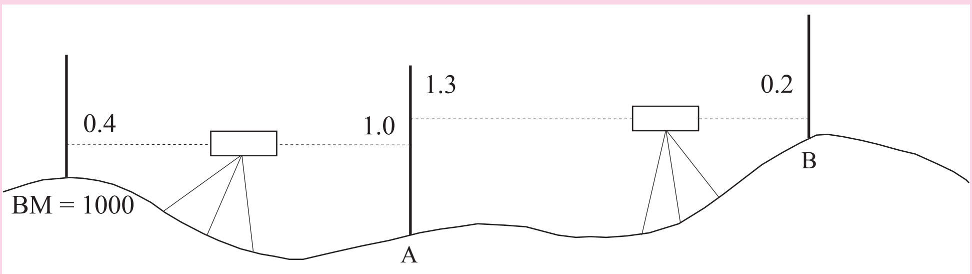
(ii) Height of collimation method.

(c) Perform the arithmetic checks for the two methods applied in (b) above.

3. Complete by filling in the following table using height of collimation method.

Station	BS	IS	FS	HC	RL	Remarks
BM	1.82				500	Benchmark
A		1.68				
B		1.42				
C	1.40		0.68			
D		1.48				
E		1.62				
F			1.84			
	ΣBS =		**ΣFS =**			

4. Record staff readings shown in the following figure and calculate the reduced level of points A, B, and C using rise and fall method.



Staff readings at BM, A, and B.

5. (a) What is the meaning of land survey to a geographer?

(b) Using relevant examples, differentiate chain survey from levelling.

(c) Explain four (4) ways in which chain survey is significant in the day to day life.

Revision exercise 3

1. (a) Write short notes on the following;
   (i) Differential levelling
   (ii) Profile levelling
   (b) Describe instruments used in leveling.
2. (a) Differentiate;
   (i) Vertical line and vertical control.
   (ii) Horizontal line and horizontal plane.
   (iii) Level surface and level line
   (iv) Mean sea level and bench mark.
   (b) Identify the sources of errors in levelling, and explain how personal errors can be reduced.
3. The following consecutive readings were taken with a level and a 4m levelling staff on a continuously sloping ground at common interval of 30 m. 0.855 on A, 1.545, 2.335, 3.115, 3.825, 0.455, 1.380, 2.055, 2.855, 3.455, 0.585, 1.015, 1.850, 2.755, and 3.845 on B.
   (a) Make the entries in a level book and apply the usual check.
   (b) Determine the gradient of AB.
4. Differentiate the following terms:
   (a) Isogonic line and agonic lines.
   (b) Irregular and secular variation.
   (c) Diurnal and annual variation.
   (d) Prismatic and surveyors compass.
   (e) Well-conditional triangle and ill-conditioned triangle.
5. Give out six differences between prismatic and surveyors compass.
6. Explain procedures of adjusting a prismatic compass.
7. The following consecutive readings were taken with a dumpy level along a chain line at common interval of 15m. The first reading was at a chainage of 165 where RL is 98.085. The instrument was shifted after fourth and ninth reading, and the following readings were recorded; 3.150, 2.245, 1.125, 0.860, 3.125, 2.760, 1.835, 1.470, 1.965, 1.225, 2.390 and 3.035.
   (a) Make entries of the observed readings.
   (b) Find the RL of all points by using the height of collimation and rise-fall methods.
8. Describe types of survey stations and survey lines.
   (a) Why perpendicular offsets are more preferred than oblique offsets.
   (b) Outline the guidelines of establishing offsets.
   (c) Outline factors that determine the length of offsets.
9. Explain eight criteria that you would consider in order to select survey stations.
10. Differentiate single-lines from double line field book.
11. Analyse eight precaution you will take while entering in the field book.

12. Describe procedures of plotting field data.
13. Describe instruments used in differential levelling.
14. Describe six natural errors in levelling survey.
15. Explain personal errors in levelling.
16. Differentiate between errors and mistakes.
17. Explain six common mistakes during leveling.
18. Suggest six ways by which errors can be minimized in leveling survey
19. A differential leveling loop began and closed on BM Tree (elevation 654.07 ft). The plus sight and minus sight distances were kept approximately equal. Readings (in feet) listed in the order taken are 5.06 (+) on BM Tree, 8.99 (–S) and 7.33 (+S) on TP1, 2.52 (–S) and 4.85 (+S) on BM X, 3.61 (–S) and 5.52 (+S) on TP2, and 7.60 (–S) on BM Tree. Prepare, check, and adjust the notes.
20. A differential leveling circuit began on BM Hydrant (elevation 1823.65 ft) and closed on BM Rock (elevation 1841.71 ft). The plus sight and minus sight distances were kept approximately equal. Readings (in feet) given in the order taken are 8.04 (+S) on BM Hydrant, 5.63 (–S) and 6.98 (+S) on TP1, 2.11 (–S) and 9.05 (+S) on BM 1, 3.88 (–S) and 5.55 (+) on BM 2, 5.75 (–S) and 10.44 (+S) on TP2, and 4.68 (–S) on BM Rock. Prepare, check, and adjust the notes.
21. Describe the method of chaining along the sloping ground.
22. (a) Analyze the common mistakes in chain survey.
    (b) Provide eight precautions against errors and mistakes in chain survey.
23. Classify survey on the basis of instruments and describe all necessary equipment for field work involving one of them.
24. With the aid of a neat sketch, describe how ranging across the chain obstacle can be done.
25. Give a critical description of different chains used in surveying while indicating relative advantages of each.
26. Identify at least six precautions to be observed when entering the field data.
27. A crossed traverse is conducted with five stations A, B, C, D, and E in anticlockwise direction to form the pentagon. If FB of AB is 400, find the FB of other sides
28. Describe methods of plotting the compass traverse
29. (a) How closing errors occurs in traverse?
    (b) By using the Bowditch's rule, explain procedures of adjusting the mis-closure.

30. (a) What is local attraction?
    (b) How will you detect and correct local attraction?
31. Describe procedures of setting up the plane table over a station
32. (a) What is three-point problem?
    (b) By using the Bessel's method describe how it can be resolved.
33. (a) Differentiate between traversing and parallelism.
    (b) How does plane table survey differs from other methods of surveying.
34. (a) What is plane table orientation?
    (b) Explain methods of orienting the plane table.
35. (a) Describe plane tabling procedural by intersection and resection.
    (b) Describe plane tabling procedural by radiation and traversing methods.
36. (a) In which circumstances does differential leveling recommended?
    (b) Differentiate height of instrument and rise-fall method.
37. Jamasule is studying at Karume Institute of Science, Faculty of Engineering. He was assigned to conduct survey around sloped area in his college environment.
    (a) Identify an appropriate surveying technique which might be used.
    (b) Describe for equipments which can be used in the surveying technique named in (a) above.
    (c) Explain four uses of the surveying techniques named in (a) above.
38. The magnetic bearing of the line CD is S 30° 15' W. find the true bearing if the declination is 20° 15' E.

Chapter Four

Maps and map interpretation

Introduction

Map reading and interpretations are important skills in the world today. Geographers and non-geographers use the skills of reading and interpreting different types of maps. In this chapter, you will learn about different types of maps, measurements on topographical maps, presentation of relief on the maps and map interpretation. The competencies acquired from this chapter will enable you to do some daily activities such as distance measurements, area calculation and decision making on socio-economic activities of an area with reference to the skills obtained from map and map interpretation.

Maps

Maps are scaled representation of all or part of the earth on a flat surface such as sheet of paper or wood. It is a graphical representation of places by using points, lines, symbols and colors to show how selected cultural and natural features are located, arranged and related to one another. Maps can represent distributions and patterns of settlements, streets, transport routes, climate and location of human activities. A person who makes maps is called a *cartographer*.

Main characteristics of a map

Maps of whatever kinds have more or less common defining identities, acting as the characterising features which include the following: A typical map is represented to scale since the area on which it is drawn is much smaller compared to reality on the earth's surface, which is much larger with a lot of features. That is why, every map is drawn to a certain scale, the size of which depends on the coverage intended by the cartographer. Therefore, the amount of reduction by which the ground reality is reduced varies from one map to another, due to the use of different types of scales. Usually, the amount of reduction increases with an increase in the ground surface coverage intended to be mapped. Therefore, a map comprises scale to show the extent or degree by which the ground reality has been reduced to suit the desired area of the material on which the map has been drawn.

The map uses signs and symbols. The surface of the earth, that a map represents, is of a wide coverage and consists of different features such as vegetation, water bodies, relief, and settlement patterns among others. Normally, symbolic representation of these features is conventionally agreed. Different symbols are used depending on the nature of the features to be represented. Common symbols used include point symbols, which stand for features that appear in point form, such as houses, line symbols representing features which appear in the form of lines such as roads and area symbols that stand for features of wide coverage such as swamps. All these symbols are defined in a key which guides meaningful map interpretation, since each symbol is purposely selected to stand for a particular real object or fact in the real ground surface.

Map is a projection. Maps are drawn from the mathematically transformed curved earth so as to present them on flat surface. Therefore, maps are representation of the three-dimensional earth into the two dimensional flat surface. A map is a model of reality. It is a representation of certain geographical features that exist in real life.

A map is a generalisation of information and is selective. Since it cannot include everything found in the area, some information is generalised. The extent of generalisation depends on the number of factors including the scale, the purpose of the map and the interest of the cartographer. Generalisation normally increases with the coverage which is determined by the size of the scale. Symbols which stand for the real objects on the earth's surface are generally selected. For instance, a dot may be used to represent houses which are not in the same size and quality.

In addition, a map is communicative as it conveys meaning of different kinds, depending on the nature of the area it represents and the purpose of its production. With important map interpretation skills, even a person who is not familiar with the place on the map can extract or interpret the map and get the meaning represented by the map.

A map is a source of geographical data. It is difficult for human beings to store in mind different trends of events on the earth's surface such as land cover and general spatial distribution of cultural and natural features. Therefore, the map is the best medium in which information is stored. Data from a map can be used in different fields such as pedology, engineering, demography, geology, hydrology and policy formulation for sustainable development. Map shows only a static situation. For example, the map of Babati produced 30 years ago would not show the current situation in the area, instead that of 30 years past. However, due to changes caused by nature and the influence of human activities geographical areas also change. Due to this it is important for the user of the map to consider the date of its production to get the most appropriate information

The value of maps to a geography student

Maps are widely used in human life and particularly in Geography as a discipline. Maps act as the bases for description of the area depending on the nature of the fields in which they are applied. Since maps represent the earth's surface, they portray the existing relationship between features such as geomorphology and hydrology.

Maps provide an outstanding base for spatial description of geographical phenomena. The knowledge and skills of map reading and interpretation are keys for understanding the geographical characteristics of the area in terms of relief, climate, drainage system, soil type and their relative significance to human life. The map orients the geography student to the knowledge of geographical skills including cartographical techniques related to map production and preparing them to become the best cartographers in the future. Maps also enhance critical thinking of the students as it requires the integration of knowledge in interpreting and understanding a certain mapped area. For instance, to understand clearly nature of drainage, a student has to integrate basic knowledge about geology, pedology and geomorphology.

Maps act as the mirror of past geographical events through which a student can see the mapped area today and detect some changes that have occurred overtime. Maps provide much information about the nature and distribution of geographical phenomena such as settlement and settlement patterns. The use of maps enable the student to provide insight into the existing relationships between igneous rocks and tectonic activities, relief and drainage, climate and vegetation, and the way these natural relationships influence peoples mode of life, particularly construction and distribution of human settlements.

Maps also provide a basis for studying geographical problems such as floods, storms and deserts. Maps provide valuable data for statistical analysis such as population distribution and rainfall patterns. Researchers provide valuable information for research project with the help of maps.

Types of maps

Maps are normally of different types. Despite the existing varieties of maps, each of them serves the purpose of its production in the intended area of specialisation. The following are different types of maps and their respective criteria for classification.

(a) Basing on the function and content; maps are classified into topographical and statistical maps:

(i) *Topographical maps:* are maps designed to represent both cultural and natural features. The word topography is derived from the Greek word “topos” which means “place”. Topographical maps are drawings of a part of the earth’s surface. These maps show location by using compass bearing, grid reference, latitudes, longitudes and names of places. They also show cultural features such as roads, railways, cities, town and dams; landscapes such as mountains, valley and plateaus; and drainage like rivers, lakes and ocean. Therefore, through interpretation of maps, someone may have a thorough understanding of an existing area even without their physical presence in the area.

Topographical maps are useful for describing features of the earth's surfaces, planning the best uses of land and guiding people to reach their destinations. In general, development of physical infrastructures such as roads, agricultural projects and sustainable human settlement are all depending on the data from topographical maps.

(ii) Statistical (distribution) maps: are maps which represent distribution of geographical phenomenon. Geographers are also interested in careful investigation and visualisation of spatial distribution of different geographical events and phenomena particularly climatic elements like rainfall, temperature, atmospheric pressure, wind speed, sunshine intensity among others. Moreover, distribution of animals, agricultural activities and movement of goods are among the interests of geographers. Statistical maps are of different types such as dot maps, isoline maps, and Choropleth maps among others. Statistical maps are also called quantitative maps as they communicate a message of magnitude. They show variation in value and quantity over a space.

(b) Basing on degree of accuracy: maps can be classified as surveyed and sketch maps.

Surveyed maps: involve mathematical principles and theories in their production. Since the map represents the earth's surface which is spherical in nature on the flat surface, mathematical principles and theories are applied so as to transform a curved and spherical shape of the earth to a flat surface. This application gives us topographical maps.

Sketch maps: are types of maps which are roughly drawn with no mathematical basis like scale. They can be drawn even in other subject text books such as history to illustrate certain concepts or showing historical sites, in a particular country.

(c) Basing on size of the scale, maps are classified as small scale, medium and large scale maps.

Small scale maps: are drawn by using a small scale to give a large coverage of the earth's surface even the entire earth. These maps usually contain large quantity of features and are less detailed, depending on the extent of coverage.

Medium scale maps: are drawn by using a medium scale to provide a medium representation of the earth's surface.

Large-scale *maps:* are drawn to a large scale to cover a small area of the earth's surface, such as school or part of an urban area. These maps contain less quantity of features and are more detailed.

Contents of topographical maps

Topographical maps consist of three major kinds of contents which are *natural contents, cultural contents* and *supportive contents*. Natural contents are all features that are not man-made, they include features such as mountains, valleys, soil types, plateaus, natural vegetation like natural forest, water bodies like rivers, lakes, and oceans. Cultural contents include all man-made features such as roads, railways, buildings, dams, artificial or planted forests and so on. The supportive contents include information of a map which are provided with the aim of assisting the reader of the map.

Supportive information

Due to the symbolic nature of maps, its correct and meaningful interpretation is impossible without supportive information. These are supportive contents of a map are written close but not limited to the margin of the map. They include title, boundary, North direction, scale and key or legend. Others include date of compilation, sheet number, publisher and copyright, grid reference, latitudes, longitudes and projection techniques. They are called supportive because they help the map user to interpret the map correctly.

Title

The title also known as the heading, is an element in a map that describes the theme or subject of a map.

The title sometimes appears as the name of the mapped area or as the combination of the name of the mapped area and the purpose intended to be shown. When it appears just as the name, it is called *general title*, for instance, "Songwe region map". A map with this kind of a title can show a wide range of information. However, when it appears in combination with its purpose it is called *specific title*. For instance, "Songwe region relief features" normally intending to show specific information like relief features of Songwe region. A title is normally communicative to some extent as it provides some important clues on the nature of the mapped area in terms of economic activities, drainage, soil quality and climate in particular. The title always should provide an answer to what, where, and when.

Margin

Margin also known as boundary, is the frame that encloses the map to show the endings and the coverage of the area, often varying in size from one map to another. If the map covers a more extended area, its boundary is likely to be larger, than when it covers a small area. Usually, the map boundary has a uniform space in all sides from the map. But there are maps which show only part of a place within its boundaries, usually, maps of this type do not have margin or boundaries.

Legend

Legend also known as a key, is a collection of symbols and signs used in the map and their respective meaning. Though some symbols used in the map are self-explanatory, the key is actually intended to act as the map dictionary, to facilitate the correct and meaningful map interpretation through describing all unknown or unique symbols used on the map. Since map symbols are conventionally agreed, the key helps the map users to translate the map language into the ordinary language which can be simply understood. Map language is the system of conventional symbols and signs used to represent features of the mapped area. It also helps the map user to know the relationship between different features on the map. For instance, point (•) symbols that stand for settlements, always appear along the line symbol which stands for roads and rivers.

Map scale

Map scale is the ratio between distance on a map and the actual distance on the ground. Therefore, it shows representation of distance on the map by translating the value of distance on the ground. This simply means that the scale is the determinant factor of each feature that is represented in terms of size. Map scale is important in map making since it commands the coverage and amount of information to be included. It also helps the map users to make the interpretation of the real features they read on the map. The scale also acts as the basis of map classification.

Direction indicator

A direction indicator is an arrow printed on a map to indicate the orientation of the map in reference to cardinals N-S-E-W. The indicator determines the orientation of the map which facilitates interpretation of the map by locating the position of each feature. This is a *North arrow* (Figure 4.1 (a)-(e)). It shows the north direction of the map used to determine other directions, such as South, West and East. It enables the map user to determine trend and alignment of features on the map, fix positions of other features by resection and intersection method. Other maps indicate direction by using a *compass rose,* with arrows pointing in all four cardinal directions.

(a) (b) (c) (d) (e)

Figure 4.1: *Examples of direction indicators commonly used on topographical maps*

Date of compilation

It indicates the time when the map was published. This guides the readers to select map versions basing on their time barred needs. It is very useful in recognising some changes that might have occurred in the area within a given time interval. Normally, land cover such as vegetation, settlement and water sources keep on changing with time. For instance, "Dodoma region map" of twenty years ago will be quite different from the current map.

Sheet number

Maps sharing the same series are distinguished by the sheet number that shows what geographical area is covered by the map. It means that maps of the same series have different sheet numbers for different areas. Sheet number also shows how many times a given map has been up-dated.

Publisher and copyright owner

Map indicates the owner of the particular map and the publishing company. The author or publisher of a map is indicated, so as to be familiar with the cartographer to easily get useful clues on information regarding the extent to which the map is biased or reliable. This will be useful in drawing attention on questions such as "Does the map maker or organization have vested interest in how the map is perceived by the map reader?"

Grid references

Grid references refer to the patterns of equally spaced vertical and horizontal lines that are perpendicularly intersecting to each other forming squares. It is the geographical coordinate system by which different parts and features on the map are located. The vertical lines are called eastings as their number increase eastwards, while the horizontal lines are called northings as their numbers increase northwards. In reading the grid reference we start with the eastings and finish with the northings. It is normally determined by the type of projection used in the preparation of a particular map. Apart from locating the position of different features, the patterns of squares, are used in determining the area of features by grid square method.

Latitudes and longitudes

These are the geographical coordinate systems by which positions of the mapped area are determined. Therefore, by using latitudes and longitudes, the angular distance of the mapped area from the equator and the prime meridian respectively can be identified. Additionally, latitudes are important elements of climate, drainage and vegetation interpretation.

Factors that influence the contents of topographical maps

Amount and the nature of the map content are a combined function of a number of factors. Maps are drawn by different cartographers, with different objectives using different scales to represent the earth's surface that differ in terms of nature and amount of the land cover. The following factors determine the content of topographical map.

Scale of the map

The choice of a scale depends on the size of the area represented, under this, the emphasis is put in three cartographic choices of a map scale namely large, small and medium scale. For example, small scale maps are less detailed. Therefore, maps of the same area produced in the same period of time, by the same cartographer are likely to differ in their content, if their scales are not the same.

Purpose of a map

Any type of a map is made by a cartographer based on a certain aim. In this regard, not all information will be depicted on the maps. The aim of the cartographer is to construct or make a map and determine what need to be shown in a given map. Therefore, the content that appears on the map is determined by desired purpose. If the purpose of the map is to show vegetation distribution, other features like settlements will automatically be excluded on the map.

Date of compilation
The date shows a period of time at which a map was produced or published. The information that exists on earth surface is not static, it changes over a period of time. Due to this fact, a map shows information which was represented by the time it was produced. Therefore, the maps of the same area drawn at different periods of time possibly differ in terms of contents. For example, the map of Dar es Salaam drawn in 1960's is definitely quite different from the map of Dar es salaam drawn in 2022.

Nature of the land
Normally the surface of the earth that a map represents is not uniformly covered by features. It is covered by features that differ in terms of amount and nature. Some parts of the earth's surface are covered by water bodies like oceans and lakes while others are covered by forests and settlements. Therefore, the map shows what is found in the area including the differences such as physical features found in a given geographical area. It can then be concluded that maps are mirror images of the real surfaces they represent.

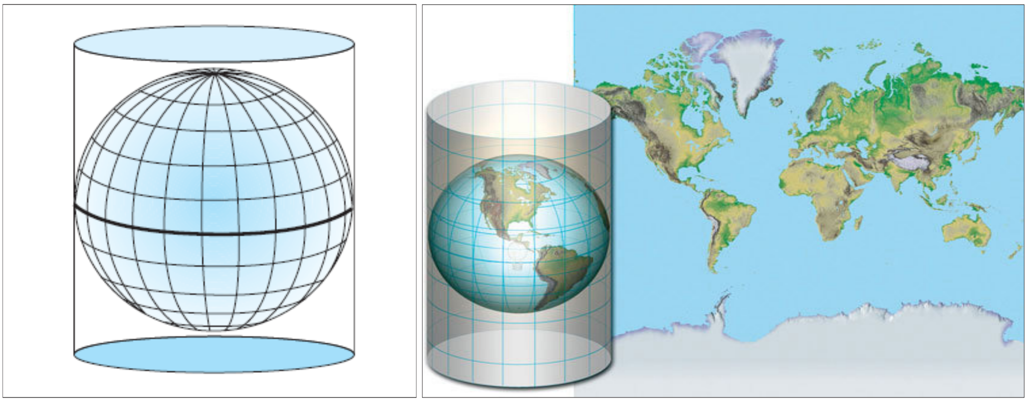
Level of technology
The maps drawn by using modern technology like computer, digital camera, and satellite image, contain more features than those produced by conventional methods such as by using a hand.

Seasons of the year
Map of the same area drawn at different seasons of the year will depict different information. Almost all places do not look the same throughout the four seasons of the year.

Map projection

Map projection refers to the mathematical transformation of the three-dimensional spherical earth into two-dimensional flat surface. Normally, the process is associated with some distortion in area, distance and angles, however the amount of distortion varies depending on the type of projection involved. Even though map projection is associated with such problems, still it is important in map production, because it enables the representation of a three-dimensional curved earth on a flat surface. Therefore, a cartographer is supposed to select a projection technique with minimal and tolerable distortions. Projection can be grouped into three geometrical shapes namely cylindrical projection, conic projection and azimuthal projection.

Cylindrical projection
Cylindrical projection is also known as Mercator projection. In this type of projection, the surface of the globe is wrapped on the surface of a cylinder, in order to transfer the details of the earth to the surrounding cylindrical surface. The details are traced on the surface and rolled out to give a flat surface map (Figure 4.2 (a) and (b)). This type of projection has maximum distortion in the polar areas than in other parts because of the nature of the earth's shape. Areas which are more curved are likely to be highly distorted.

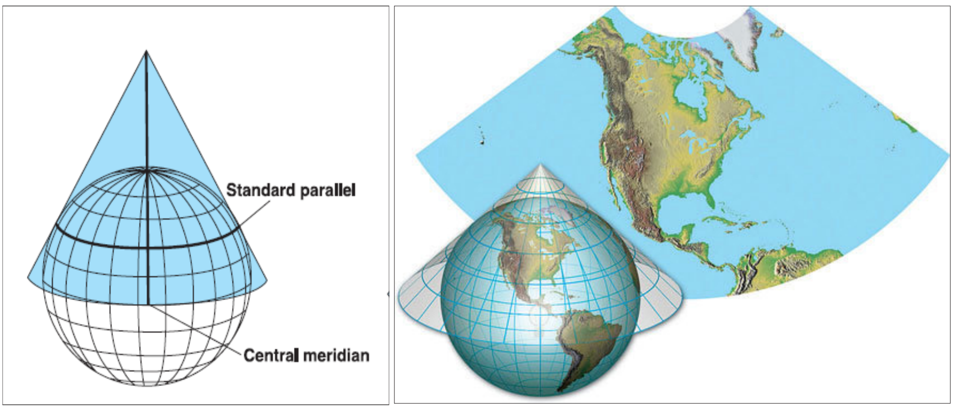


(a) (b)

Figure 4. 2 (a) and (b): *Cylindrical projection technique*

Conic projection

This is a method of projecting maps of the earth's spherical surface on the surrounding cone which is then flattened to plane surface having concentric circles as parallels of latitudes and radiating lines from the apex as meridians. The method works best over mid latitudes (Figure 4.3 (a) & (b)). The cone touches the globe at all points on a single parallel of latitude and the resulting map is extremely accurate for all areas near the parallel but becomes extremely distorted with distance from it. The surface of the globe is projected onto a cone, which rests on top of it, resulting to a flat map with a shape of a fannel. Since the globe only touches the cone at a single line of latitude, this projection is best used in smaller areas of the world, such as countries in the temperate regions including USA and Canada. This method has less distortion in the middle latitudes, however, distortion increases as the distance increases away from the middle latitude.

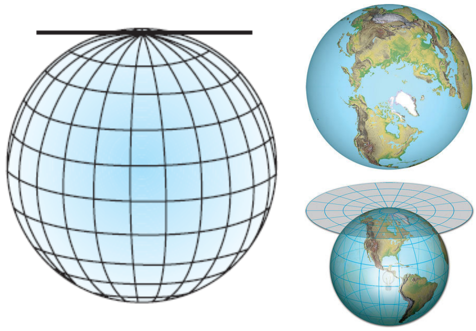


(a) (b)

Figure 4.3 (a) and (b): *Conical projection technique*

Azimuthal projection

Azimuthal projection is also called plane, or Zenithal projection. This is a map projection in which a globe is assumed to rest on a flat surface whose features are projected. In this method, the global surface is at one point and the scale is only accurate at this point. Azimuthal projection is good for map focusing on a hemisphere continent or the poles. When used to show a large area great distortions occur at the edge. It is common projections when mapping the Arctic and Antarctic regions (Figure 4.4 (a) and (b)).



(a) (b)

Figure 4.4 (a) and (b): *Azimuthal projection technique*

Activity 4.1

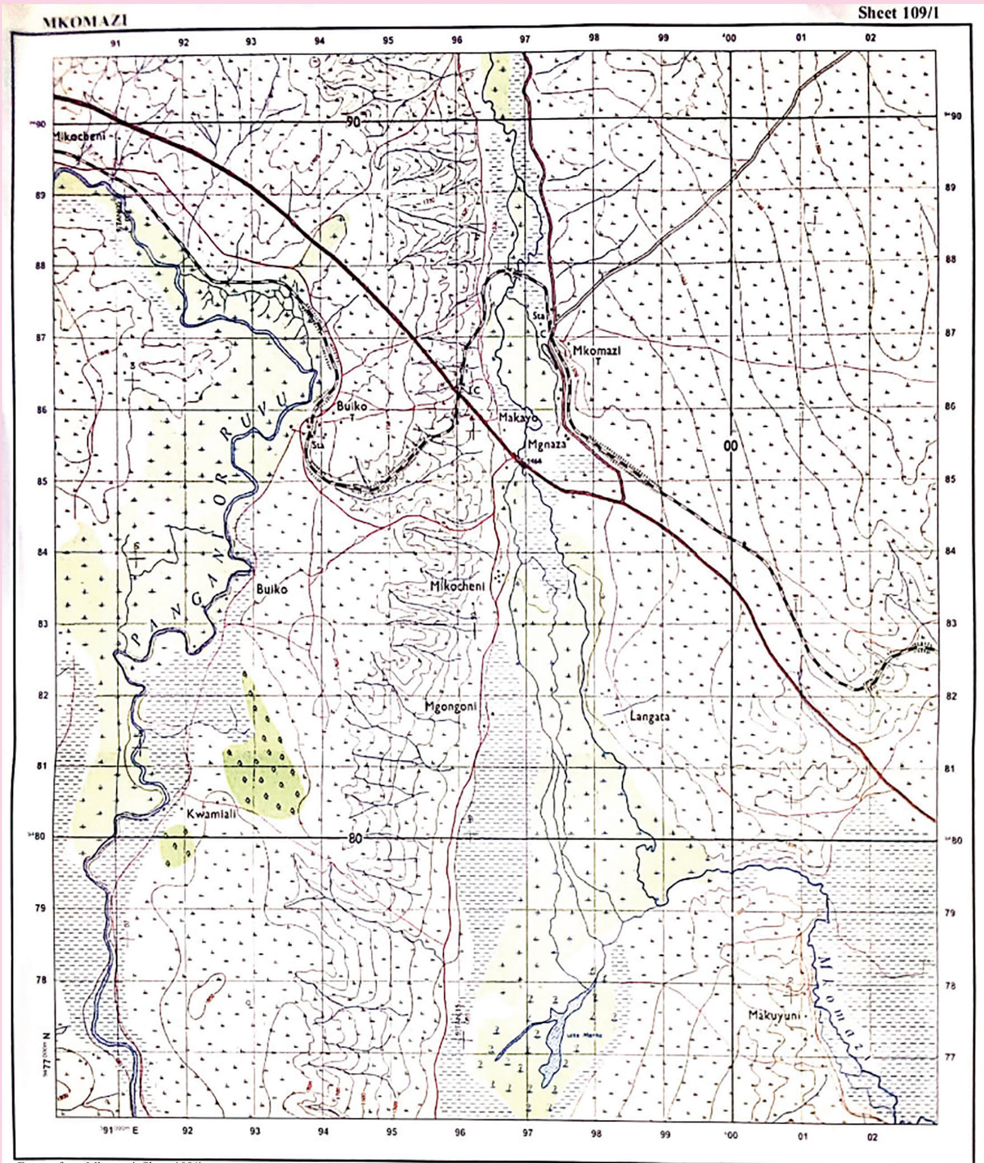
In groups of four students, prepare the sketch map of your school compound, and answer the following questions appropriately:

(a) State in which category your map falls.
(b) Classify symbols that you have used in your map.
(c) State the kind of title of your sketch map.

Exercise 4.1

Answer all questions

1. Explain the following concepts:
   (a) Map reading
   (b) Map interpretation
   (c) Map analysis
2. Why do you think maps are important to you?
3. Suppose you want to show the population distribution on a map, which kind of a map will you use and why?
4. With examples, explain the importance of direction indicators and scale to map maker and user.
5. What do you understand by the term 'map projection'?
6. With examples, explain factors that influences the contents of topographical maps.
7. Classify maps based on the content and degree of accuracy.
8. Study the map extract of Mkomazi sheet 109/1 given below and answer the questions that follow:
   (a) Explain six supportive contents of the given map.
   (b) Provide at least four characteristics of the map extract given.
   (c) Highlight five factors that have influenced the content of the given map.
   (d) With examples, classify the content of the given map.
   (e) When was the map printed?
   (f) Who is the owner of the map.
   (g) State projection technique used in constructing the map and state its usefulness.



Extract from Mkomazi. Sheet 109/1
Series Y 742, Edition 1 . TSD, Ministry of Lands
Government of the United Republic of Tanzania, 1974

HEIGHTS IN METRES

Scale 1: 50,000

1 0.5 0 1 2 3 Kilometers

KEY

- Town or area with Permanent Buildings
- Other Populate Area, Houses
- All Weather Road: Bound Surface
- All Weather Road: Loose Surface
- Dry Weather Roads
- Main Track (Motorable)
- Other Track and Footpath
- Cut Line
- Railway, Siding, Station, Level Crossing
- Railwa Light
- Steep Slope
- Contours (V,1.20m) Depression
- Air Photo Principal Point with Film No.
- Water Course, Waterfall Rapids, Dams
- Water Course, (Wide), Waterfall Rapids
- Watercourse (Indefinite)
- Borehole, WaterHole, Well, Spring
- Bund, Major Fence, Hedge
- Cliff
- Forest
- Tree Swamp
- Papyrus Swamp, Marsh, Boge
- Riverine Trees
- Plantation: (Coffee C, Palm, Sisal S, Sugar Su, Wattle W
- Woodland
- Scrub
- Scattered Trees
- Palm Trees
- Seasonal Swamp

Map scale and its importance

Map scale

Map scale is the relationship or a ratio between the distance measured on the map and its corresponding actual distance on the earth's surface (ground). The earth's surface is much larger than the paper on which a map is drawn. This necessitates reduction of such wide earth's surface, to the extent which depends on the intended coverage. Therefore, a scale shows the extent which a given area has been reduced to fit a particular size of the paper. As a reflection of the reduced degree, map scale can be small, large or medium. Map scale is generally very important to the map maker as it determines the content and the coverage of the area being mapped. On the other hand, map scale is important to the map user as it is a tool for interpretation.

In fact, the map scale tells the reader how the map relates to the real world features it represents. To represent the earth's surface on a map requires sufficient adjustment of the scale to cover the desired objective. The extent of reduction is expressed as a ratio or fraction in which the numerator represents the distance on the map while the denominator represents the corresponding ground distance. The larger the denominator the smaller the scale and the smaller the denominator the larger the scale.

A scale can be expressed as

$$\text{Map scale} = \frac{\text{Map distance}}{\text{Ground distance}}$$

Types of map scale

The map scale is broadly classified into three types namely; small medium and large scale (Table 4.1).The selection of the type of map scale is guided by the following factors namely; the size of the area to be represented, the size of space to represent and amount of details to be shown on a particular map. If the area to be mapped is large, the small scale is selected but if the area is small the large scale is chosen (Table 4.2).

Table 4.1: *Classification of map scales and their units*

S/No.	Type of scale	Scale units in RF	Scale units in statements
1	Small scale map	1:250 000 -1:1 000 000	1 cm to 2.5 km 1cm to 10 km
2	Medium scale map	1:50 000 -1:125 000	1 cm to 0.5 km 1 cm to 1.25 km
3	Large scale map	1:5 000 - 1:25 000	1 cm to 0.05 km 1 cm to 0.25 km

Small scale map

Small scales are scales ranging from 1:250 000 to 1:1 000 000 which are used when much detail is not required. The ratio of these scales has the largest denominator indicating the high reduction of the mapped area which is reflected on the size of the resultant. A small scale map contains large quantity of the content of the covered area. The map covers a large area such as country or a continent or the whole world. Features are greatly reduced and appear very small. In small scale maps the ratio has a large number or large denominator. The bigger the denominator the smaller the scale.

Medium scale map

Medium scale ranges from 1: 50 000; to 1: 1 240 000 used for maps of medium sized areas. They are scales that represent areas which are neither too large nor too small. The maps show moderate contents as the features on the ground are relatively reduced. The ratio has a moderate denominator

Large scale map

Large scales have scales ranging from 1:5 000 to 1:25 000 and are used when we want to represent higher levels of detail. The map using scale of this type shows detailed information as everything can be seen clearly because of the minimal reduction. This scale however, contains little content due to small area covered. This scale is used to represent areas like schools or hospital compounds and small scale villages.

Table 4.2: *Type of scale surface, coverage and details*

Type of scale	Surface area	Detail
Small scale map	Large	Little
Medium scale map	Medium	moderate
Large scale map	Small	Large

Factors determining size of the scale on a map

The content, area represented and the size of the map are the major factors which determine the size of scale on a map. The size of scale on the map depends on the amount of contents to be shown on a map. For example, large scale map is more detailed than others. The scale can also be determined by the area represented. For example, large area like continent or the whole world can be shown by using small scale while a map of a certain school compound uses large scale. However, the scale may differ in relation to the size of map, because maps of different sizes differ in scale though they can represent the same ground area.

Ways of expressing scale

A scale can be expressed in three different ways namely representative fraction, statement, and linear scale.

Representative Fraction

Representative fraction (RF) scale is also known as ratio scale. RF is a form of scale which is expressed in ratio and fraction in which the numerator represents the map distance while the denominator represents the ground distance. So, the RF 1:10 000 means 1 unit on the map represents 10 000 units on the ground.

The size of scale in this form can simply be determined by the size of the denominator. The scale indicates how many units on the earth's surface are represented by one unit on the map. It can either be expressed as $\frac{1}{100\,000}$ or 1:100 000. With regard to the given example here, it means one centimeter on the map represents 100 000 centimeters (1 kilometer) on the ground. Other common RF scale include 1:63 360 (1 inch to 1 mile) and 1:1 000 000 (1 cm to 10 km). The numerator of a representative fraction is always 1.

Statement scale

It is a written description of a scale, such as 'One centimetre on the map represents one kilometre on the ground' or 'One centimetre to ten kilometres.' Based on these two statements, the first map would show much more detail than the second because one centimetre on the first map covers a much smaller area than the second map. It should be noted that both RF and statement scales are ineffective particularly for a map produced through photocopying and when the size of the map is modified. Under this circumstance there is a possibility of a mismatch of distances in the produced map and the original map. This can however, be addressed using a linear or graphic scale.

Linear scale

Linear scale also called line scale, bar scale, plain or graphical scale is the way of expressing the scale by the use of line representing the distance on the ground (Figure 4.5). It is commonly placed at the bottom of the map. It consists of two main parts, the primary section on the right side with units in kilometres and the secondary section on the left sidewith units in metres. It helps the map user to determine quickly the ground distance of two points on the map.

However, the scale cannot be directly used to calculate area, slope, and vertical exaggeration and in redrawing the map instead demands some skills to prepare it. One of the major advantages of the linear scale is that it is not affected by photocopying.

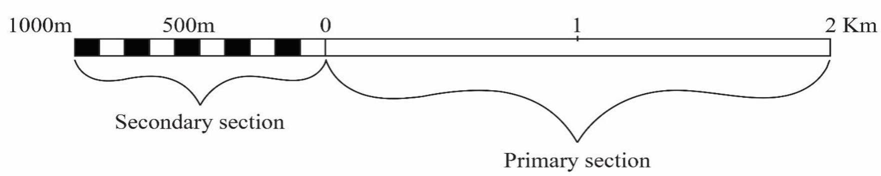


Figure 4.5: *A simple linear scale*

Also it is easy to understand. Similarly, it allows direct linear measurement. However, its construction requires time, special skills and experience. Furthermore, the scale can be used by those who are familiar with the units of measurement used in the linear scale.

Scale conversion

Dealing with scale is possible to change one form of scale and express it into another form. For example, from representative fraction scale to statement scale, from representative fraction scale to linear scale, from statement scale to representative fraction scale, from statement scale to linear scale, from linear scale to representative fraction scale, and from linear scale to statement scale.

Example 1:

Change the statement form of scale to representative fraction scale given that, one centimetre on the map represents half a kilometer on the ground.

Solution

Data given

Statement scale, 1cm = 0.5 km

Constant 1km = 100 000 cm

Representative fraction scale =?

From the data given

1km = 100 000 cm

0.5 km =?

$$\frac{0.5\text{ km} \times 100\,000\text{ cm}}{1\text{ km}}$$

$$= 50\,000\text{ cm}$$

RF scale is 1: 50 000

Example 2:

Change the Representative Fraction scale of 1:50 000 to simple statement scale.

Solution

This means 1 unit to 50 000 units.

If the unit is in centimetres then

$1\text{cm} \approx 50\ 000\text{cm}$

Unit on the ground distances are expressed in kilometers

$1\text{km} = 100\,000\,\text{cm}$

$? \quad = 50\,000\,\text{cm}$

$$\frac{1\text{km} \times 50\,000\,\text{cm}}{100\ 000\,\text{cm}}$$

$$= 1\text{km} \times \frac{5}{10}$$

$$= 0.5\,\text{km}$$

Therefore, statement scale is one centimetre on the map represents a half kilometre on the ground.

Exercise 4. 2

Answer all questions

1. On a map of 1:40 000 scale, the distance measured between town A and town B is 8 cm, what ground distance in kilometers does this represent?
2. What is the R.F scale, if the statement scale is one centimetre represents two kilometres and a half?
3. Convert the statement scale of one centimetre to one hundred kilometre into ratio scale.

How to construct a linear scale

The construction of a linear scale can be divided into two ways:

(a) Drawing of linear scale

Linear scale can be drawn into forms which are simple or plain or normal scale and as graphic scale.

Procedures of constructing linear scale are basically the same though graphic scale will involve some more additional steps. The following are the procedures to be considered when constructing a graphic scale:

(i) Determine the scale given that such as 1: 50 000

(ii) Convert scale into statement scale. For example, 1:50 000 becomes 1cm to 0.5 km

(iii) Use statement scale to find length of scale or length of baseline (If not guided, choose any reasonable length of baseline or length of scale, for instance 12 cm).

(iv) Then,

$1\text{cm} \approx 0.5\text{km}$

$12\text{ cm} = \ ?$

$\frac{12\text{ cm} \times 0.5\text{ km}}{1\text{ cm}}$

$x = 6\text{ km}$

Thus

$12\text{ cm} \approx 6\text{ km}$

(v) Draw a baseline and divide it into primary and secondary sections.

(vi) Draw perpendicular auxiliary lines at the starting and the ending point of the the secondary section, downwards and upwards, respectively from the baseline with ten division.

(vii) Join the points of perpendicular auxiliary lines to divide secondary section into ten equal parts.

(viii) Draw oblique auxiliary lines at both ends of baseline. These auxiliary lines should be drawn to equal angle between 25° to 30° from the baseline. Auxiliary lines should have length which can be easily divided to required sections.

(ix) Join the points of auxiliary lines to divide the baseline in equal divisions.

(x) Trace a clear linear scale at the bottom of drawing.

Example 1

Use 1:50 000 to draw a graphic scale to read 4 km.

Solution

Data given

R.F scale = 1:50 000

Ground distance = 4 km

Constant, 1km = 100 000 cm

To convert RF scale to statement scale

1km = 100 000 cm

? = 50 000 cm

$\frac{1\text{ km} \times 50\,000\text{ cm}}{100\,000\text{ cm}}$

$= 0.5\text{ km}$

$1\text{cm} \approx 0.5\text{ km}$

To find how many cm will represent 1 km

If, $1\text{cm} = 0.5\text{ km}$

$? = 1\text{ km}$

$\frac{1\text{cm x }1\text{km}}{0.5\text{ km}}$

$= 2\text{ cm}$

Therefore

$2\text{ cm} \approx 1\text{ km}$

To find the length of the base line

If $2\text{ cm} \approx 1\text{ km}$

$x = 4\text{ km}$

$\frac{x \times 1\text{km}}{1\text{ km}} = \frac{2\text{ cm} \times 4\text{km}}{1\text{ km}}$

$x = 8\text{ cm}$

The baseline length = 8 cm

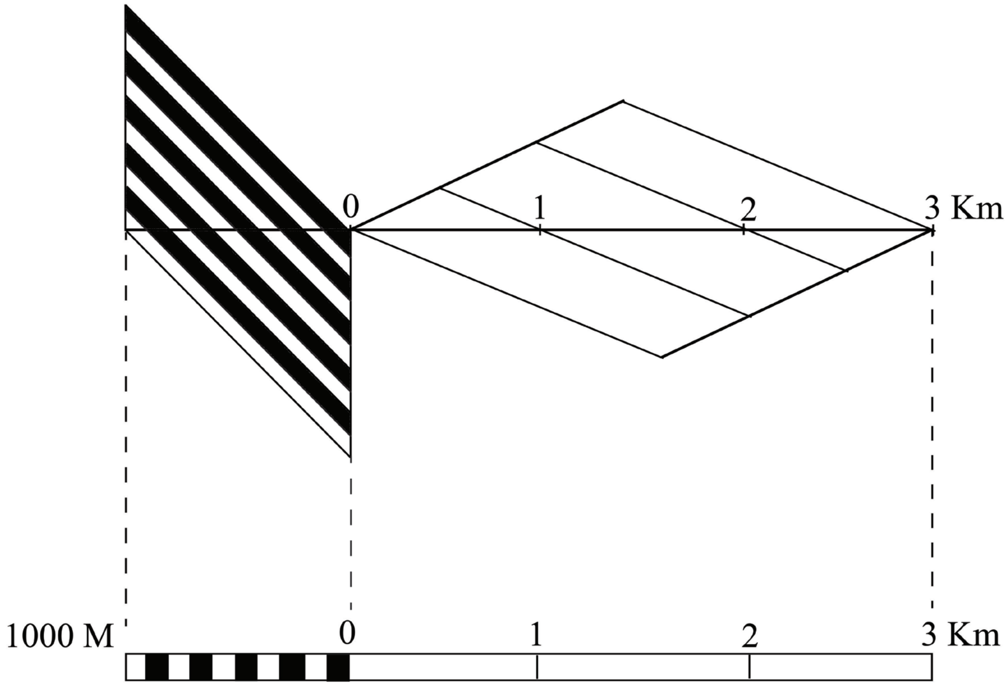


Figure 4.6: *Graphic scale to measure 4 km*

Scale

Primary side 2 cm ≈ 1 km

Secondary side 2 mm ≈ 100 m

Activity 4.2

Draw a linear scale to measure 4.5 km

(b) Linear scale in relation to speed of a moving object

Graphic scale can also be constructed from the relationship between distance and time that describes a speed (that is, speed is the ratio of distance to time) of the moving body or object such as the motorcycle, train or any other object in motion.

Example 2

A bus travels at a speed of 180 km/h from Morogoro to Dodoma covering a map distance of 30 cm for 20 minutes.

(a) Calculate ground distance

(b) Determine the statement scale

(c) Draw the graphic scale

Solution

Data given

Speed of the bus = 180 km / h

Map distance = 30 cm

Time taken = 20 minutes

From the data

Formula: $\text{Speed} = \frac{\text{Distance}}{\text{Time}}$

Distance = Speed × Time

$$= \frac{180 \text{ km}}{\text{h}} \times \frac{20}{60} \text{h}$$

$$= 60 \text{ km}$$

Ground distance = 60 km

Change 60 km into centimetre

1 km = 100 000 cm

60 km = ?

$$\frac{60 \text{ km} \times 100\,000}{1\text{km}}$$

$= 6\,000\,000$ cm

Statement scale:

$$\text{Map scale} = \frac{\text{Map distance}}{\text{Ground distance}}$$

$$= \frac{30 \text{ cm}}{60 \text{ km}}$$

$$= \frac{30 \text{ cm}}{6\,000\,000 \text{ cm}}$$

$$= \frac{1}{200\,000}$$

Map scale is 1: 200 000

1km = 100 000 cm

?= 200 000 cm

$$= \frac{1 \text{ km} \times 200\,000 \text{ cm}}{100\,000 \text{ cm}}$$

$= 2$ km

In statement, one centimetre on the map, represents two kilometres on the ground.

Determining the baseline length

Since, the length of the scale is not provided, we can choose any

So, let it be 22 km

Then,

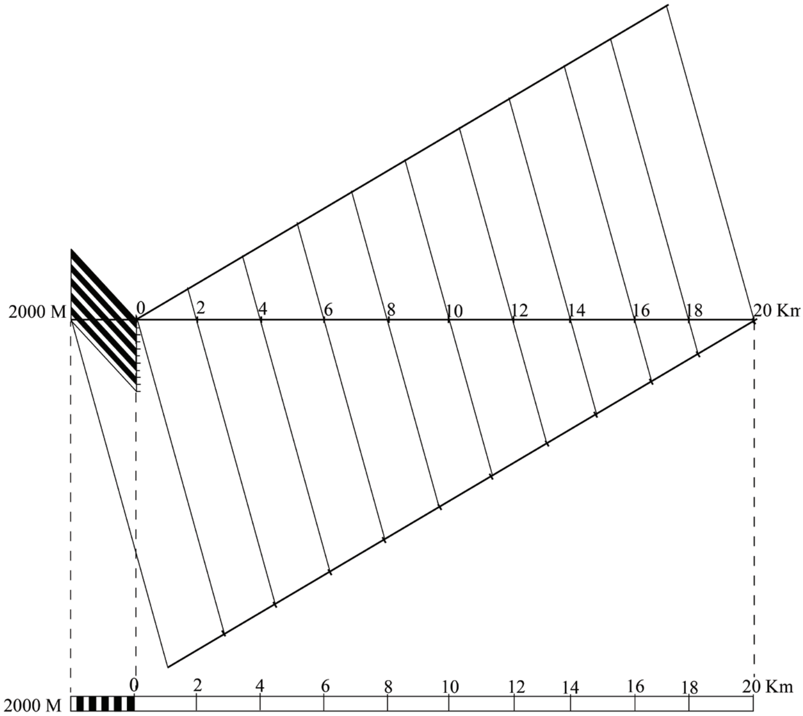
If 1 cm→2 km

x →22 km

$$= \frac{x \times 2 \text{ km}}{2 \text{ km}} = \frac{1 \text{ cm} \times 22 \text{ km}}{2 \text{ km}}$$

$x = 11$ cm

The baseline length = 11 cm



Scale

Primary side = 1 cm ≈ 2 km

Secondary side = 1 mm ≈ 200 m

Figure 4.7: *Graphic scale to read 22 km*

Linear scale based on a given distance can be drawn when RF scale and specific distance on the ground are given, see the example below.

Example 3

A Bus Rapid Transit (Mwendokasi) in Dar es Salaam, travel for a speed of 70 km/hr covering a distance of a road between Kivukoni to Mbezi Magufuli bus terminal in 30 min. Assuming the same distance measured in a map is 7 cm. Construct a linear scale to read 60 km.

Solution

Data given

Speed of the bus = 70 km/h

Time taken = 30 min

Map distance = 7 cm

Ground Distance = ?

Formula

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

Distance = Speed × Time

To change minutes into hours

= 70 km/h × 30 min

If 1 h = 60 min

? = 30 min

$$= \frac{x \times 60\,\text{min}}{60\,\text{min}} = \frac{1\,\text{h} \times 30\,\text{min}}{60\,\text{min}}$$

x = 0.5 h

Distance = Speed × Time

= 70 km/h × 0.5 h

= 35 km

To find scale of the map (Map scale)

7 cm on map ≈ 35 km on the ground

$$\frac{7\,\text{cm}}{7} = \frac{35\,\text{cm}}{7}$$

1 cm = 5 km

To find the length of the baseline

If 1cm = 5 km

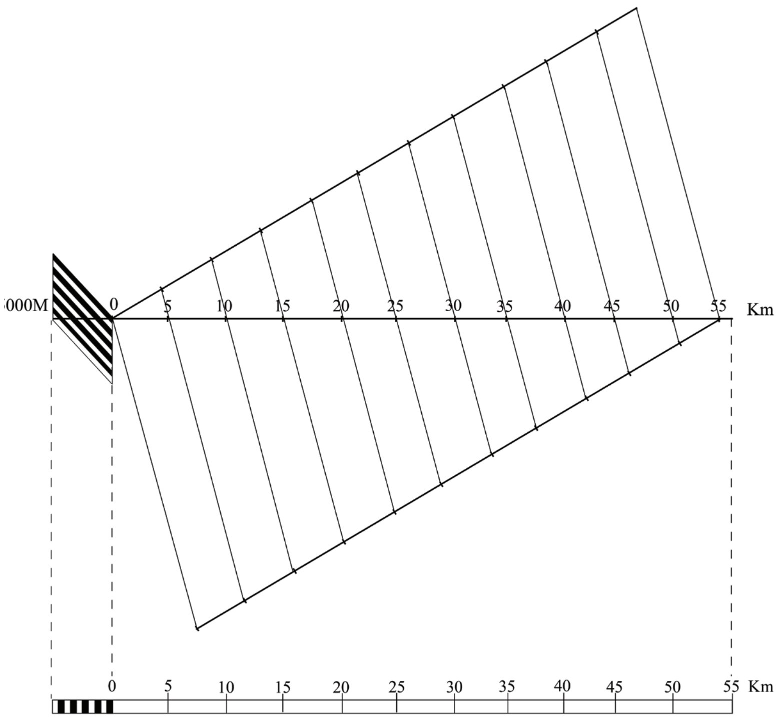
? = 60 km

$$\frac{1\text{cm} \times 60\,\text{km}}{5\,\text{km}}$$

= 12 cm

Base line length = 12 cm (It represents 60 km). In the baseline, every 1cm will represent 5 km.

To construct a linear scale.



Scale

Primary side = 1 cm represents 5 km

Secondary side = 1 mm represents 500 m

Figure 4.8: *Graphic scale to read 60 km*

Exercise 4 . 3

Answer all questions

1. Explain the uses of a map scale to the map maker and to the map user. Write 3 points for each.
2. Describe basic procedures for the preparation of the graphical scale and state its strength.
3. Explain the differences between primary and secondary sections of a graphical scale.

Activity 4. 3

1. In groups of five students, use a topographical map from your school library then prepare a graphical scale of 5 km and show the reading of 4.7 km, then submit your work to the teacher for assessment.
2. Summarise the procedures that were considered to prepare the graphical scale in (1) above.

Measurements on topographical maps

With the map scale, the size and length of both natural and man-made features can accurately be transferred from the map to the actual ground. It is also possible to know the extent of steepness on the real ground surface. The method used in measurement of the length and size, depends on the nature of the feature in terms of shape and straightness. Among the common measurements in topographical maps include distance and area.

Distance measurements

Measurement of distances on maps involves features that occur in linear forms such as roads, coastline, rivers and railway lines. It can also involve two points that are not connected by any elongated feature. Basing on such a concept, distance measured on the map are of two types namely; straight and curved or winding distances.

Straight distance

Measuring the distance of this kind, the line is drawn to connect the identified points, then the distance is directly measured by the ruler and the actual distance is obtained with the aid of the linear scale, or by using the representative fraction scale. This kind of distance is much less common on elongated features.

Winding/curved distances

This is very common in the elongated features such as road, railway and pipeline. The methods for measuring distance of curved feature includes the following: a pair of dividers, a string and a straight edge of the paper.

A pair of dividers

It is commonly used to measure short straight distances between two points on a map.

Procedures:

(i) Identify the starting and the ending points where measurements are to be taken.

(ii) Divide the feature under measurement in straight units.

(iii) By means of a pair of dividers, transfer each unit length on a straight paper to form the total length.

(iv) Change the map distance into ground distance using linear scale or representative fraction scale.

Map scale 1:100 000

Figure 4. 9: *Marking of distance on linear scale using a pair of dividers.*

From Figure 4.9, let the measured distance in the map be 25 cm, which equals to 25 km by using linear scale.

By Representative Fraction scale, the distance from the map can be converted into the actual ground distance as follows:

Data given

Map distance = 25 cm

Map scale = 1:100 000

Ground distance = ?

Constant 1 km = 100 000 cm

From the data given,

1 km = 100 000 cm

? = 100 000 cm

$$= \frac{1\text{ km} \times 100\,000\text{ cm}}{100\,000\text{ cm}}$$

= 1 km

1 cm→1 km

25 cm→?

$$= \frac{25\text{ cm} \times 1\text{ km}}{1\text{ cm}}$$

= 25 km

Therefore, ground distance between two points = 25 km

String or thread

A piece of a thread can be used to measure curved distances on a map using the following procedures.

Procedures:

(i) Identify the two end points you want to take measurements.

(ii) Lay a piece of a string along the points.

(iii) Shift the string onto the linear scale or ruler to read the actual distance (using a linear scale) or converting the map distance to actual distance using a ruler.

For example,

Determine the ground distance of the curved line by using thread method provided that the map scale is 1:25 000.

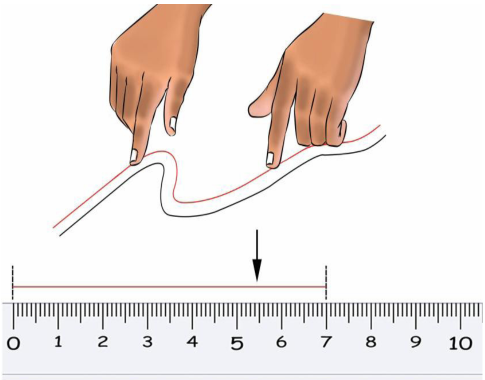


Figure 4.10: *Measuring distance by using a string or thread*

Data given

Map distance = 7 cm

Map scale = 1:25 000

Constant 1 km = 100 000 cm

From data given,

1 km = 100 000 cm

?=25 000 cm

$$= \frac{1\,\text{km} \times 25\,000\,\text{cm}}{100\,000\,\text{cm}}$$

= 0.25 km

1 cm = 0.25 km

7 cm = ?

$$= \frac{0.25\,\text{cm} \times 1\,\text{km}}{1\,\text{cm}}$$

= 1.75 km

Therefore the ground distance of the curved line =1.75 km.

Straight edge of a paper

A piece of paper with a straight edge can be used to measure curved distances (Figure 4.11).

Procedures:

(i) Identify the two end points of the feature you want to measure.

(ii) Divide the distance into small short straight distances.

(iii) Take a straight edge of paper and lay it on the map and measure all portion of straight distances along the features being measured.

(iv) Shift the piece of paper onto the linear scale or ruler to get the ground distance.

For example,
Find the ground distance of the curved feature in Figure 4.11 by using a staright edge of paper method provided that map scale is 1:50 000 and the measured map distance is 8.6 cm

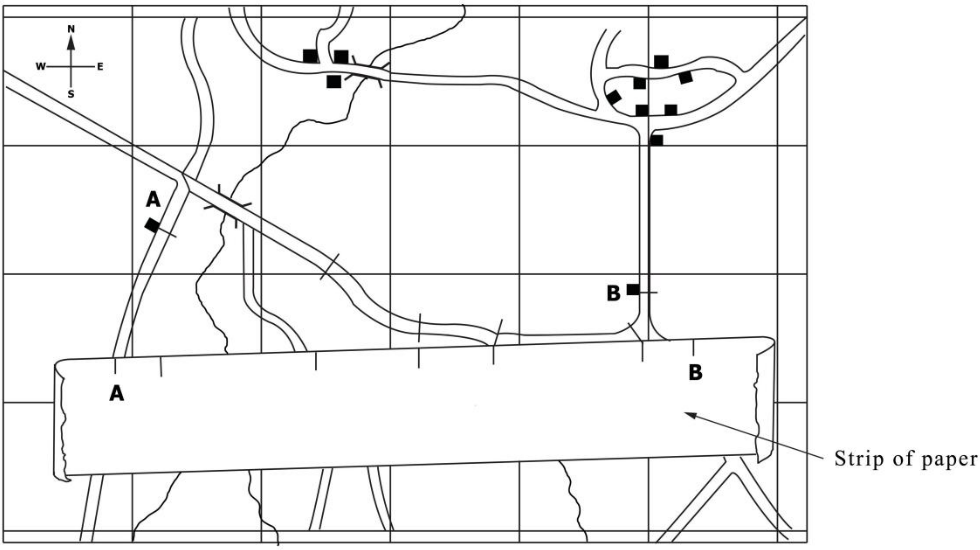


Figure 4.11: *Measuring distance of the curved feature by using a straight edge of a paper*

Data given

Map distance 8.6 cm

Constant 1 km = 100 000 cm

Map scale = 1: 50 000

Ground distance = ?

From data given,

1 km =100 000 cm

? = 50 000 cm

$$= \frac{1\text{km} \times 50\ 000\text{cm}}{100\ 000\ \text{cm}}$$

= 0.5 km

1 cm = 0.5 km

8.6 cm = ?

$$= \frac{8.6\ \text{cm} \times 0.5\ \text{km}}{1\ \text{cm}}$$

= 4.3 km

Therefore, ground distance of the curved feature is 4.3 km.

Area measurements

In topographical maps, area of natural features such as swamps and cultural features such as race truck can be actually determined on the ground. The method applied in determining the area depends on the shape of the particular feature. Actually, some features are regularly shaped while others are irregularly shaped. It is the interest of the map user to determine the area coverage of features for the social, economic and cultural purposes.

Regular shaped areas

The area of regular shaped features such as triangle, rectangle, trapezium and circle on the topographical maps can be simply determined by applying mathematical formula depending on the shape of that feature. For instance, to calculate the area of a rectangle, multiply its length by width. Remember, if you want to determine area in ground measurements, use the map scale to convert length and width from map into ground distances.

Examples of formula for calculating areas of different shapes are shown in Figure 4.12.

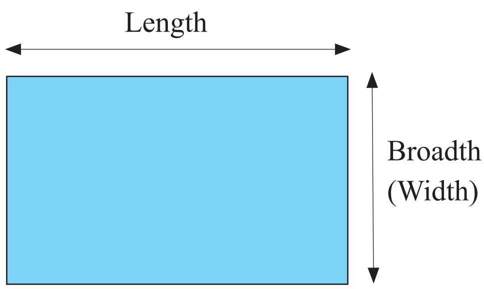
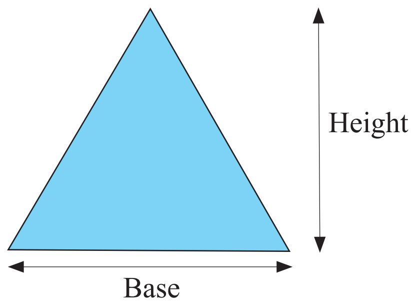
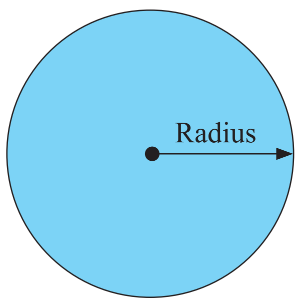
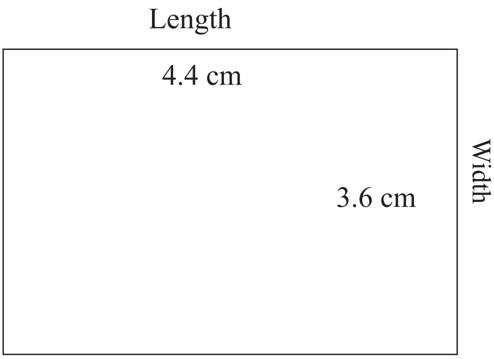
Shape	Formula
 (a) Rectangle	$Area = Length \times Broadth/Width$
 (b) Triangle	$Area = \frac{1}{2} \times Base \times Height$
 (c) Circle	$Area = \pi \times radius^2$ or πr^2

Figure 4. 12: *Different shapes and formulas for calculating areas*

Example

Find the ground area of the following feature



Scale 1 : 50 000 cm

Solution

Formula: L (to scale) × W (to scale)

Data given

Map length = 4.4 cm

Map width = 3.6 cm

Map scale = 1:50 000

Ground length = ?

Ground width = ?

Constant 1 km = 100 000 cm

From the data given

1 km = 100 000 cm

? = 50 000 cm

$$= \frac{1\,\text{km} \times 50\,000\,\text{cm}}{100\,000\,\text{cm}}$$

= 0.5 km

1 cm = 0.5 km

Ground length

If 1 cm = 0.5 km

4.4 cm→?

$$= \frac{4.4\,\text{cm} \times 0.5\,\text{km}}{1\,\text{cm}}$$

Ground length = 2.2 km

Ground width

If 1cm = 0.5 km

3.6 cm→?

$$= \frac{3.6\,\text{cm} \times 0.5\,\text{km}}{1\,\text{cm}}$$

Ground width = 1.8 km

Area = ground length x ground width

= 2.2 km × 1.8 km

= 3.96 km^2

Irregular shaped areas

Irregular shapes on topographic maps include swamps, lakes, forest and alike. The area of such feature is obtained by using various methods such as grid method or square method or tracing method, strip method, graph paper method, and geometrical figures method.

Grid method

This is the method which is more accurate for calculating areas of irregular features. The shape of the land which has to be calculated is covered by complete and incomplete units (squares).

Procedures:

(i) Count the complete grid units (square) covered in the required area.

(ii) Count the incomplete grid units (squares).

(iii) Divide the total number of incomplete squares by 2.

(iv) Add the results in (ii) and (iii) to get total number of squares.

Therefore, total square =

$$\text{Complete squares} + \frac{\text{Incomplete squares}}{2}$$

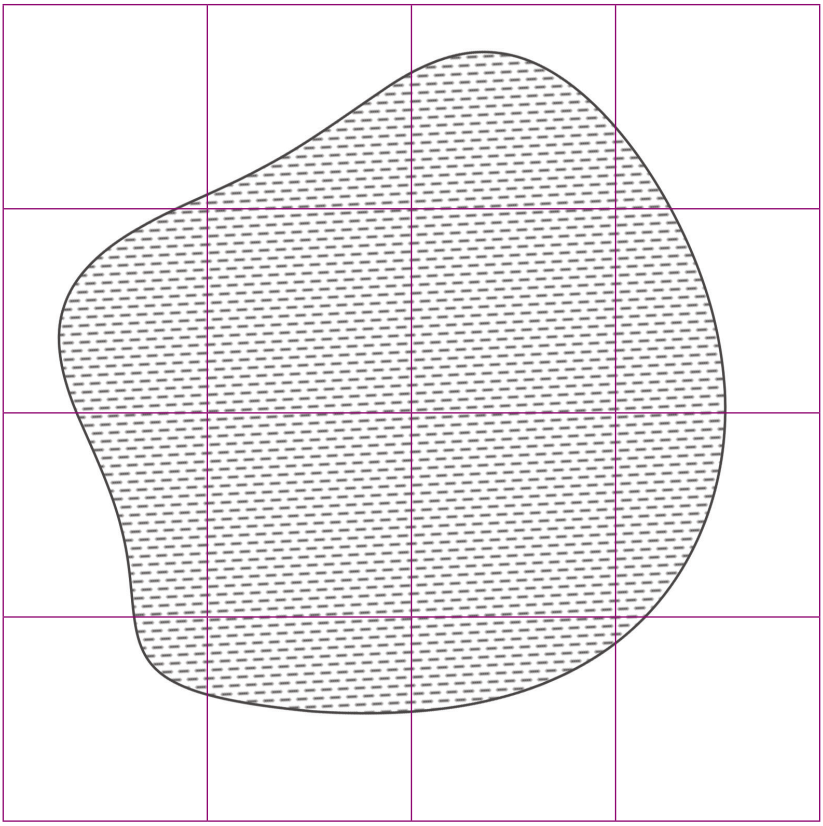
(v) Change the RF scale into simple statement scale;

(vi) Find the area of one square;

(vii) Formula for calculating area

(viii) Multiply the area of one square by the total number of squares counted

For example, find the area covered by the pond in Figure 4.14



Scale 1: 50 000

Figure 4.14: *The area covered by the pond*

Solution

Complete squares = 4

Incomplete squares = 12

Map scale = 1:50 000

Total number of squares = $\text{Complete squares} + \dfrac{\text{Incomplete squares}}{2}$

$= 4 + \dfrac{12}{2}$

$= 4 + 6$

= 10 squares

Map scale = 1 : 50 000

= 1 cm ≈ 0.5 km

If = 1 cm ≈ 0.5 km

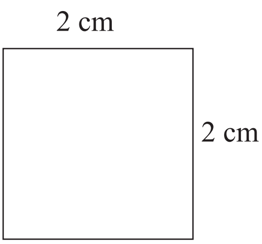
2 cm = ?

$= \dfrac{2\text{ cm} \times 0.5\text{ km}}{1\text{ cm}}$

= 1 km

Considering the grid square

Calculate area of one square



$1\text{ km} \times 1\text{ km} = 1\text{ km}^2$

Therefore, Area = $\left(\text{Complete squares} + \dfrac{\text{Incomplete squares}}{2}\right) 1\text{ km}^2$

$10 \times 1\text{ km}^2 = 10\text{ km}^2$

Area of the feature is 10 km^2

∴ Area of the feature is 10 km^2

The method is useful on the map with grid lines.

The strip method

The strip method is used to find the area of irregular shaped features which involves the division of the feature into strips of equal width. The area of the feature is the sum of all strips.

Procedures

(i) The required area is divided into strips of equal width.

(ii) Calculate the area of each strip (that is, strip 1-5) by the formula length x width.

(iii) The ends of the strips are drawn across the area boundary to balance areas left outside the boundary.

(iv) Use the map scale to obtain the actual area.

Example 1

Find the area of the feature in Figure 4.16 by using the strip method. Use 1: 25 000 as your map scale.

Solution

Suppose that strip 1 measures 1cm by 4 cm, strip 2, 1cm by 6cm, strip 3 1cm by 5cm, strip 4, 1cm by 6 cm and strip 5, 1cm by 5 cm.

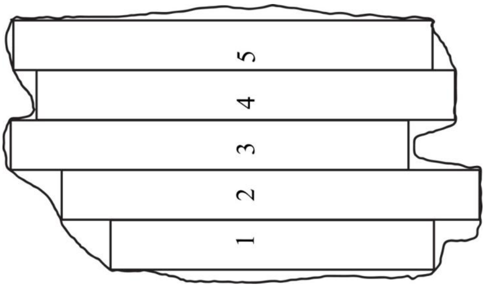


Figure 4.16: *Strip method*

Data given

Map scale = 1 : 25 000

Strip 1 = 1 cm by 4 cm

Strip 2 = 1 cm by 6 cm

Strip 3 = 1 cm by 5 cm

Strip 4 = 1 cm by 6 cm

Strip 5 = 1 cm by 5 cm

1 km = 100 000 cm

= 25 000 cm

$= \frac{1 \text{ km x } 25\ 000 \text{ cm}}{100\ 000 \text{ cm}}$

= 0.25 km

For the first strip,

Area of strip 1 = length x width

1 cm ≈ 0.25 km

4 cm = ?

$\frac{4 \text{ cm x } 0.25 \text{ km}}{1 \text{ cm}} = 1\text{km}$

Length of strip 1 = 1 km

Width

1 cm = 0.25 km

1cm = ?

Width of strip 1 = 0.25 km

Area 1 = 1 km x 0.25 km

Area 1 = 0.25 km^2

For the second strip,

1 cm = 0.2 km

6 cm = ?

Length $= \frac{6 \text{ cm x } 0.25 \text{ km}}{1 \text{ cm}}$

Length = 1.5 km

Width 1cm = 0.25 km

Width = 0.25 km

Area 2 = 1.5 km x 0.25 km

Area 2 = 0.375 km^2

For the third strip

Lenth 1 cm = 0.25 km

5 cm = ?

$$\text{Length} = \frac{5 \text{ cm} \times 0.25 \text{ km}}{1 \text{ cm}}$$

$$= 1.25 \text{ km}$$

Width 1 cm = 0.25 km

$$\text{Area } 3 = 1.25 \text{ km} \times 0.25 \text{ km}$$

Area 3 = 0.3125 km^2

For the forth strip

$$\text{Area } 4 = 0.375 \text{ km}^2$$

For the fifth strip

$$\text{Area } 5 = 0.3125 \text{ km}^2$$

Tota area of the feature = Sum of strip areas

$$\text{Total area} = 0.25 \text{ km}^2 + 0.375 \text{ km}^2 + 0.3125 \text{ km}^2 + 0.375 \text{ km}^2 + 0.3125 \text{ km}^2$$

Therefore, area = 1.625km^2

The geometrical figures method

This is also called division method, it involves the division of the feature into several geometrical figures such as triangle, rectangle, and square depending on the shape of the feature itself. The area of the whole feature is the sum of all individual figures obtained geometrical method. Using the area of the feature can be calculated as follows;

Procedures

(i) Divide the area into convenient figures such as A, B, C, D and E

(ii) By using appropriate methods, calculate area of each figure separately such as, A, B, C, D and E

(iii) Determine the area by adding the area of A, B, C, D and E

(iv) Use the map scale to get the actual area on the ground.

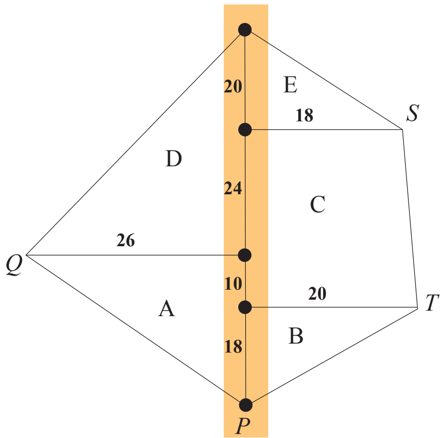


Figure 4.17: *Geometrical figures method*

Activity 4. 4

Calculate the area of the feature in Figure 4.17 by using geometrical figure method.

Map enlargement and reduction

Map enlargement and reduction can be described as a cartographical technique of increasing or decreasing the size of a map in a given area according to scale.

Map reduction and enlargement (re-drawing the map) is governed by two mathematical principles. Firstly, when the small scale map is redrawn by using a large scale, its size becomes large, and the process is referred to as map enlargement. Secondly, when the large scale map is redrawn by using a small scale, its size becomes smaller as well, and the process is referred to as map reduction. Both of them involve the same redrawing procedures as follows;

Procedures

(i) Study the map or required area of the map to be redrawn.

(ii) Identify the map scale and covert it into statement.

(iii) Determine changing factor/ scale factor

$$\text{Scale factor} = \frac{\text{New scale}}{\text{Old scale}}$$

(iv) Measure the length, width and side of the grid square. But if the distances are given, convert the map distance into ground distance.

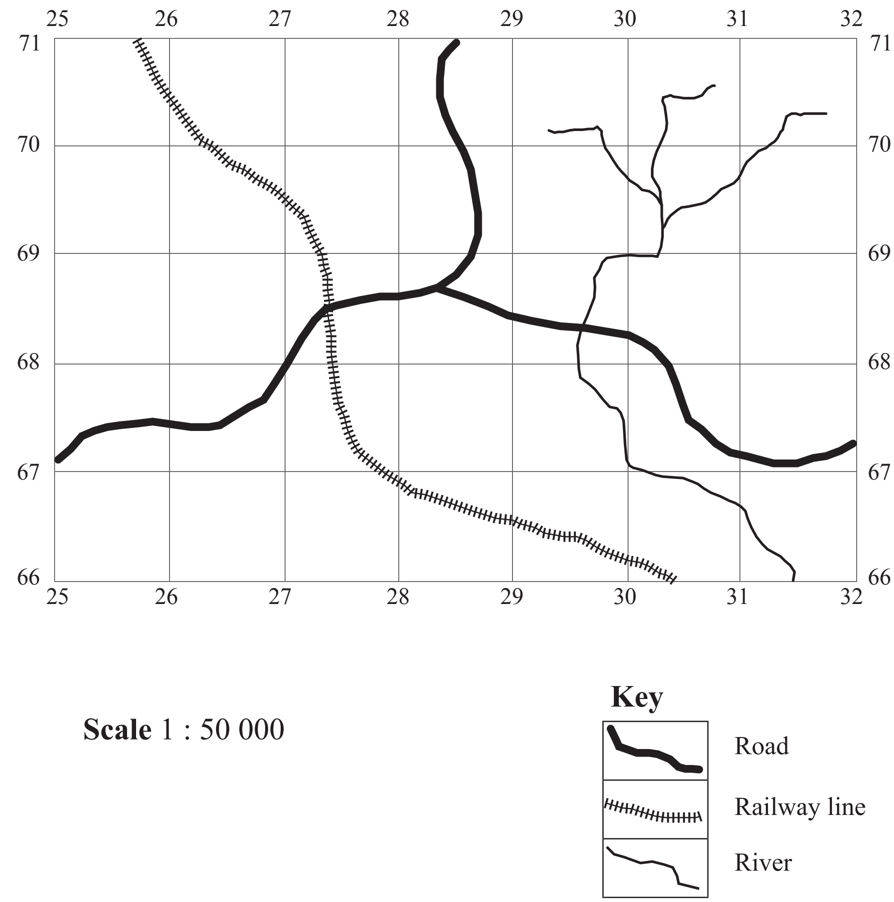
(v) Using the given map scale for re-drawing, convert or change the old map dimensions into new map dimensions, by using the scale factor.

(vi) Redraw the map and if the original map had grid references then indicate them in the new map.

(vii) Show main features and remember to show the title, key and the scale.

Example 1

Re-draw the map provided below by using the scale of 1:100 000



Scale 1 : 50 000

Solution

Data given

Old map scale = 1:50 000

New map scale =1: 100 000

Side of each grid square = 2cm

Old width = 10 cm

Old length = 14 cm

New side =?

New width =?

New length =?

Since the new scale is smaller than the old scale, then the resultant map will be small in size (reduction).

Then

$$\text{Scale factor} = \frac{\text{New scale}}{\text{Old scale}}$$

$$= \frac{1/100\ 000}{1/50\ 000}$$

$$= \frac{1}{100\ 000} \times \frac{50\ 000}{1}$$

$$= \frac{50\ 000}{100\ 000}$$

$$= \frac{1}{2}$$

Finding the new dimensions:

New side of a grid = Old side × Scale factor

$= 2 \text{ cm} \times \frac{1}{2}$

$= 1 \text{ cm}$

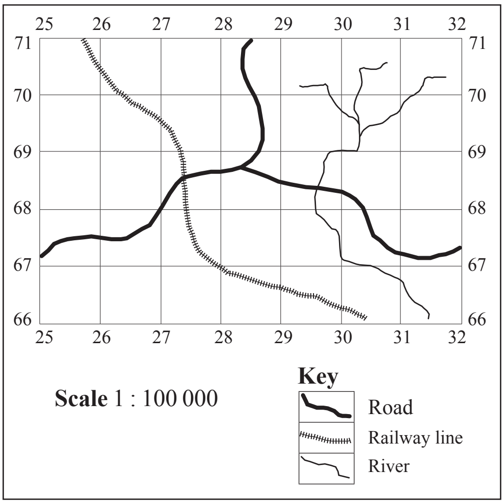
New length = Old length × Scale factor

$= 14 \text{ cm} \times \frac{1}{2} = 7 \text{ cm}$

New width = Old width × Scale factor

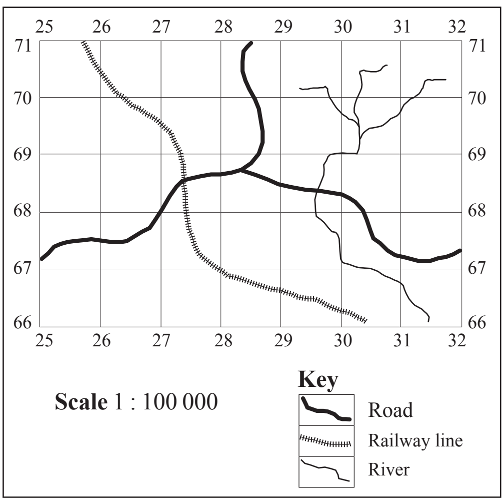
$= 10 \text{ cm} \times \frac{1}{2}$

$= 5 \text{ cm}$



Example 2

Study the hypothetical map provided and redraw it using a scale of 1: 50 000



Solution

Data given

Old map scale = 1:100 000

New map scale =1: 50 000

Old side of grid square = 1 cm

Old width = 5 cm

Old length = 7 cm

New side of the grid square =?

New width =?

New length =?

Comparison between the old and the new scale shows that, the new scale is larger than the old scale. Therefore the resultant map will be larger in size than the old map (Enlargement).

$$\text{Scale factor} = \frac{\text{New scale}}{\text{Old scale}}$$

$$= \frac{1/50\ 0000}{1/100\ 000}$$

$$= \frac{1}{50000} \times \frac{100000}{1}$$

$$= \frac{100\ 000}{50\ 000}$$

$$= 2$$

Finding the new dimensions:

New side of a grid = Old side × Scale factor

$= 1 \text{ cm} \times 2$

$= 2 \text{ cm}$

New width = Old width × Scale factor

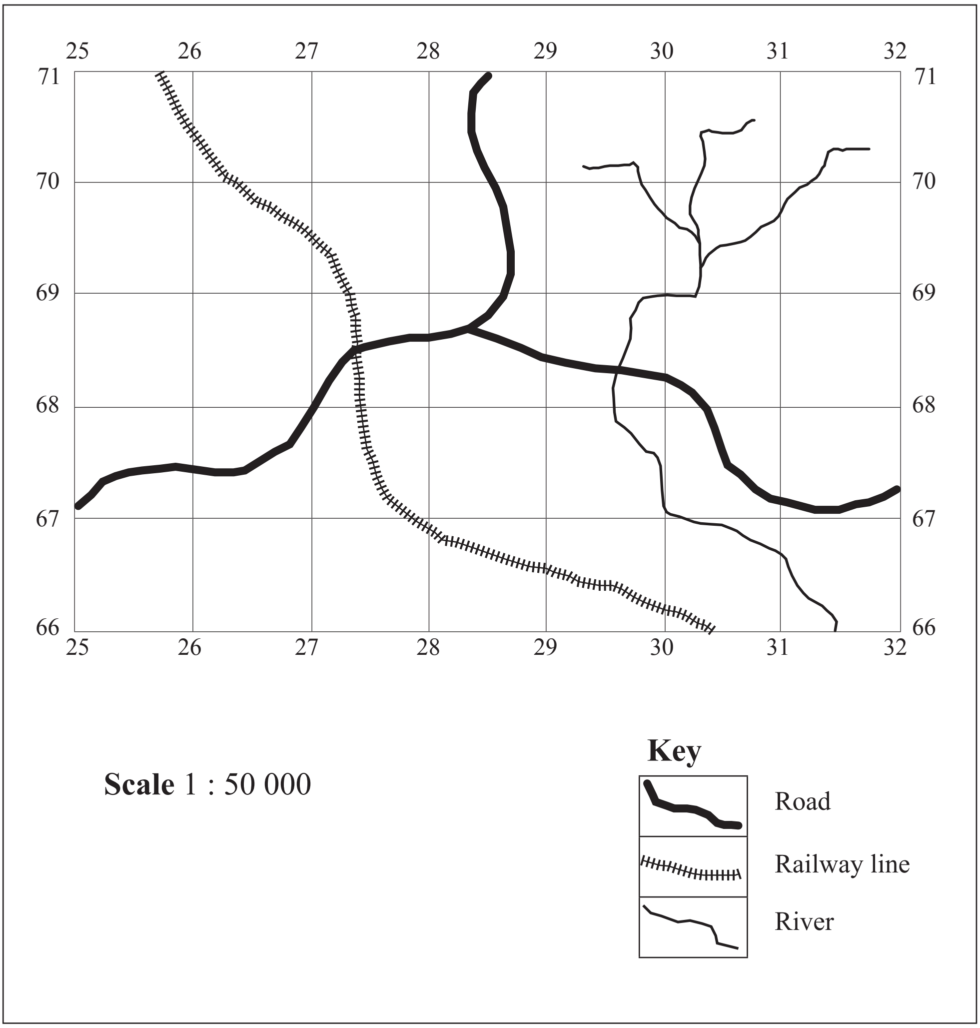
$= 5 \text{ cm} \times 2$

$= 10 \text{ cm}$

New length = Old length × Scale factor

$= 7 \text{ cm} \times 2$

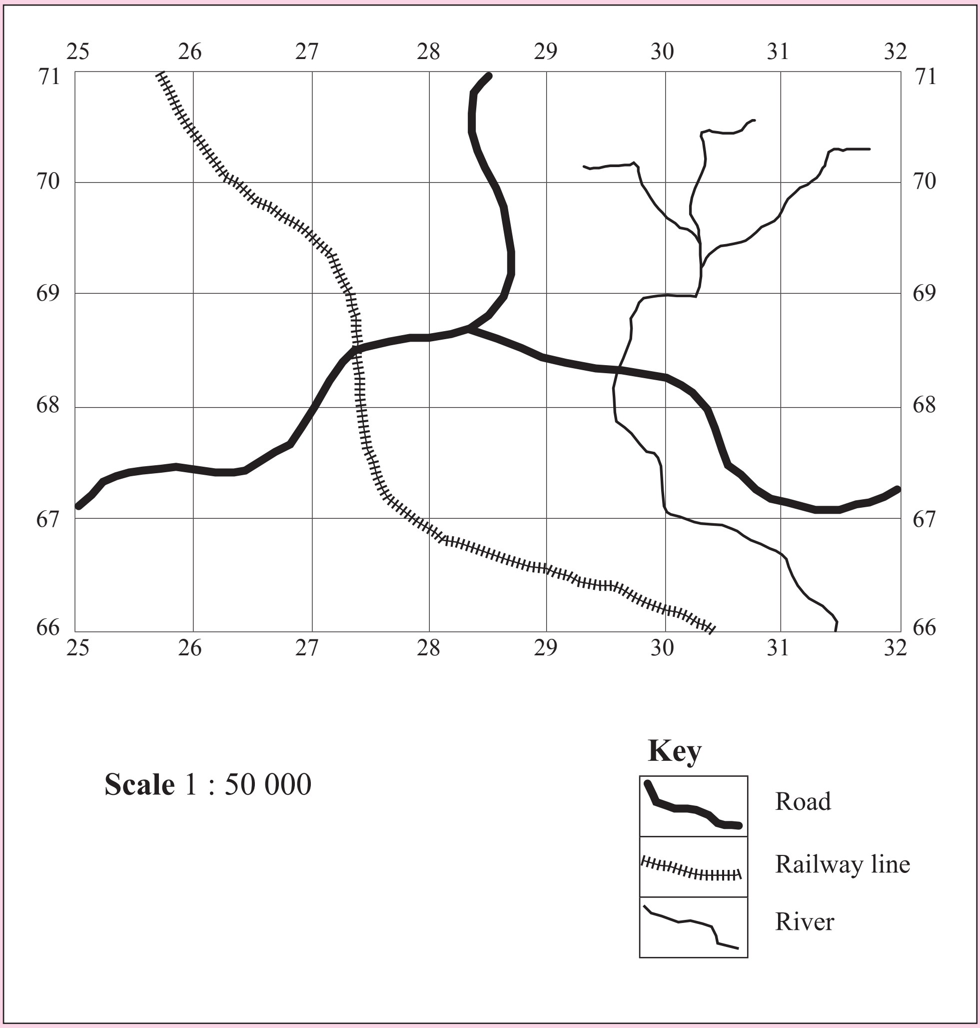
$= 14 \text{ cm}$



Exercise 4.4:

1. Analyze three effects that are likely to occur when the map is reduced or enlarged.
2. Study the hypothetical map of area X and redraw it by using the scale of 1:25 000.

Hypothetical map of area X.



Determining locations and directions of places

Location, direction and distance are everyday ways of assessing the space around us and identifying our position in relation to other features and places of interest. They are also very basic in understanding the processes of spatial interaction that are important in the study of both physical and human geography.

Location: Location can be classified in two different ways that are absolute and relative locations.

Absolute location

Absolute location also known as mathematical location, is the identification of place by some precise and accepted system of coordinates. There are several such accepted systems of pinpointing positions, for example global grid of parallels and meridians that is latitude and longitude. Absolute location is unique to a specific place and it is independent of any other characteristics or observation.

Geographers remark location matters a lot although their reference is usually not absolute but relative. Location that is the position of a place or things in relation to that of other place or things expresses spatial interconnection.

Relative location

Relative location tells us that people, things and places exist in the world of physical and cultural characteristics that differ from one place to another. In reality when geographers talk of location, they refer to the physical and cultural characteristics like climate, soil, minerals, and attributes of the place itself.

Direction

This is another important aspect in geography. It is also expressed in absolute or relative terms. Absolute direction is based on the cardinal points of North, South, East and West. Relative direction refers to "far West" or far East.

Distance links location and directions

Distance is also divided into absolute and relative sense. Absolute distance refers to the spatial separations between two points on the earth's surface, measured by some accepted standard unit such as miles or kilometers. Relative distance transforms those linear measurements into other units more meaningful for spatial relationship.

Fixing or locating position on maps

Fixing or locating position on maps is an important aspect in map reading. A person is able to identify a place after position has been fixed and located. The position and direction of the place on the earth's surface and on maps can be expressed in various ways such as use of place names, latitudes and longitudes, grid reference systems and bearing.

Place names

The place in the topographical maps are identified and located by the name of the particular area. For example, in the map of Tanzania, different regions can be identified by their names such as, Arusha, Dodoma, Pemba and Iringa (Figure 4.22).

Latitude and longitude

These are West-East and North-South angular distances on the earth's surface. They are the traditional and mostly used geographical ways in locating position of features on the earth's surface. Most topographical maps indicate latitude and longitude along their edges, so as to give their respective location on the earth's surface although not all maps show these divisions in detail. Therefore, by means of these lines, one can identify the exact location of a feature on the mapped area.

In reading the latitude and longitude, start with latitudes then longitudes. For example, Dare es Salaam region is located at 6^{o} 48'S and 39^{o} 12'E. Latitude and longitude in maps are important for locating places precisely whereby two reference lines are needed and adopted on the uniform basis by all countries in order to avoid confusion. Using latitude and longitude, we can know how far an area is from the equator and prime meridian respectively. Also, latitudes are very important in characterizing the climate of the mapped area.

Figure 4.22: *A map of Tanzania locating position by place naming*

Grid reference system

A grid system is a pattern of horizontal and vertical lines of uniform sizes which are drawn on a map. The vertical lines are called eastings since their values increases eastward from the grid origin while horizontal lines are called northings since their values increases northwards. Grid reference system depends on the type of projection used to prepare the map. For example, in Africa the grid systems are based on the Universal Transverse Mercator (UTM) projection which divides the continent into zones. Within each zone, coordinates are measured as northings and eastings values in meters. These lines are essential for fixing position. The reading in a grid system is referred as grid references and is provided in a six-digits in which the first three digits are eastings and the last three digits are northings. For example, the position of point A in Figure 4.23 is 280610.

Figure 4.23: *Locating position by grid reference*

Bearing and direction

This is another way of fixing position or showing geographical position on the map. The compass bearing can be measured by using a compass. A compass is an instrument used to find direction and bearing. It consists of free-swinging magnetic needle which can pivot to align itself with magnetic north. If the local variation between magnetic north and the true north is known then direction of magnetic north gives the direction of true north. Compass bearing can be explained along the points such as compass direction, bearing of compass, direction of a place (trend and alignment) and North direction.

Compass directions are measured from North 000° to 360° of a circle clockwise. It is the bearing which determines the direction. For example, when the measured bearing is 45°, then the direction is North East, when the bearing is 90°, then its direction is East. The directions are divided into three categories which are the four cardinal points, the eight cardinal points and the sixteen cardinal points as shown in Figure 4.24.

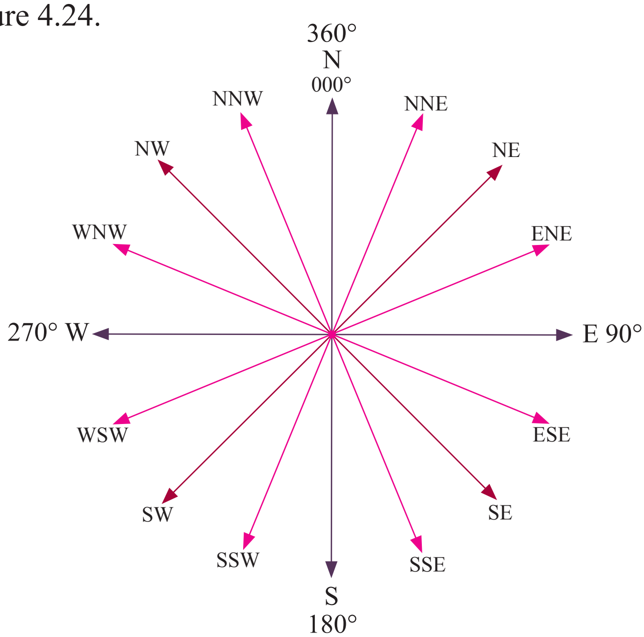


Figure 4. 24: *Sixteen cardinal points*

Bearing of compass shows the direction of point with respect to another point measured clockwise from 000º to 360º. Bearing is expressed in degrees, which are further subdivided into minutes and seconds.

Calculation of bearing

There are two types of bearings namely:

(a) Forward bearing (FB).
(b) Back bearing (BB).

Forward bearing (FB)

This is the degree measured from an observer to the object along the line of sight or the degree reading to an object in front of the observer along the line of sight, with reference to the earth's magnetic north pole. An observer can check FB's accuracy by taking BB from the object to his former position.

Procedures of measuring bearing

(i) Identify the two points.

(ii) Join the two points with a straight-line. For example from grid reference A to grid reference B (Figure 4.25).

(iii) At one point either A or B (depending on the question asked) draw a line parallel to the North direction or grid vertical lines.

(iv) Using a protractor, measure the angle or bearing at point A or B depending on the question.

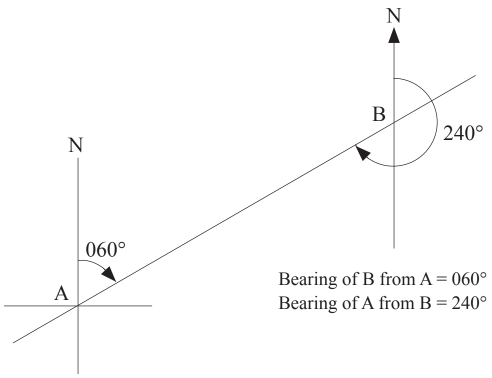


Figure 4.25: *Forward and back bearing*

Back bearing (BB)

This is the degree measured from an object to the observer along the line of sight. The rule is that, if the FB is greater than 180º then subtract 180º from the FB to obtain BB. This implies that BB = FB -180º. If the FB is less than 180º then add 180º to the forward bearing to get BB. This implies that BB = FB + 180º.

The parallel lines and angle transverse

Forward and back bearing from one point to the next on the given map can be revealed by the application of parallel lines and angles of transverse (Figure 4.26). This rule provides a map-reader with pairs of corresponding angle and pairs of vertical opposite.

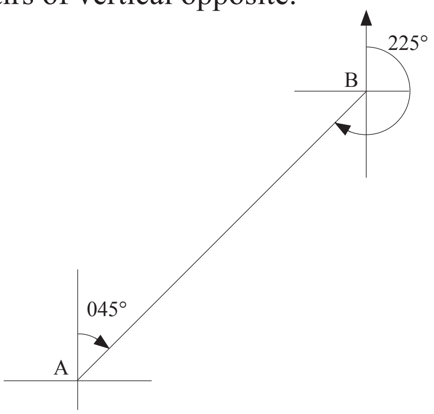


Figure 4.26: *Back Bearing and Forward Bearing*

FB of 'A' to 'B' is the same as FB of 'B' from 'A' = 45º

FB of ' B' to ' A' is the same as FB of 'A' from B = 225º

FB of 'B' from 'A' is equal to 'BB' of ' A' from B = 045º

FB of 'A' from ' B' is equal to BB of 'B' from A = 225º

The significance of backward bearing

Backward bearing is useful for checking the accuracy of forward bearing reading as taken from the observer to the object along the line of sight. The accuracy is normally checked by identifying the difference in degrees between the forward and backward bearing. The difference between backward bearing and forward bearing is normally 180º. If the difference appears to be less or greater than 180°, it shows that forward, backward or both bearings are not correct. It indicates the presence of errors which may be caused by different factors during surveying. The errors are corrected by mean error method as shown below.

Example 1

A prismatic compass surveyor recorded forward bearing as 68^{O} and its back bearing 250^{O}. Correct the discrepancy of these readings

Solution

Data given

$FB_0 = 68°$

$BB_0 = 250°$

Procedures

(i) Find the difference between BB and FB

$250° - 68° = 182°$

Difference = 182°

The difference (D) is above 180°, implying presence of a positive error.

(ii) Determine amount of errors

Amount of error = Difference − 180°

$182° - 180° = 2°$

(iii) Find the mean error

$$\text{Mean error} = \frac{Error}{2} = 1°$$

Mean error = 1°

Subtract the mean error from a reading with large value.

(iv) Add the mean error to the readings with a small value.

$BB_1 = BB_0 - 1°$

$250° - 1°$

$= 249°$

$FB_1 = FB_0 + 1°$

$= 68° + 1°$

$= 69°$

$FB_1 = 69°$

(v) Prove the readings,

$BB - FB = 180°$

$249° - 69° = 180°$

Therefore, the correct readings are;

$BB_1 = 249°$

$FB_1 = 69°$

Example 2

Correct the discrepancy if the forward and back bearings are 254° and 75° respectively.

Solution

Data given

$FB_0 = 254°$ $FB_1 = ?$

$BB_0 = 75°$ $BB_1 = ?$

Procedures

(i) Find the difference between FB and BB

$FB - BB = 180°$

$254° - 75° = 179°$

The difference (D) is below 180°, implying presence of a negative error.

(ii) Determine the amount of error.

Amount of error = D − 180°

$= 179° - 180°$

$= -1°$

(iii) Find the mean error $= \dfrac{\text{Error}}{2}$

$= \dfrac{-1}{2}$

$= \dfrac{-1}{2}$

$= -0.5$

Mean error = − 0.5°

(iv) Add the mean error to the reading with small value and subtract mean error from the reading with large value

$BB_1 = BB_0 + \text{Mean error}$

$BB_1 = 75° + (-0.5°)$

$BB_1 = 74.5°$

$FB_1 = FB_0 - \text{Mean error}$

$FB_1 = 254° - (-0.5°)$

$FB_1 = 254° + 0.5°$

$FB_1 = 254.5°$

(v)Prove the readings

$FB_1 - BB_1 = 180°$

$254.5° - 74.5° = 180°$

Therefore, the correct readings are:

$FB_1 = 254.5°$

$BB_1 = 74.5°$

Example 3

Detect errors and correct if any in the following forward and backward bearings as recorded by surveyor.

FB = 249°, BB = 66°, FB_1 = ? BB_1 = ?

Solution

Data given

FB = 249°

BB = 66°

Procedures

(i) Find the difference between the FB and BB

$FB_0 - BB_0$

$= 249° - 66°$

$= 183°$

Difference = 183°

The difference (D) is above 180°, implying of positive error.

(ii) Determine amount of error

Amount of error $= D - 180°$

$= 183° - 180°$

$= 3°$

(iii) Find the mean error $= \frac{\text{Error}}{2}$

$= \frac{3°}{2}$

$= 1.5°$

(iv) Add the mean error to the reading with small value and subtract mean error from the reading with large value.

$BB_1 = BB_0 + \text{Mean error}$

$= 66° + 1.5°$

$= 67.5°$

$BB_1 = 67.5°$

$FB_1 = FB_0 - \text{Mean error}$

$= 249° - 1.5°$

$= 247.5°$

$FB_1 = 247.5°$

(v) Prove the readings

$FB_1 - BB_1 = 180°$

$247.5° - 67.5° = 180°$

Therefore, the correct readings are;

$FB_1 = 67.5°$

$BB_1 = 247.5°$

Exercise 4.5:

1. An amateur surveyor reads forward bearing as 265° and backward bearing as 80°. Correct the discrepancy.
2. The headmaster's office is located at the centre of the school compound. The bearing measured by Fatma from the headmaster's office to the library was 320°, but Mr Azwar measured the bearing of 144° from the library to the headmaster's office. Correct the discrepancy of their measurements.

Fixing position of an object on the map by intersection and resection method

Bearing and direction as the method among others of locating position, is the basis of intersection and resection methods.

Intersection method

Intersection method is a method of fixing unknown position of object on the map by taking bearings to it from two or more fixed points and using the data to fix the object's position on a map. Intersection involves more than one observer and only the single object, which is at the unknown position. In this method, forward bearings are used but not changed into back bearing. It is the simplest method of identifying the position of an object compared to resection.

When the two forward bearings are provided and their locations are known, it is possible to locate the position of the unknown point or the object, by fixing the positions of the given points and taking the bearings towards the unknown point as directed by the bearing method.

Example

Suppose the forward bearings of Dar es Salaam and Morogoro from Arusha were 353° and 22°30', respectively. Using Figure 4.26, find the position of Arusha by grid reference, if the grid reference of Morogoro and Dar es Salaam are 515225 and 555223, respectively.

Procedures

(i) Identify two points on a map, for example Dar es salaam and Morogoro;

(ii) Draw the north direction at both, Dar es Salaam and Morogoro;

(iii) Measure the FB of the two points Dar es Salaam and Morogoro;

(iv) Draw straight lines from each point along the angles measured; and

(v) Read the grid reference location where the two lines intersect. The point where lines intersect is the coordinate location of Arusha.

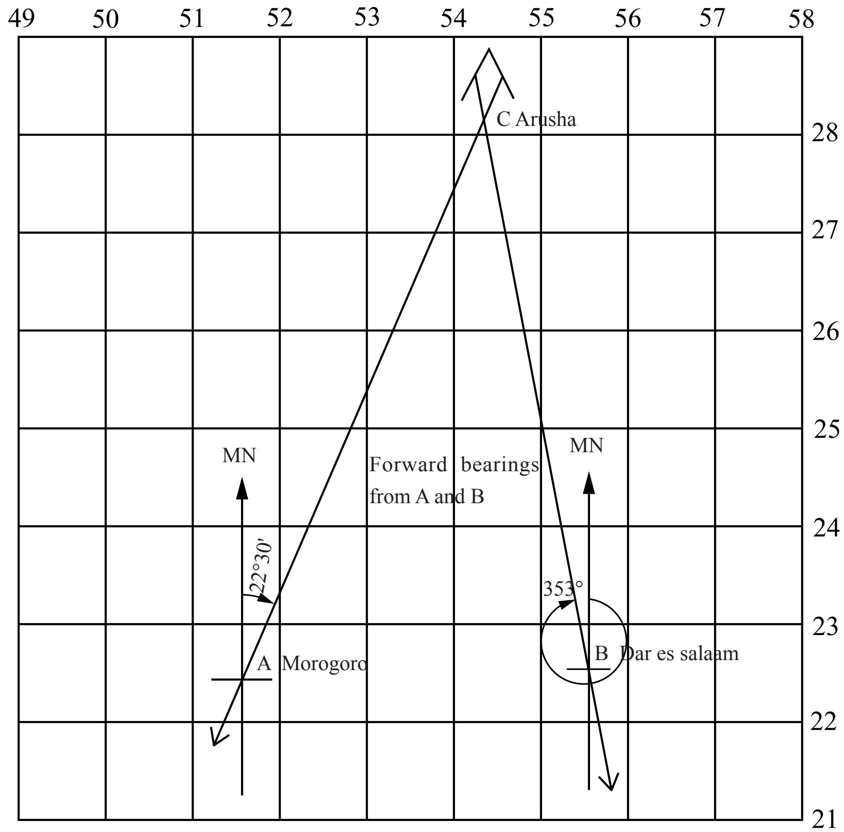


Figure 4.26: *Intersection of points*

Therefore, Arusha is located at grid reference 545 283

Resection method

Resection method identifies the location of the unknown object by taking the bearings from it to two or more known points located on the map. The readings are converted to back bearings and angle lines drawn from the points to meet at the observer's position. It involves only one observer who is at the unknown position, viewing more than one object at the same time.

Procedures

(i) Identify the location of each object by using grid reference.

(ii) Identify the forward bearing of each object.

(iii) Change the forward bearings to back bearings.

(iv) Establish the cardinal points at respective points.

(v) Measure the back bearings at their respective points; and

(vi) Draw the straight lines along the bearings measured. The observer's location is the point where two lines cross each other.

Example 1

Ms Audrey observed a feature 'x' at grid reference 040160 from a bearing of 45°and feature 'y' at 060115 from a bearing of 135°. Locate the position of Ms Audrey

Changing the forward to back bearings

$BB = FB \pm 180°$

From X $45° + 180° = 225^0$

From Y $135° + 180° = 315°$

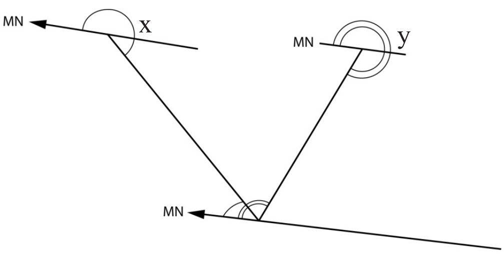


Figure 4.27: *Plotting point C by resection using back bearing of x and y point C is plotted.*

Trend and alignment

Trend, also known as direction of place, is a general layout of elongated features such as a river, valley, coastline, railway or road. Trend is expressed in degrees. Usually trend is given in compass bearings and the bearings are used to determine the direction. It helps the map user to know the general layout of features and extent of the general curvature.

Procedures

(i) Identify the two points;

(ii) Join the two points with a straight line;

(iii) Note the middle point of the line;

(iv) Draw a North direction on the noted point (middle point); and

(v) Measure the angles and give their degrees.

Trend involve two angles. The first bearing is measured from the North direction clockwise until it touches the drawn line that joins the two points. The second bearing is drawn in the same ways but it crosses the drawn line and touches it in the second part as shown in Figure 4.28.

If the first angle is well measured, the second angle is given by the use of mathematical formula.

Using Figure 4.28, let the first bearing be Y° and the second bearing be X°.

X° = Y° + 180 °

If Y°=55 °,

Then, X°=55 °+ 180 °

X°= 235°

X°=235 °

Note, the correct second bearing will be obtained only if the first bearing is properly measured

Trend is 55 ° to 235 °.

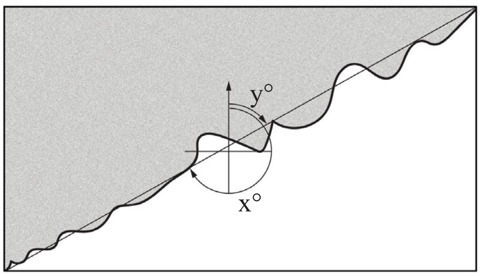


Figure 4.28: *Trend of a coastline*

Alignment is a general direction of elongated features such as ridge and coastline. Usually, alignment is stated using direction in which the feature lies. The same procedures of determining trend are used to determine alignment. But in alignment, the measured angles are used to describe the general direction of the feature involved. For example, if the trend of the feature is 55° to 235° as shown in Figure 4.28, its alignment is NE to SW. From the illustration above, trend and alignment can be started in a general form as 55° NE to 235° SW.

NB: The best way of showing trend or alignment is by using both bearing and direction.

Types of North direction

The North direction on a map can be shown by using different types of north. These are True North (TN), Magnetic North (MN) and Grid North (GN) (Figure 4.29).

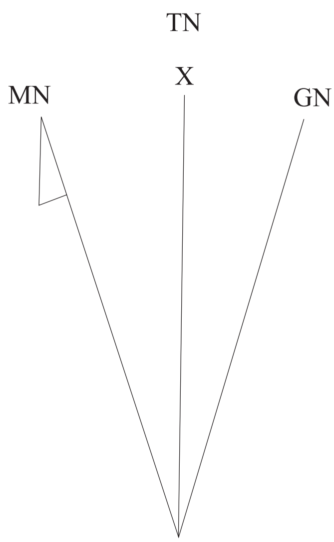


Figure 4.29: *The types of North direction*

True North

This is the type of north direction in which all meridians or longitudes converge in the northern hemisphere. Its direction is towards the 000° North from any place on the earth's surface. It is very near to the point at which the rotation axis of the Earth passes through. It is shown on the map by the star headed line. It is also called geographical North Pole and it is always fixed. The angle measured clockwise from geographical north to the object along the line of sight is called true bearing.

Magnetic North

This is direction indicated by the freely suspended magnetic needle. Magnetic North is the line representing the direction of the needle of a magnetic compass pointing when the map was published. It enables to obtain the magnetic bearing. It is the point in northern Canada where lines of the earth's magnetic field intersect. It is naturally a migratory point caused by by the shifting behavior of the earth's magnetic field which is influenced by a number of factors including the earth's rotation and ionisation of the liquid metal in the outer core. This is called polar shift theory, as the world is not static, but dynamic. The earth is changing every day, plate tectonic push continents apart, sea levels fluctuate up and down, volcanic eruption discharge ash and smoke on the surface, denudation occurs and climate changes.

Grid North

Grid north is the direction towards the north in maps drawn by grid system. Grid north is a direction that is parallel to the easting lines found on the Universal Transverse Mercator (UTM) grid system. The grid north aids in obtaining a topographical map since it is used as a baseline of clockwise direction. It is shown by bare line.

True bearing

A true bearing is an angle in which a line from the observer's position to the object meets with a line pointing to True North. The angle is measured clockwise from true north to the object along the line of sight.

Magnetic bearing

A Magnetic bearing is the angle, which a line from the observer's position to the object meets with a line pointing in the direction of magnetic north. The angle measured clockwise from the magnetic north to the object through the line of sight is called magnetic bearing.

Magnetic variation

Magnetic North and the True North never coincide. They normally leave a gap apart which is always changing with time due to the shifting tendency of the magnetic influence. Therefore, magnetic variation is the angular distance between the Magnetic North and the True North, which usually keeps on changing with time and space. The decrease and the increase of the angle depends on the position of the Magnetic North in relation to True North. Magnetic North keeps on changing its position at specific rate with time in relation to the position of the True North. It may be located in the western or eastern part of the True North which never changes its position. However, in the African continent, Magnetic North is located to the west of the True North. Determination of magnetic variation depends on the position of MN in relation to the TN.

Principles governing calculations of magnetic variation, magnetic bearing and true bearing when the magnetic north is to the west of the True North.

As shown in Figure 4.30, the position of Magnetic North is west of the True North. The gap between Magnetic North and True North denoted by MV_1 is the initial angle recorded before the change in position of Magnetic North. As the Magnetic North started to shift eastward, slowly the gap started to become smaller with time, giving the second angle in between denoted by MV_2. The angle between the new position and old position of the Magnetic North is called total change. The observation made from the Figure 4.30, therefore establishes that: *when the Magnetic North is to the West of the True North and the rate of annual change is eastward, the final magnetic variation is the difference between the initial magnetic variation and the total change (TC).*

$MV_2 = MV_1 - TC_1$

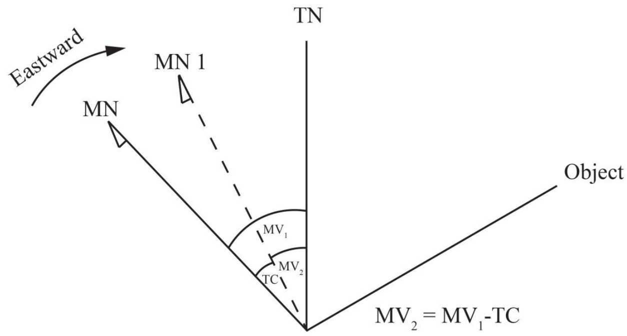


Figure 4.30: *Annual change of magnetic variation from eastward*

Example 1.

Find the magnetic variation of town X in March 2020, if in September 2010 its magnetic variation was 20°10'05" W and the rate of change stood at 10' eastward per year.

Solution

$MV_2 = MV_1 - TC$

Data given

MV_1= 20° 10' 05"

T_2= Year Month

2020 3

T_1= Year Month

2010 9

Rate = 10' E

TC = ?

MV_2 = ?

MV_2 = ?

Find the difference in time

T_2 - T_1

Years	Months
2020	03
− 2010	09
09	06

$=9\frac{1}{2}$ years

Find the total change.

Then, if 1 year =10 rate of change

$9\frac{1}{2}$ years = ?

$\frac{9.5 \times 10}{1}$ = 95′ W

Remember; 1° = 60' and 1' = 60"

Therefore, 95' W=1°35'00" W

Total change =1°35'00" W

New magnetic variation

$MV_2 = MV_1 - TC$

MV_1 = 20°10'05" − 1°35'00" = 1°835'05"

Therefore, magnetic variation of town X in March 2020 was 18°35'05" W

If you carefully study Figure 4.31, you will note that the diagram represents a bit opposite idea compared to the first diagram. The arrow pointed in solid line marks the initial position of the Magnetic North (MN) separated by narrow angular distance from the True

North (TN), denoted as MV_1. Slowly the narrow angular distance started to widen as the Magnetic North (MN) shifted westward into the new position indicated by the dotted arrow pointed line MN_1. Then the new wider angel denoted as MV_2 exists between the new position of the Magnetic North and the True North. Similarly, the narrow angle denoted as TC is seen between the new and the old position of Magnetic North. This can generally be concluded that, *when the position of the Magnetic North is to the West of the True North, and the rate of annual change is westward, the final magnetic variation is the sum of the initial magnetic variation and the total change.*

$MV_2 = MV_1 + TC$

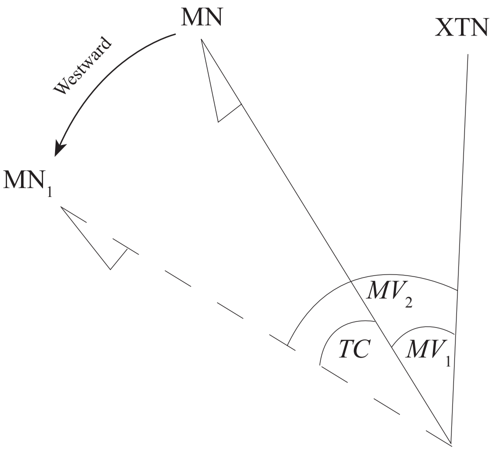


Figure 4.31: *Magnetic variation from westward annual change*

Example 2

Find the magnetic variation of town X in March 2020, if in September 2010 its magnetic variation was 20°10'05"W and the rate of change stood at 10' westward per year.

Solution

$MV_2 = MV_1 + TC$

Data given

$MV_1 = 20° 10' 05"$

T_2 = Years Months
2020 03

T_1 = Years Months
2010 09

Rate = 10'W

$TC = ?$

$MV_2 = ?$

Find the difference in time

$T_2 - T_1$

	Years	Months
	2020	03
−	2010	09
	09	06

$= 9\frac{1}{2}$ years

Find the total change.

Then, if

1 Year = 10' W

$9\frac{1}{2}$ Years = ?

$\frac{9.5 \times 10}{1} = 95'$ W

Remember 1° = 60' and 1' = 60"

Therefore, 95' W= 1°35' 00"

Total change = 1°35' 00" W

New magnetic variation

$MV_2 = MV_1 + TC$

$MV_2 = 20°10' 05" + 1°35' 00" = 21°45'05"$

Therefore, magnetic variation of town X in March 2020 was 21°45'05" W.

Rules governing calculations of magnetic variation, magnetic bearing and true bearing when the magnetic north is to the East of the true north.

As shown in Figure 4.32, the position of Magnetic North is to the East of the True North. The gap between magnetic north and the true north denoted by MV_2 is the initial angle recorded before the change in position of magnetic north. As the Magnetic North started to shift eastward, slowly the gape started to become larger with time, giving the new wider angle in between denoted as MV_2. The angle between the new and old position of the Magnetic North is called total change. From the observation made in Figure 4.32, it can therefore be deduced that: *when the Magnetic North is to the East of the True North and the rate of annual change is eastward, the final magnetic variation is the sum of initial magnetic variation and the total change.*

$\rightarrow = MV_2 = MV_1 + TC$

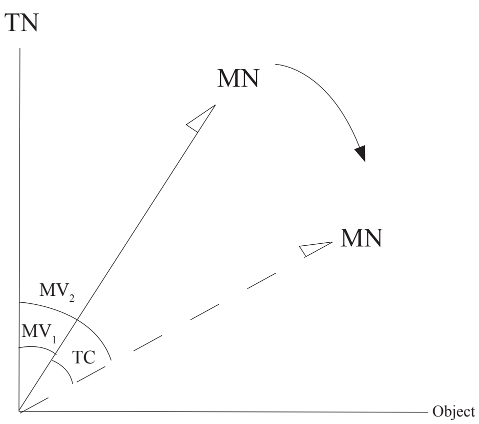


Figure 4.32: *Magnetic variation from eastward annual change*

Example 1.

Determine the magnetic variation of Mafia Island in April 2025 if its magnetic variation in September 2010 was 15°30'12" E and the rate of change is 8' eastwards per year.

Solution

$MV_2 = MV_1 + TC$

Data given

MV_1=15°30'12"

Rate of change = 8′ E

T_2 = Years Months
2025 04

T_1= Years Months
2010 09

TC = ?

MV_2= ?

Find the difference in time.

$T_2 - T_1$

Years	Months
2025	04
− 2010	09
14	07

$= 14\frac{7}{12}$ years

= 14.58 years

If 1 year = 8'

14.58 = ?

$= \frac{14.58 \times 8'}{1}$

= 116.64

=116.64' E

Remeber; 1° = 60' and 1' = 60"

Therefore,=116.64' E = 1°56’38”

Total change = 1°56'38" E

New magnetic variation

$MV_2 = MV_1 + TC$

= 15°30'12" + 1°56'3"

= 17°26'50" E

Therefore, magnetic variation of Mafia Island in April, 2025 will be 17°26'50" E.

As shown in the Figure 4.33, the position of Magnetic North is still to the East of the True North. The gap between Magnetic North and True North denoted by MV_1 is the initial angle recorded before the change in position of Magnetic North. As the Magnetic North started to shift westward, slowly the gape started to become smaller and smaller with time giving the new narrow angle in between denoted as MV_2. The angle between the new position and old position of the Magnetic North is called total change (TC). Generally, it can be deduced that, *when the magnetic north is to the East of the true north and the rate of annual change is westward, the final magnetic variation is the difference of initial magnetic variation and the total change.*

$MV_2 = MV_1 - TC_1$

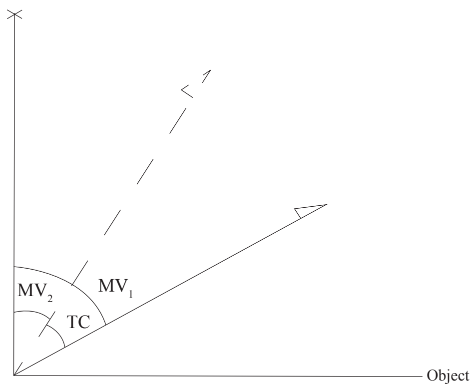


Figure 4.33: *Magnetic variation from westward annual change*

Example 2.

Find the magnetic variation of town X in March 2020, if in September 2010 its magnetic variation was 20°10'05" E and the rate of change stood at 10' westward per year.

Solution

$MV_2 = MV_1 - TC$

Data given

MV_1 = 20°10'05"

T_2 = Years Months
2020 03

T_1 = Years Months
2010 09

Rate = 10' W

$TC = ?$

$MV_2 = ?$

Find the difference in time

$T_2 - T_1$

Years	Months
2020	03
− 2010	09
09	06

$= 9\frac{1}{2}$ years

Find the total change.

Then, if

1 year → 10' W

$9\frac{1}{2}$ years → ?

$\frac{9.5 \times 10}{1} = 95'$ W

Remember; 1° = 60' and 1' = 60"

Therefore, 95' W = 1° 35' 00"

Total change = 1° 35' 00" W

New magnetic variation

$MV_2 = MV_1 - \text{TC}$

$MV_2 = 20° \ 10' \ 05'' - 1° \ 35' \ 00''$

$= 18° \ 35' \ 05'' \ \text{W}$

Therefore, magnetic variation of town X in March 2020 was 18° 35' 05" W

The following are rules governing calculation of true baring, if magnetic bearing of an object from its observer is given:

(a) When the magnetic declination is to the West of the True North as shown in Figure 4.34, subtract magnetic declination or magnetic variation (MV) from the magnetic bearing (MB) to obtain the True Bearing (TB).

That is, TB = MB – MV and MB = TB + MV.

(b) When the Magnetic North is to the East of the True North, as shown in Figure 4.34, add Magnetic deflination or Magnetic variation (MV) to magnetic bearing (MB) to obtain two bearings that is, TB = MB +MV and MB =TB – MV.

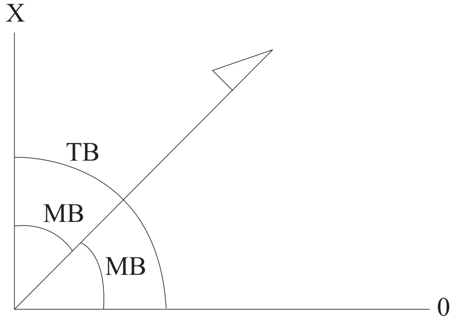


Figure 4. 34: *East declination of MN*

When magnetic variation changes magnetic bearing changes as well, but Magnetic North remains constant.

Example 1

True Bearing and Magnetic Bearing of Mbuyuni village in September 2010 were 120°35' 25" and 75°30' 36" respectively. Determine its magnetic declination and Magnetic Bearing in May 2020, if the rate of change was 20' W. Given Magnetic North is declined to the East.

Solution

$MV_2 = MV_1 - TC$ and $MV_1 = TB - MB$

Data given

T_1 = Years Months
2010 09

T_2 = Years Months
2020 05

Rate = 20' W

Determine the position of MN

If $MB < TB$, it means that MN is to the East of TN

Rate of change

$T_2 - T_1$

Year	Month
2020	09
− 2010	05
09	08

= 9.67 years

Find total change

If 1 year = 20'

9.67 years = ?

$$= \frac{9.67 \text{ years} \times 20'}{1 \text{ year}}$$

= 193.4' W

Remember; 1° = 60' and 1' = 60"

Therefore, 193.4' W = 3°13'24"

Total change 3°13'24" W

$MV_2 = MV_1 - TC$

MV_1 = TB - MB

Thus,

$MV_1 = 120°35'25" - 75°30'36"$

$MV_1 = 45°04'49"$

From

$MV_2 = MV_1 - TC$

$MV_2\ 45°04'49" - 03°13'24"$

= 41°51'25"

Therefore, magnetic variation and magnetic bearing at Mbuyuni village in May 2020 were 41°51'25" E, *respectively.*

Example 2

Magnetic variation of town Y by October 2012 and December 2021 were 45°30'05" E and 36°50'09" E respectively, while Magnetic Bearing was 85°45'35" by October 2021.

(i) Determine the annual rate of change

(ii) Compute Magnetic Bearing and True Bearing in 2021 December

Solution

Data given

Magnetic Variation$_1$ (MV_1) = 45°30'05"

Magnetic Variation$_2$ (MV_2) = 36°50'05"

Magnetic Bearing$_1$ (MB_1) = 85°45'35"

	Years	Months
T_1 =	2012	10
T_2 =	2021	12

Rate of change (R) = ?

MB_2 = ?

Old TB = ?

Find change in time (t)

$T_2 - T_1$

	Year	Month
	2021	12
−	2012	10
	9	2

$= 9\frac{2}{12}$ years

Time interval = 9.17 years

Since both old and new magnetic variations are given with Eastern directions, magnetic north is to the east of true north. Further, the direction of annual change is westward since old magnetic variation is (MV_1) is greater than new magnetic variation (MV_2).

$MV_2 = MV_1 - TC$

Then,

$TC = MV_1 - MV_2$

= 45°30'05' − 36°50'09"

= 8°39'59" ≈ 519.98'

Total change = 519.98'

To find magnetic variation, if

$9.17\text{years} = 519.98'$

$1\text{year} = ?$

$$\frac{1\text{year} \times 519.98}{9.17\text{years}}$$

$= 56.7'$

$= 56.7'$ = westward

The annual bearing in 2021 December (MB_2)

$TB = MB + MV$

Remember; MV is to the East of TN

$TB = MB_1 + MV_1$ or $= MB_2 + MV_2$

Note: When Magnetic Variation changes, Magnetic bearing change as well, but

True Bearing remain constant.

But, $TB = MB_1 + MV_1$

$= 85°45'40''$
$+ 45°30'05''$
$131°15'45''$

$TB = 131°15'45''$

$MB = TB_1 - MV_1$

$= 131°15'45''$
$- 36°50'09''$
$94°25'36''$

New Magnetic Bearing in 2021(MB_2) = 94°25'36"

Example 3

Given that Magnetic Bearing of town Y was 248°05'00" and magnetic variation was 15°26'00". Find the true bearing of the town Y.

Solution

Data given

$MB = 248°05'00''$

$MV = 15°26'00''$

$MB = MV + TB$

$MB - MV = TB$

When the magnetic declination is to the East of the True North, add the magnetic declination to the magnetic bearing to obtain the True Bearing. It means, if variation was 15° 26' 00"

Solution

$TB = MV + MB$

$= 15°26' + 232°29'$

$= 248°05'$

Therefore, the True Bearing of the town Y is 248°05'.

Exercise 4.6

1. By March 2007, town Z located in West Africa had MB and TB of 45°23'12" and 250°34'57", respectively. If the rate of change was 15 minutes per annum negatively; calculate the following by September 2022:
   (b) Magnetic variation
   (c) True bearing
   (d) Magnetic bearing
2. Magnetic bearing of Kibo Hill in September 2010 was 120°35'25" while its TB was 75°30'36". Determine its magnetic variation in May 2020.if its annual rate of change was 20' eastward.

Representation of relief on a map

The relief of an area is the surface form of the ground which shows size, shape, slope of the highlands and lowlands. It can also be defined as the changing nature of the land or variation in the shape and form of the earth's surface as observed from the sea level. The depiction of relief and land form on a flat map is an attempt to show three dimensional forms on a two-dimensional surface.

Methods of representing relief on a map

There are two methods of showing relief, which are; quantitative and qualitative methods. A quantitative method shows exact number, for example. contour, spot height, trigonometrical, benchmark and so on. Qualitative method does not show numbers but uses hachuring, hill shading, block diagram (physiographic diagram), layer coloring, form lines and naming methods.

Hachuring method

Refers to the non-numerical traditional way of showing the nature of the terrain, by means of their value and their thickness (Figure 4.35). Their thickness and values increase with the increase in the degree of land steepness. Despite the fact that they are non-numerical, hachures can successfully communicate a quite specific shape of the terrain. They are suitable for mountainous regions for depicting landforms such as craters. They also give general ideas on the nature of the slope. Hachures have the following limitations; They cannot show the extent of height and steepness of the landform they represent. Different relief features such as mountains, hill, and direction of the water courses are difficult to be interpreted with the use of hachures. They are likely to obscure other features and their use consumes more time.

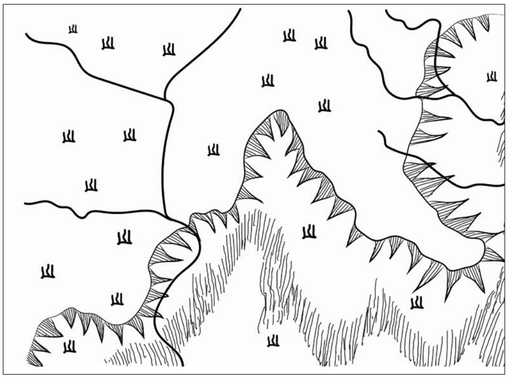


Figure 4.35: *Hachuring method*

Contour method

Contour lines on a map join points representing equal elevation above a datum or reference line (mean sea level). For example, the datum line for Nigeria is taken as mean sea level at Lagos. In East Africa, the dutum line is based on the mean sea level at Mombasa, and much of the survey work in South and Central Africa is based on the datum line at Cape Town. Usually, contours show various features or landforms like hills, plateaus, mountains and valleys, basins and plains. Contours, also show gentle slope when the contour lines are drawn far apart from one another and steep-slope when they are drawn closely. Contour lines are drawn at definite intervals for instance 20 m or 50 feet and do not cross one another. Contour lines form a 'V' pointing upwards to denote a valley and 'V' pointing downwards to denote a spur. The merits of contour is to give exact height for a particular area since the contours are numbered (Figure 4.36). They are also used to give clue of physical features depending on the contour layout and it can be integrated with other methods like spot height and trigonometrical station.

Example

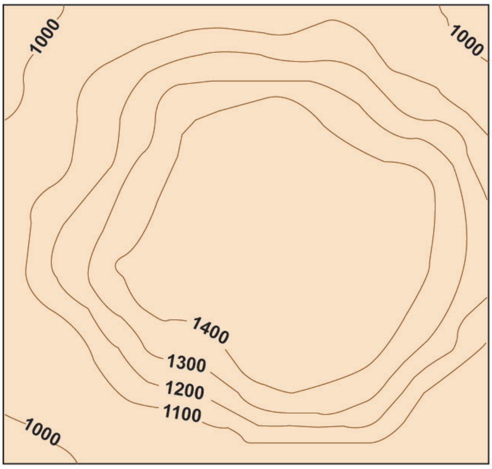


Figure 4.36: *Contour lines*

Form lines: are usually unnumbered lines drawn on a map joining points of nearly the same height. They are like contours but they use unnumbered lines.

Hypsometric colouring method

Hypsometric coloring also known as layer tinting or colouring is a method used on maps to re-enforce the impression of relief and to make the land forms more easily understood by map users. It is not a complete method in itself because it relies upon the presence of either contours or form lines to provide the basis for coloring. By convention, the lower elevations are colored in various shades of green, intermediate areas in yellow, higher altitude zones in brown or red, then purple and white. The lighter colour are used where most details are in the lowland areas and the brightest colors where details are sparsely high.

With layer coloring, it is simple to identify the nature of the relief whether lowland or highlands just by observing the change in colour rather than striving to find the values of height as with other methods like contour lines. It is mostly used on small scale maps and atlas maps. Different tones used in indicating the change in elevation make the map more attractive. For instance, green colour is used to indicate lowland and white or red colour is used for highland. A stereoscopic is produced in which the warmer colors such as brown and red appear nearer the map reader while the cooler colors like green and blue at lower elevations, appear further away. It may bring about confusion to some people since colors have multiple implication in people's minds. For example, green colour may suggest vegetation or fertility. However, not all lowlands coloured green are fertile. Additionally, layer tint maps are very expensive to produce. Lastly the method cannot show a clear boundary between highland and lowland areas, though it uses different colors to indicate them.

Hill Shading

Hill shading is a method of showing relief in which parts of the map are darkened by a tint or stipple of chosen colour as if they are in shadow cast by an imaged object. It can give a fine, modeled impression of relief that strikes out eyes at once. The slopes can be shown easily as the shadow tone is darker on steep slopes and lighter on gentle slopes. It tends to make the slopes in shadow to look steeper than they really are. The impression of relief is sometimes much greater than the sense of it, for example, the location of "ups" and "downs" (Figure 4.37).

Figure 4.37: *Hill shading method*

Trigonometric point method

Trigonometric point is the method of representing relief whereby a point is accurately surveyed and shown on the map, with their actual height in metres or feet above mean sea level. The method is usually represented on the map by a triangle and a dot with exact height. For example, ⚠8848 m. After surveying, the surveyors erect concrete pillars on the summits of the hills, which act as corners of the main triangles of the survey. The method is easy to recognize the height of a given point on the map. Sometimes a trigonometric point is called a trigonometric station. Like trigonometrical stations, the method is used with contour lines for mathematical interpretation of the map, such as determination of the slope and drawing of relief section.

Spot height method

Spot height is the method of representing relief whereby a point is accurately surveyed and its actual height above mean sea level is shown in metres or feet on a map. The method is normally represented by dot and exact height such as ● 5895 m or represented by small circle with dot and height number for example ⊙ 5895 m. In this method, there is no physical evidence of spot heights in the field, but they appear frequently on maps, along road and between contours near sea-level to help in interpretation of relief.

With trigonometric station and spot height it is easy to recognise the height of a given point on the map, unlike with the use of contour lines and psychometric tinting method. It can be used with contour lines to prepare the cross section. It is also very useful in some mathematical interpretation of the mapped area such as determination of slope. It may provide important elements or clues on the nature of the relief, and become the basis of the relief description. The use of trigonometric stations as the method of showing relief features does not obscure other details. However, with this method, it is very difficult to clearly understand the nature of relief features like mountains, valleys and steep slopes in a particular mapped area.

Benchmarks methods

A benchmark (BM) is a mark on a permanent object, which indicates an elevation of a given area. Benchmark serves as a reference point from which measurement of topographical surveys may be made. They can be found in the brick or stone of a building or a wall. It is shown by a symbol followed by a numerical height, for example BM 1554.

Naming method

Naming method is the method of showing relief whereby specific landforms (relief features) are identified on topographical map by using their names.

Map interpretation

Once the conventions and alphabet of maps are mastered, it becomes possible to spell out situations in the landscape from the association and relationships of symbols. In topographical maps all the information about location, landscape and cultural features are depicted with the assistance of conventional signs and symbols. It should be noted that convection signs and symbols are used to define the features represented on the map. Thus, they should be relevant to the actual features represented. They should also be common, familiar and widely accepted by map readers; otherwise there will be misinterpretation of the information. From such information, one can read and interpret the position, climate, relief, vegetation, drainage, settlement, rocks and human activities of a particular location shown on the map.

Position

The use of latitude and longitude of an area studied will tell where the piece of land lies in the world. When one knows this, it becomes easy to picture out the chief geographical characteristics of the area by applying general knowledge of geography. In addition to that, latitude degree helps to determine hemispherical position (location) of the mapped area. If a latitude degree is followed by the letter 'S' means it is taken from the Southern hemisphere and letter 'N' indicates the Northern Hemisphere. For example, a map of Vanga, sheet No. 111/1 lies from 4°40'00" S to 4°45'00" S indicates that it is taken from the southern hemisphere.

Therefore, it is possible to find a position of a piece of land or object on the earth surface by using latitudes and longtudes (graticule system).

Example 1. Locate Dodoma town which is found at grid reference 328590 by using longitude and latitude, starting with 30° E and 05°, S respectively (refer Figure 4.23).

Solution

Longitude

(i) Find difference in degrees

$$40° \text{ E} - 30° \text{ E} = 10° \text{ E}$$

$$\text{If } 14.8 \text{ cm} = 10° \text{ E}$$

$$8.2 \text{ cm} = x$$

$$\frac{x \times 14.8 \text{ cm}}{14.8 \text{ cm}} = \frac{8.2 \text{ cm} \times 10°}{14.8 \text{ cm}}$$

$$x = 5.54°$$

(ii) To change degree to minutes

$$\text{If } 1° = 60'$$

$$0.54° = x$$

$$\frac{x \times 1°}{1°} = \frac{0.54° \times 60'}{1°}$$

$$x = 32.4'$$

(iii) To change minutes into seconds

$$\text{If } 1' = 60''$$

$$0.4' = x$$

$$\frac{x \times 1'}{1'} = \frac{0.4' \times 60''}{1'}$$

$$x = 24''$$

The combined degree in (i),minutes in (ii), and seconds in (iii) gives 5°32'24"

Thus, 30°00'00" E
+ 5°32'24"
35°32'24" E

Latitude

(i) Find difference in degrees

$$10° - 5° \text{ S} = 5°$$

If 7.6 cm = 5°

1.8 cm = x

$$\frac{x \times 7.6 \text{ cm}}{7.6 \text{ cm}} = \frac{1.8 \times 5°}{7.6 \text{ cm}}$$

$$x = 1.18°$$

If 1° = 60'

0.18° = x

$$\frac{x \times 1°}{1°} = \frac{0.18° \times 60'}{1°}$$

$$x = 10.8'$$

If 1' = 60"

0.'' = x

$$\frac{x \times 1'}{1'} = \frac{0.8' \times 60''}{1'}$$

$$x = 48''$$

Thus, 1° 10' 48"

Hence, 5°00'00" S
+ 1°10'48"
6°10'48" S

Therefore, position of Dodoma town at grid reference 328590 lies at longitude 35° 32' 24" E and latitude 6° 10' 48" S.

Climate

A great deal of climatic information can be deduced from the topographical map using latitude, drainage (water bodies), relief and vegetation as follows;

Latitude

This is the most common hint used in the mapped area. It gives general indications concerning rainfall and mean annual temperature. For instance, areas between 0º to 5º north or south of the equator fall under equatorial climate. These areas are characterised by high temperature and high rainfall. Area between 5º and 15º North or South of the Equator are in category of tropical climate with moderate rainfall marked by wet and dry seasons and the temperature is also high. Areas between 15º and 35º North or South of the Equator are categorised as desert climate with very high temperature and little or non rainfall.

Altitude: the mean temperature decreases with altitude at an average rate of 6.5º C for every 1 000 m. Thus if one notes the height of a place can make an easy arithmetic guess whether the area experiences high or low temperature. Rainfall type can also be determined by the presence of mountains which induce orographic rainfall. So, the latitude sometimes does not give exact type of climate. When relief interrupts the area, it results to modified climate such as modified equatorial climate, modified tropical climate and mountainous climate.

Water bodies

These are very good guide to climate types. The presence of many rivers indicates high rainfall; hence, suggests equatorial climate, while the presence of salty lakes, bore holes, water holes, springs and wells imply dry conditions or semi-arid climate. Seasonal lakes and swamps suggest low rainfall and the area is marked by wet and dry seasons which denote a tropical climate.

Vegetation

This is a good guide for map interpretation. The presences of forests and bamboo trees indicate high rainfall, which denotes equatorial climate in the area. Moreover, woodlands or grasslands reflect medium rainfall while scrubs, thickets, thorny bushes and scattered bushes imply low rainfall which represent a semi-arid climate.

Crops

Crops can indicate the type of climate of an area. Some of the crops such as coffee, rubber and tea are grown in areas which receive high rainfall, hence indicate presence of equatorial or mountainous climate. Other crops such as sisal, millet and cassava tolerate dry conditions and survive under moderate rainfall, hence indicate presence of tropical climate.

Relief

This can be defined as the changing nature of the land as observed from the sea level with its characterising landforms. An area can be described as highland relief if its average elevation is higher than one thousand metres above mean sea level. Highland relief is normally characterised notably by highland landforms such as mountains, escarpments, ridges, plateaus, valleys and spurs as well as, hills and ridges. Lowland relief is normally with the average elevation below one thousand metres above the mean sea level. It is characterised by lowland features such as deltas, plains, estuaries and cliffs.

Relief on topographical map can be shown by using various methods of representing relief such as contour lines, spot height, trigonometric stations or hill shading.

Contour lines form a 'V' pointing upstream to denote a valley and pointing down to denote a spur. Where contour opens is where the river and water streams go and when several contour lines are merging it indicates a cliff.

Transport and communication

Though all types of transport are shown in topographical maps, the most common is land transport which includes railway lines, pipelines, and roads. Roads are shown in different forms like tarmac roads also called all weather roads which are represented by thick red line. Loose surface roads are indicated by thick broken line, dry weather roads are indicated by continuous white line and footpath. Some topographical maps show well developed and distributed transport and communication routes than others. This shows that there is unequal development of transport and communication systems. Some of the factors that determines unequal development and distribution of transport and communication includes drainage, relief, human activities and climate.

Apart from land transport, topographical maps also show air transport which is indicated by airfield runway and water transport indicated by large water bodies like lakes, sea and oceans.

Land use and functions

Different land uses both in urban and rural areas are well shown in the topographical maps. Urban land use is indicated by commercial land use, industrial land use, residential land use and open space land use. Rural land is used for different economic, political and social activities including commercial cultivation. The common land uses in rural areas are intensive cultivation land use, forestry land use, grazing land use and village settlement land use.

Drainage system

Drainage can be defined as the runing water in an area by natural or artificial streams, rivers, and infiltration as it is commanded by the nature of geology and relief of the particular area. Variation in the nature of relief and rocks determine the quality, and types of drainage patterns. Drainage pattern is the layout or plan made by rivers and their tributaries on the landscape. Streams and rivers are by far the most important landscapes forming elements. In map reading and interpretation, the drainage basin forms a convenient unit of study which can be outlined and readily defined on a map. Drainage can be classified according to the pattern formed in relation to surface relief or the slope of the land, differences in rock hardness and rock structure. Various drainage patterns are related to the surface rock structure.

Dendritic pattern

It is a shaped like trunk and branches of a tree usually with tributaries converging on the main stream from many directions and merge at acute angles (Figure 4.38). They occur in rocks which are homogeneous (similar). They are commonly formed on massive crystalline rocks like granite or horizontal to gently dipping sedimentary strata. They are not related to rock structure or differences in rock hardness.

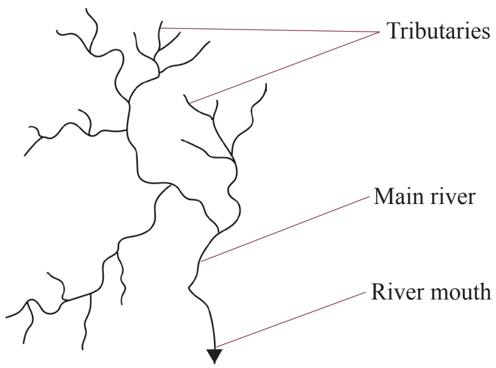


Figure 4.38: *Dendritic drainage pattern*

Trellis drainage pattern

It is a linear pattern in the shape of a lattice with the chief tributaries joining the main stream approximately at right angles (Figure 4.39). Usually, minor tributaries join the chief tributaries at right angles and flow more or less parallel to the main stream. The pattern is strongly related to structure or differences in rock hardness (heterogeneous rocks) and is commonly found in scarp land areas and regions of folded rocks. Normally, it is found in folded sedimentary rocks and metamorphic rocks. The chief tributaries are usually aligned along down fold or parallel zones of weak rock separated by resistant uplands.

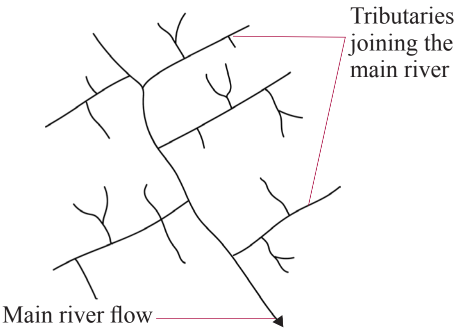


Figure 4.39: *Trellis drainage pattern*

Radial drainage pattern

This is an arrangement of streams flowing outwards down the flanks of a dome or cone-shaped upland such as a large volcano (Figure 4.40). It is common in volcanic region and controlled by the gradient of the land.

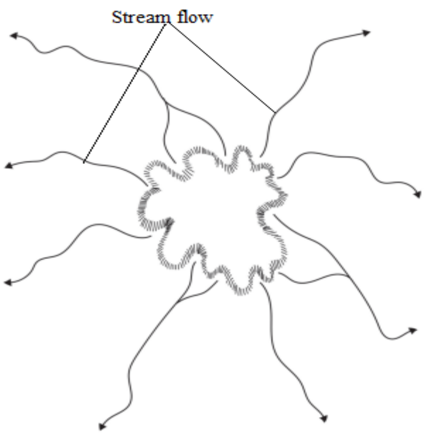


Figure 4.40: *Radial drainage pattern*

Annular drainage pattern

Is the pattern with streams often joining at sharp angles but arranged in a series of curves about a dissected dome, basin or crater area. On a dissected dome with alternating bands of hard and soft rock the pattern may appear as several concentric curves (Figure 4.41). It is common in volcanic region.

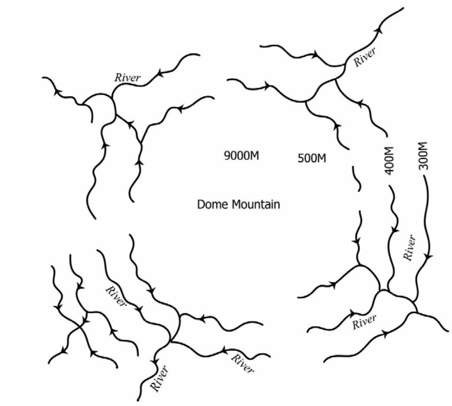


Figure 4.41: *Annular drainage pattern*

Rectangular drainage pattern

This pattern is similar in plan to the trellis, with tributaries joining each other at approximately right angles. Rectangular pattern also tends to have individual streams taking sharp angular bends along their course (Figure 4.42). It is the result of structural control, with streams following joints or fault lines in the rock. It is common in volcanic region, and granitic rocks.

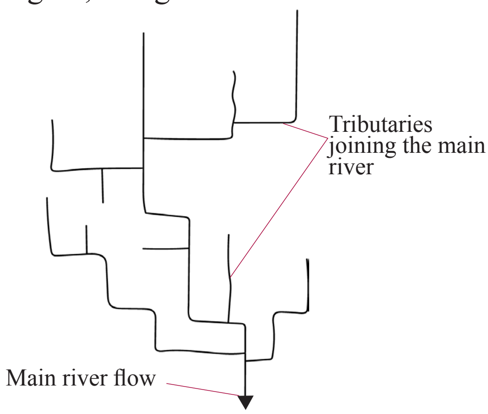


Figure 4.42: *Rectangular drainage pattern*

Braided drainage pattern

This is common on broad flood plains with low gradients, often due to back tilting (Figure 4.43). A good example is in Mazinde area at Lushoto in Tanga region.

Figure 4.43: *Braided pattern*

Regulated drainage pattern

Regulated pattern is common in flat sediments of recent age in coastal zones, associated with tidal rivers, numerous cracks and coastal swamps (Figure 4.44). It is very common along the coasts of West and East Africa.

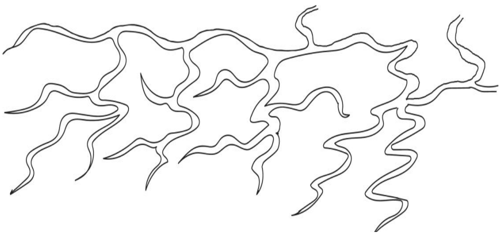


Figure 4.44: *Regulated drainage pattern*

Anastomotic drainage pattern

It is very common in area on flood plains in coastal zones or reduced gradients inland due to back tilting (Figure 4.45). It is very common for numerous double channels, ox-bow lakes, cut-offs, and abandoned meanders.

Rivers or streams will generally follow the line of least resistance such as along a band of softer rock, a fault line or the crushed fault breccia between two faults.

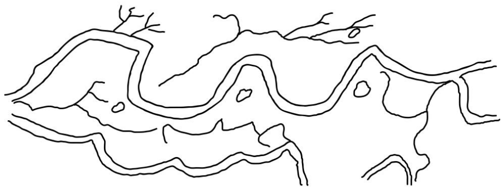


Figure 4.45: *Anastomotic pattern*

Centripetal drainage pattern

This drainage is opposite to the radial drainage pattern because it is characterised by the streams which converge at a point which is generally a depression or basin. This drainage is formed when a series of streams converge in a central low basin or crater lake (Figure 4.46). A good example of this drainage pattern can be found in Kondoa District.

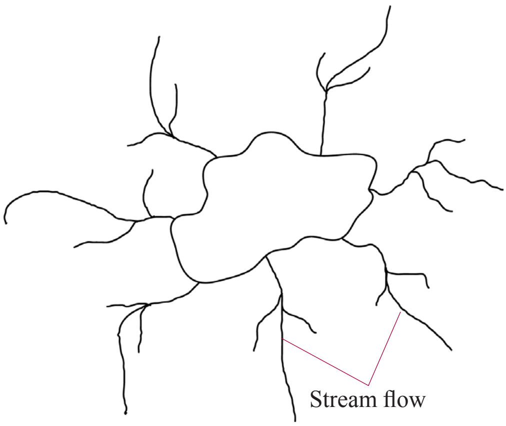


Figure 4.46: *Centripetal drainage pattern*

Parallel drainage pattern

Parallel drainage pattern comprises number of rivers which are parallel to each other and follow the original slope (Figure 4.47). This pattern is more frequently developed on uniformly sloping and dipping rock beds such as Cuesta or newly emerged coastal plains.

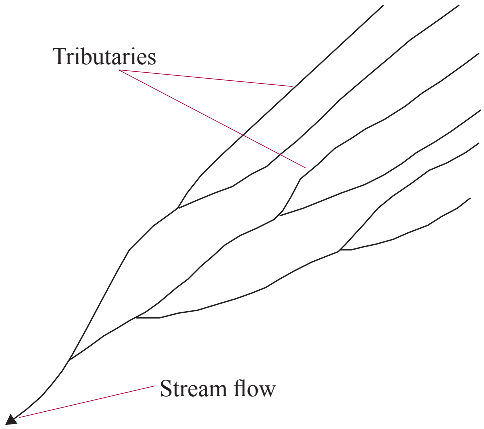


Figure 4.47: *Parallel drainage pattern*

Vegetation

A topographical map shows both natural vegetations such as forest, Savanna, thicket, shrubs, thorny, swamp vegetation, bamboo, mangrove swampy, scattered bushes and others as well as artificial vegetation which may be indicated by plantations. Sometimes vegetation is also indicated by pictorial symbols which shows increasing density by placing the symbols closer together or giving the area a green tint. Dark green color may be used. In interpretation of vegetation, a geographer should consider the nature or type and the way it is distributed. To determine what vegetation appear in which part of the mapped area, consider the cardinal points or names to indicate the nature of distribution. For example, the Eastern side of the mapped area is covered by scattered trees and scrubs while in the North West part is dominated by thick forest. In describing vegetation distribution, a geographer should also consider factors which account for the presence or absence of vegetation in the particular area. Normally the number of factors including soil quality, relief, drainage, human activities and climatic condition influences vegetation distribution. A detailed description of vegetation, soil and climatic relationships is presented in Table 4.3.

Table 4.3: *Vegetation, soil and climatic relationships*

Vegetation type	General description	Climatic relationship	Soil relationship
Forest	Closely spaced tall and medium trees, mixed or in simple stands with or without bushy undergrowth.	Rain most of year, rainy slopes of mountains, tropical and equatorial coastal lowlands.	Thick and fertile soil.
Savanna	Open with fewer trees than closed savanna. Scattered threes, tall grasses and thorn.	A pronounced dry season but annual total rainfall permits tree growth.	Widely varying soil from black cotton to sandy or volcanic.

Dense, medium or sparse bush	The drier the climate, the frequent the bush, thickets frequent (tangles of several bushes) tufts of grass or bare sandy patches between bushes and thickets.	Long dry season generally prevents trees growth except for occasional euphorbias or baobab.	Similar to Savanna but usually thinner and drier sandy types.
Scrub	Low profile thorn trees often gnarled and twisted with scattered clumps of thorny bush and drought resistant grass.	Very long dry season, rain unreliable.	Usually sandy thin soils.
Heath	Tufts of grass growing in close formation, heath and sometimes grant groundsel and lobelia.	Moderate to heavy reliable rainfall at high altitudes (above 3500 m) cool temperature.	Infertile acidic soil.
Mangrove swamp	Low bush-lie trees with long roots often exposed at low water. All strong grass with stiff spikey which often key sense growth.	Hot, wet lowland areas along coasts or lake shores and rivers, high humidity. High temperature, rainfall not liable water supplies by lake.	Silt or mud soil, salt or fresh water. Water logged soil along river banks and lakes.

Settlement

Settlement refer to an organised permanent or temporary inhabitation of humans on a small or large area of land including slum or the requisite infrastructural facilities. Settlement range in size from small to largest. Settlement is another basic aspect on topographical map interpretation.

Types of settlement

There are two types of settlement, namely urban and rural settlement. Urban settlement is an area where its population approximately 80% are engaged in non-agricultural activities. Its is commonly found in district head quarters, regional administrative centres and along transportation routes. Rural settlement is an area where its population approximately 80% are engaged in agricultural activities. Commonly found in a countryside and villages. In interpretation of settlements geographers have to consider how and where the dots representing people, house or buildings and the town are located. Urban settlement is simply identified through highly built areas, as well as densely linear and nucleated settlement patterns; while rural settlements are revealed in the map by sparsely hurts, light linear and nucleated settlement patterns.

In actual sense, settlement should be studied systematically looking on aspects such as site, situation, form, pattern and function.

Site: is the nature of land on which the settlement is built or where town or village is built. The site may be chosen for different reasons such as relief and gradient. For example, flat areas may be preferred for easy building. Areas with availability of water bodies such as of rivers, streams, and lake; fertile soil; presence of transport and communication network, defensive site such as mountainous area can also be chosen for the purposes they serves. Sometime, site choice can be influenced by government policies. The government can allocate the use of land depending on its potentiality.

Situation: is the settlement's position in relation to other conditions such as physical features, important economic zones and communication. For example, the village may be situated on a river bank above flood level. The site will be convenient because of availability of water nearby. This means that, settlement is well established in an area when site and situation conditions are not conflicting.

Form: this refers to the general shape of the settlement. Usually, a topographical map may indicate the features which have influenced the form of the settlement. For example, the basic urban forms are linear which may result from a constructed site such as valley, the alignment of a route way or river or an elongated relief feature such as a ridge or escarpment base. Other forms of settlement are as follows: concentric circular form which is the form where growth has been generally outward from a central core or nucleus. With rectangular form, the town develops in blocks. A good example is Hastings town in Sierra Leone.

Settlement pattern: this is how the settlement is distributed. In this aspect, we can examine the size of settlements in relation to the environment and we can study the pattern and shape of settlements. Normally settlement morphology (pattern) is determined or controlled by its main function. In other words, it depends on the human activities. There are three types of settlement pattens, namely linear, nucleated and dispersed settlement patterns (Figure 4.48).

Linear settlement pattern: occurs in the area where the marketing of cash crops depends upon ease of transport, or along communication and transport routes such as roads and railways. Some areas follow the pattern of river valleys. This settlement is linear in shape where business and collecting are the major activities.

Nucleated settlement patterns: represents settlement areas characterised by clustered or closed buildings normally for economic and social purpose. It is common in town centers, village centers, borders of two countries and around the coastal areas. It is common in places where there is settlement around nuclei areas such as market centre or mining centers.

Dispersed settlement pattern: occurs in the area with sparsely or scattered people, with few houses far apart. Such pattern can be found in pastoral societies.

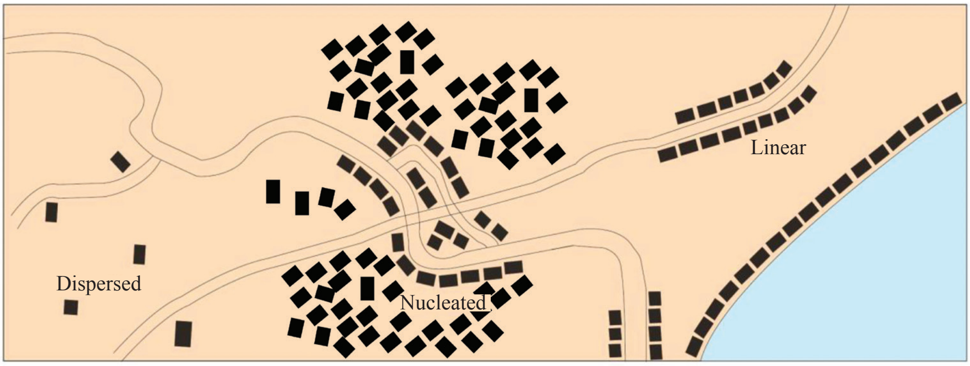


Figure 4.48: *Three types of settlement patterns*

NOTE: Settlement morphology or pattern changes with time due to social, political and economic development. An area with scattered settlement may over time be dominated by nucleated settlement.

Function: is another technique of interpreting settlement. Land use pattern within a form of larger settlements may reveal well-defined functional zones, in which there are varieties of specified activities. Such zones include the Central Business District (CBD), which is a rectangular grid pattern of high class and specified shops, offices and banks located near the centre of the settlement. The zone is neither residential nor industrial. Generally function of a settlement reflects its economic and social development activities. More examples of functional zones which can be indicated on a map are as follows:

The administrative function is indicated by government offices such as Headquarters (HQ), District Council (DC) and Regional Council (RC).

Recreational function is usually indicated by different man-made features such as car parks, gardens, football grounds, boating lakes, race courses, golf courses and zoos.

Cultural function is normally is indicated by cinemas, museums and libraries.

Educational function is depicted by schools, colleges, universities, research centers library building and education offices.

Industrial function is usually spacious in layout and well away from the main centre and residential areas and very often downwind to avoid pollution.

Cultivation function: is normally located in margins of most large towns and cities. Horticulture is practiced to serve the industrial and business purposes.

Marketing/Trade function is indicated by buying posts town, market, and nuclear settlement pattern.

Residential function is classified on the basis of low, medium and high density. The infrastructure serving the settlement like electricity, water pipes, dams, railways lines and roads are good indicators of residential zone.

The number of institutions such as government offices, police stations, army barracks, churches, colleges and alike; are significant to support living, hence considered important indicators for this zone.

Functional zones may be more easily defined in large urban centres than in smaller settlements. In smaller settlements one looks for emerging or embryo functional zones and tries to depict what future development they are likely to produce.

Types of rocks

Rocks vary in hardness with metamorphic being the hardest while the sedimentary being the softest. Table 4.4 shows some hints that help to deduce types of rocks on a given topographical map.

Table 4.4: *Identification of types of rocks on a topographical map*

Types of rock	Possible evidences		
	Land forms	**Water bodies**	**Vegetation & Crops**
Igneous rocks	• Mountain • Hill • Crater • Caldera	• Radial drainage pattern • Dendritic drainage pattern • Annular drainage pattern	• Thick dense forest • Tea plantation • Coffee plantation • Pyrethrum
Sedimentary rocks	• Coral reef • Coast land • Cave • Delta • Cliff • Depression	• Salt lake • Regulate pattern • Braided drainage pattern • Water holes • Bore holes	• Mangrove swamps • Tree swamps • Seasonal swamp • Sugarcane plantation • Rice plantation • Sea weed plantation
Metamorphic rocks	• Outcropped rock • Undulating plateau	• Trellis drainage pattern	• Scrubs

Describing forces affecting the landscape

In topographical maps it is possible to spell out exactly about geomorphic activities that reshaping the mapped area. A geographer can identify both endogenic (folding ,faulting and vulcanism) and exogenic (denudation and deposition) activities. This can be done with the help of the nature of relief depicted and its associated landforms. Table 4.5 shows some hints for description of forces affecting the landscape.

Table 4.5: *Forces affecting the landscape*

SN	Process/ activity	Common evidence
1	Vulcanism	Crater, Hill, Mountain
2	Faulting	Escarpment, Mountains, Valleys
3	Folding	Mountain, Valleys and spurs
4	Erosion	Rivers, Lakes, Oceans, Hills, valleys
5	Deposition	Lakes, Rivers, Swamps, Oceans
6	Weathering	Rocks, Out crops, Mountains

Human Activities

Maps describe the way man feeds himself and earns his living. The following are some simple hints being used to describe economic activities.

Cultivation

Farming is among of the basic and the widespread economic activities of man. The topographical maps show both small and large-scale farming. Small scale farming is represented by scattered settlements, scattered cultivation and inland water bodies while large scale farming is portrayed by estates or plantation.

The presence of ginneries for cotton; hullers for coffee; jiggery works for sugar; tea factories Cotton Buying Post (CBP) and maize mills indicates farming. In addition, cultivation can be presented by the word scattered cultivation.

Pastoralism

Livestock keeping is not easily seen on maps. Grassland areas with scattered clusters of dwellings and perhaps water pans, water holes, dams and boreholes are the likely settings to represent pastoralism. In addition, look out for named veterinary installations, water-pump tanks, cattle and quarantine camps, trough races, cattle and creameries.

Manufacturing Industries

Ginning, hulling, tea and sisal processing are often done in the countryside, but East African industries are in or near the larger towns. Normally urban settlement indicates industrial activities. Special symbols and signs also can be used to identify industries. Some words such as ginnery, factory or industry can be applied. Similarly, large scale plantation indicates the presence of processing industry.

Trade

It focuses on buying and selling goods and services. It is depicted by the presence of communication network (roads, airways and railways), markets, shops, trading centres and settlement.

Mining and quarrying

Some places in the drier rift valley floor are exploited for salt or soda. Nevertheless, mineral symbols, salt works, mineral works and quarries are mostly preferable. They are also indicated by presence of brick or cement industries since they depend on limestone or sand as their raw materials.

Logging

Logging also known as lumbering refers to the activity of cutting down trees in order to use their related products like wood. Woods are used to produce timber (lumbering), charcoal and poles for electricity, furniture as well as different industrial materials. On a map, evidence such as saw mills and minor roads ending in forested area depict logging. Some forest reserves are exploited for timber, but many are not meant to be exploited.

Fishing

Settlement along water bodies such as rivers, sea, ocean and dams indicate fishing activities. Similarly, this is indicated by the presence of fish trap, fishing market centers and net drying yard.

Tourism

The presence of National Parks or National Reserves antiquities, volcanic features and coastal features, hotels, gymnasium, cultural features, physical or scenery can be preferred to indicate tourism in the mapped area.

Social Activities

Social activities are services provided for the benefit of the community. They are activities which aim at solving social problems or need and therefore generate social impact. Some social activities are like; religious activities, health services, educational activities, transport and communication, administrative activities, Security services, power supply services, banking services and recreational activities. These social activities can be presented on a map in different ways.

Religious activities can be indicated by worshiping centres such as churches, mosques, and temples. Health services are indicated by health facilities such as health centres, hospitals, dispensaries and clinics. Educational activities are depicted through schools, colleges and training centres. Administrative activities, are indicated by Headquarters (HQ) offices and local government Headquarter (LGHQ). Security services are shown through Police post and military camps. Recreational activities are denoted by play grounds, such as tennis grounds stadium, cinema halls, race tracks, camp sites, and resorts. Water supply services are denoted by water tank, tap, large water body, or underground pipe line. Power supply services are shown through power station, power house and electricity poles. Transport and communication are indicated by road, railway line, airport, aerodrome, port, large water body, and telephone line.

Relief section

A relief section also known as cross section shows the shape of a feature (such as a mountain) viewed from the side, as if cut through with a knife. It is lateral view of the relief. It is a graphical representation of the two dimensions of the part of the mapped area in three dimensions.There are three (3) forms of cross section;

The fisrt is simple relief section shows only relief between two points. The second is annotated section that shows relief with other information that crosses between two points including vegetation, road and river. Lastly, sketch transcend section that shows only the highest and the lowest points. It portrays a rough picture of general appearance of the landscapes.

Procedures of constructing a relief section

(i) Identify the two given end points and mark their positions, features and heights.

(ii) Draw a light-pencil line joining the two points.

(iii) Transfer the line drawn on the map between two points to the graph paper

(iv) Place or lay the straight edge of the paper along the drawn line, and mark the point of elevations on the paper. If you cross the same contour twice or more, mark it with the same number.

(v) Choose a vertical scale which will show the variations in relief but without exaggerating them too much. For suitable vertical scale, use guidelines by observing the type of scale given

(vi) Draw the vertical lines and plot the points.

(vii) Link the dots, produced with a continuous smooth line to indicate relief.

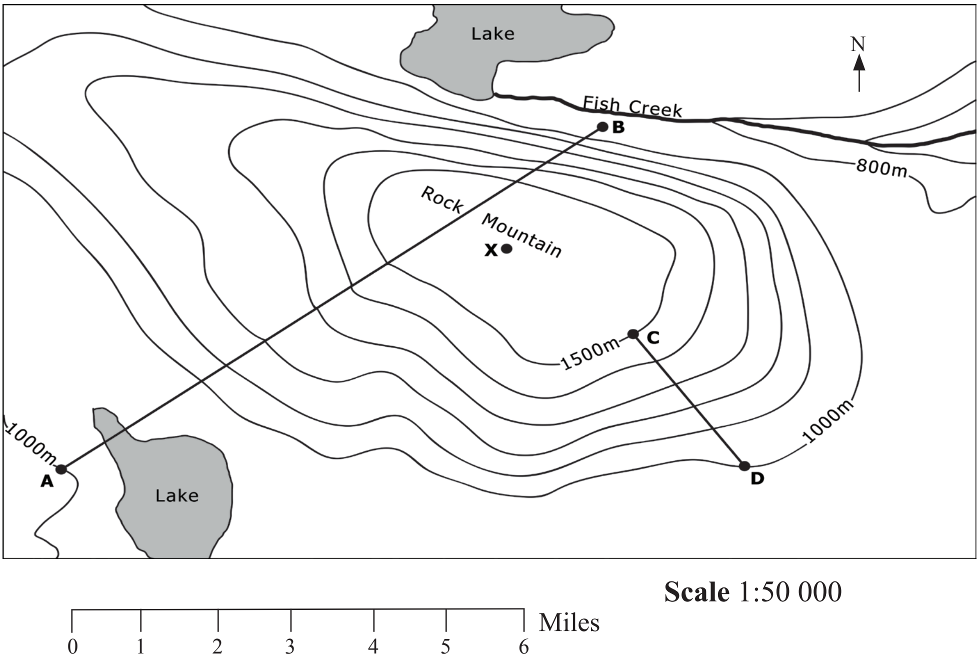
Example 1

Study the contour map and answer the following questions.

(a) Prepare simple cross profile between point A and B.

(b) Draw an annotated relief section between point A and B.

(c) Prepare sketch/transcend relief section between point A and B.



Scale 1:50 000

Solution

How to find vertical interval (V.I) mathematically

$$V.I = \frac{H_1 - H_2}{n+1} = \frac{D}{n+1}$$

Where by

D = Difference between two contours, example $\overline{AB}$

n = Number of contours lines which are unnumbered

From the map

H_1 = 1500m at c

H_2 = 1000m at D

n = 4

Then $V.I = \frac{(1500-1000)m}{4+1}$

$= \frac{500m}{5}$

= 100 m

V.I = 100m

Therefore, interval between two consecutive contour lines is 100 m

An annotated cross profile between point A and B

V.S = 1 cm : 100 m

1 cm = 100 × 100 cm

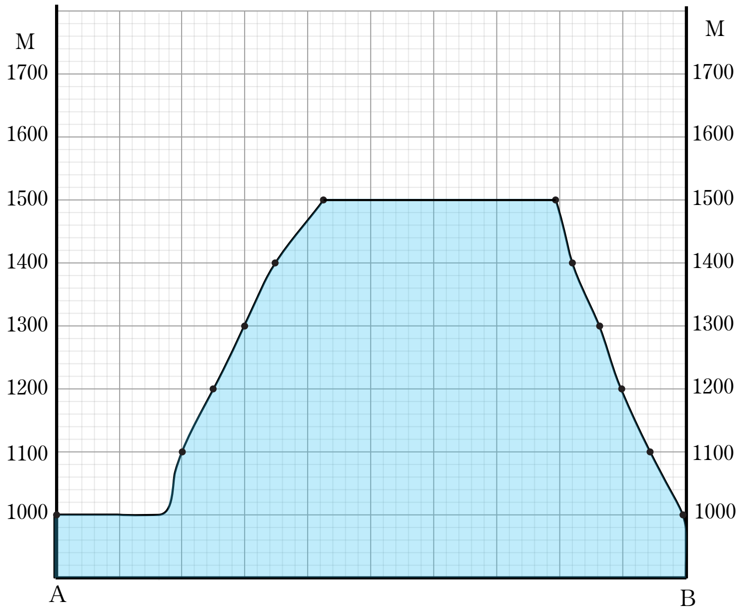
$\frac{1cm}{1cm} = \frac{10000cm}{1cm}$

V.S = 1:10 000

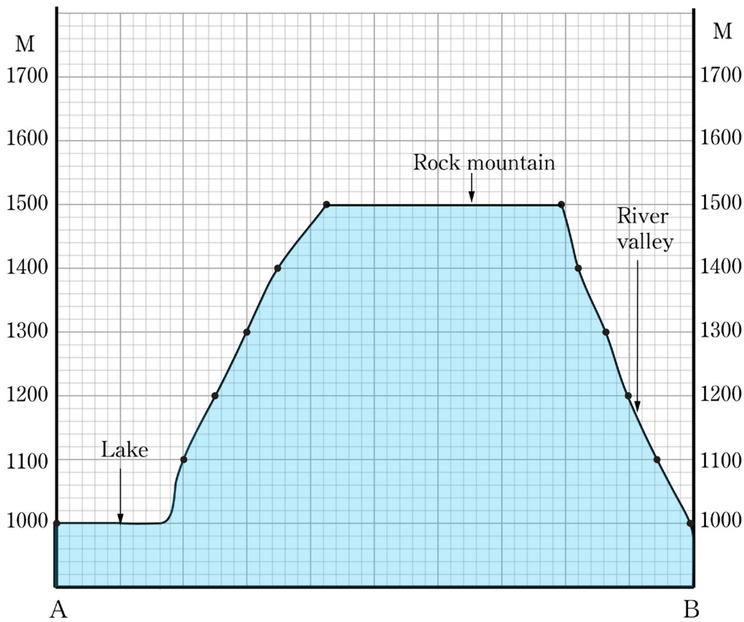
Therefore: V.S: (1 cm represents 100 m)

H.S = 1:50 000 (1cm represents 50 000 cm)

(a) Simple cross profile between point A and B



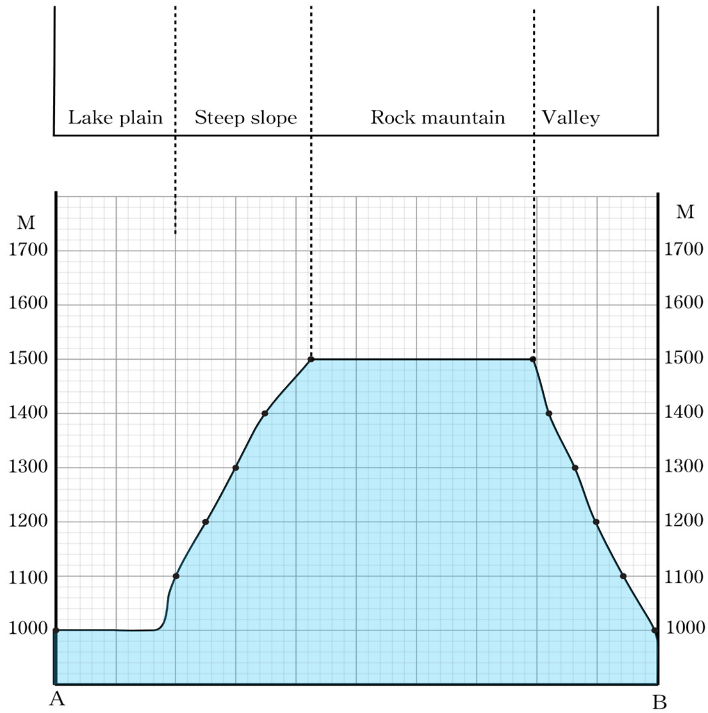
(b) An annotated cross profile between point A and B



(c) Transcend/sketch relief section between point A and B

All procedure used to draw annotated cross section are the same for drawing sketch or transcend cross section only that in sketch cross section labeling of relief features and other information found between the points of cross section area are shown on the table above the cross-section graph.

Transcend/sketch relief section between point A and B



VS = 1 cm represent 100 m

HS = 1cm represent 0.5 km

Vertical exaggeration

Vertical exaggeration is a scale that is used in raised- relief maps, plans and technical drawing in order to emphasize vertical features, which might be too small to identify relative horizontal scale. Alternatively, it is defined as the number of times the horizontal scale is greater than the vertical scale. For example, from the above relief section vertical exaggeration can be calculated as follows:

$$\text{Vertical Exaggeration} = \frac{\text{Vertical scale}}{\text{Horizontal scale}}$$

$$\text{Or} = \frac{\text{Dominator of horizontal scale}}{\text{Dominator of vertical scale}}$$

For example, if

VS = 1:10 000

HS = 1:50 000

$$VE = \frac{1:10\,000}{1:50\,000}$$

$$OR = \frac{50\,000}{10\,000} = 5$$

VE = 5 times horizontal scale

Note: V.E Has no unit.

Gradient

Gradient refers to the steepness or gentleness of the ground in relation to the horizontal plane. Gradient is expressed as the ratio or fraction of vertical rise to the horizontal equivalent, in which the numerator represents vertical rise and the denominator represents the horizontal equivalent. The extent of steepness or gentleness depends on the size of denominator, in the sense that, when the denominator is too small, gradient is steeper and when the denominator is too large, the gradient is gentle.

Procedure for calculating gradient.

(i) Identify the two points by reading grid reference or any other means of locating position as instructed in the question

(ii) Join the two points by a straight line and measure the map distance apart

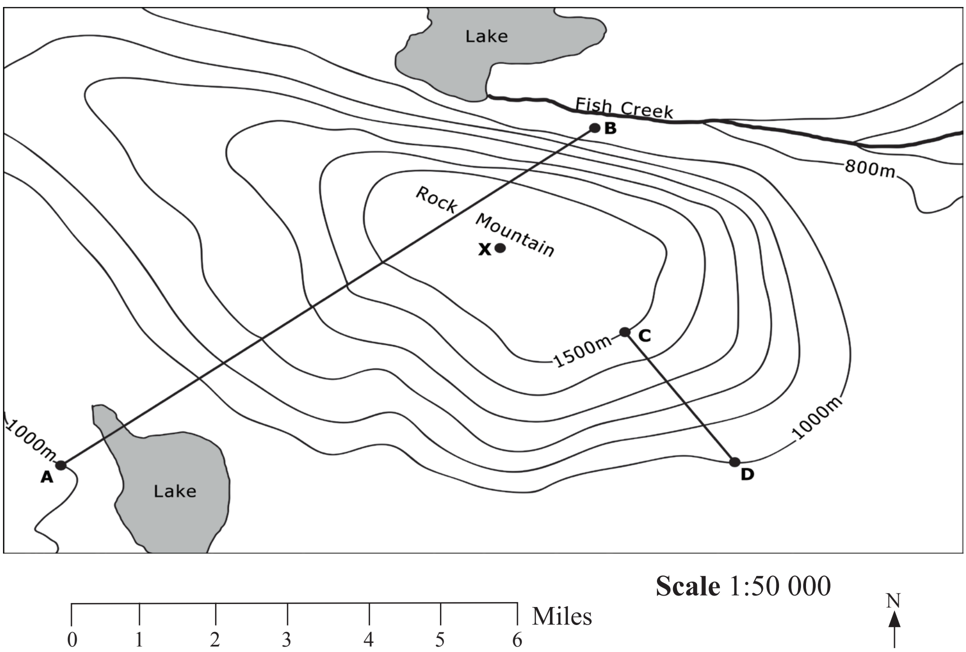
(iii) Identify the highest and the lowest point of elevation, if they are in feet change them into meters.

(iv) Convert the map distance measured into ground distance in meters to get horizontal distance.

(v) Divide the difference between the highest and the lowest elevation or V.I by horizontal equivalent. Leave your answer in the simplest form of fraction such that gradient $= \frac{a}{b}$ where "a" represents vertical increase and "b" represents horizontal equivalent.

Example 1

Study the map provided below and then find the gradient from point C to point D.



Solution:

Gradient from point C to D

$$\text{Gradient} = \frac{\text{Highest point} - \text{Lowest point}}{\text{Horizontal equivalent}}$$

Data given

Highest point = 1 500 m

Lowest point = 1000 m

Map distance = 7 cm

Map scale = 1:50 000

Changing map scale,

Convert map distance into ground distance

1 km = 100 000 cm

? = 50 000 cm

$$= \frac{1\,\text{km} \times 50\,000\,\text{cm}}{100\,000\,\text{cm}}$$

= 0.5 km

1 cm = 0.5 km

7 cm = ?

$$= \frac{7\,\text{cm} \times 0.5\,\text{km}}{1\,\text{cm}}$$

= 3.5 km

Changing 3.5 km into meters so that to get horizontal equivalent

1 km = 1 000 m

3.5 km = ?

$$= \frac{3.5\,\text{km} \times 1000\,\text{m}}{1\,\text{km}}$$

= 3 500 m

$$\text{Gradient} = \frac{1\,500\,\text{m} - 1\,000\,\text{m}}{3\,500\,\text{m}}$$

$$= \frac{5\,00\,\text{m}}{3\,500\,\text{m}}$$

$$= \frac{5}{35}$$

$$= \frac{1}{7}$$

= 1:7

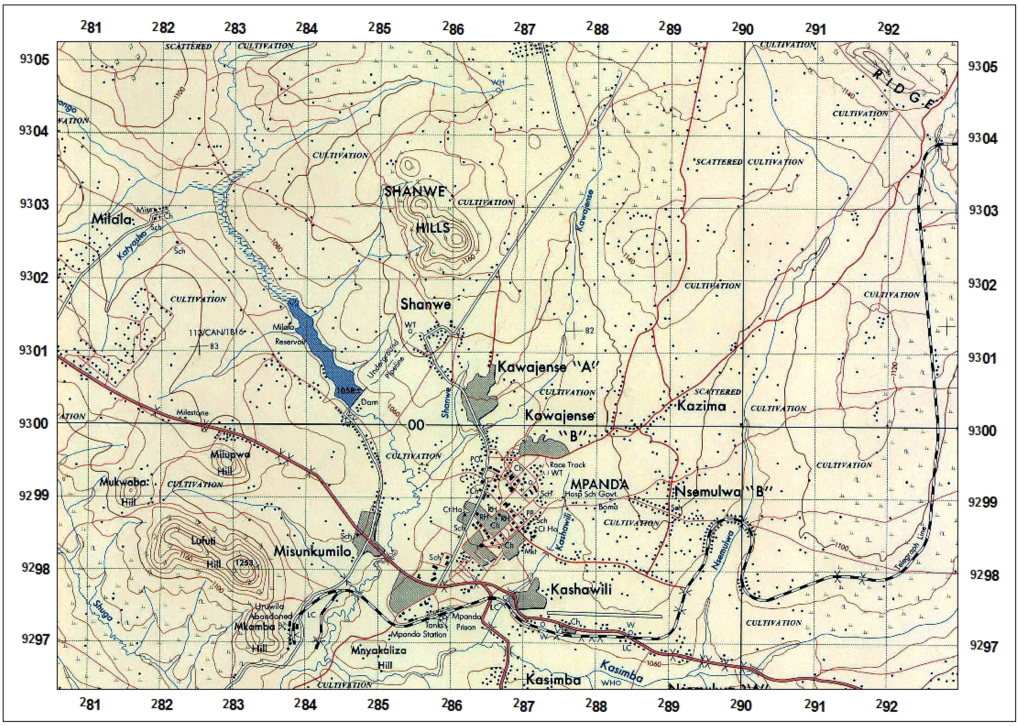
Gradient = 1 in 7 or 1:7

It implies that, for every horizontally distance of 7 m, the land rises for 1 m.

Revision exercise 4

1. Study carefully the map extract of Mpanda and answer the following questions.

MPANDA



Scale 1:50 000

KEY

- Town or area with Permanent Buildings
- Other Populate Area, Houses
- All Weather Road: Bound Surface
- All Weather Road: Loose Surface
- Dry Weather Roads
- Main Track (Motorable)
- Other Track and Footpath
- Cut Line
- Railway, Siding, Station, Level Crossing
- Railwa Light
- Steep Slope
- Contours (V,1.20m) Depression
- Air Photo Principal Point with Film No.
- Water Course, Waterfall Rapids, Dams
- Water Course, (Wide), Waterfall Rapids
- Watercourse (Indefinite)
- Borehole, WaterHole, Well, Spring
- Bund, Major Fence, Hedge
- Cliff
- Forest
- Tree Swamp
- Papyrus Swamp, Marsh, Boge
- Riverine Trees
- Plantation: (Coffee C, Palm, Sisal S, Sugar Su, Wattle W
- Woodland
- Scrub
- Scattered Trees
- Palm Trees
- Seasonal Swamp

(a) Re-draw the map provided using a scale of 1:100 000, then show the following features:

(i) Shanwe hill (ii) Railway line (iii) Dam (iv) ridge (vi) Airport

(b) Madam Halima was driving a car from Kasimba village grid reference 867964 to milestone area grid reference 823001.

(i) Find distance covered by Madam Halima in km if the map scale is changed to 1:25 000.

(ii) Find its gradient trend and alignment.

(c)

(i) Draw an annotated cross profile between grid reference 810970 and 840010.

(ii) Calculate its vertical exaggeration.

(iii) Are the two points inter visible? Give reason(s).

(d)

(i) Name a feature located 4.75 km (270^0) from grid reference 890005.

(ii) Determine the area of the feature in (d) (i).

(iii) Enumerate ecological, social, and economic importance of the feature mentioned in d (i).

(e) Re-draw the part of the map bounded by the following grid references 840040, 860040, 840010, and 860010. Recommended scale is 1:25 000.

(f) Mr. Kipanda a regional surveyor recorded 256^0 and 78^0 as his forward and backward bearing respectively. Correct discrepancies.

(g) Describe the type of the map title.

(h) Why contour is used as most common method of showing a relief?

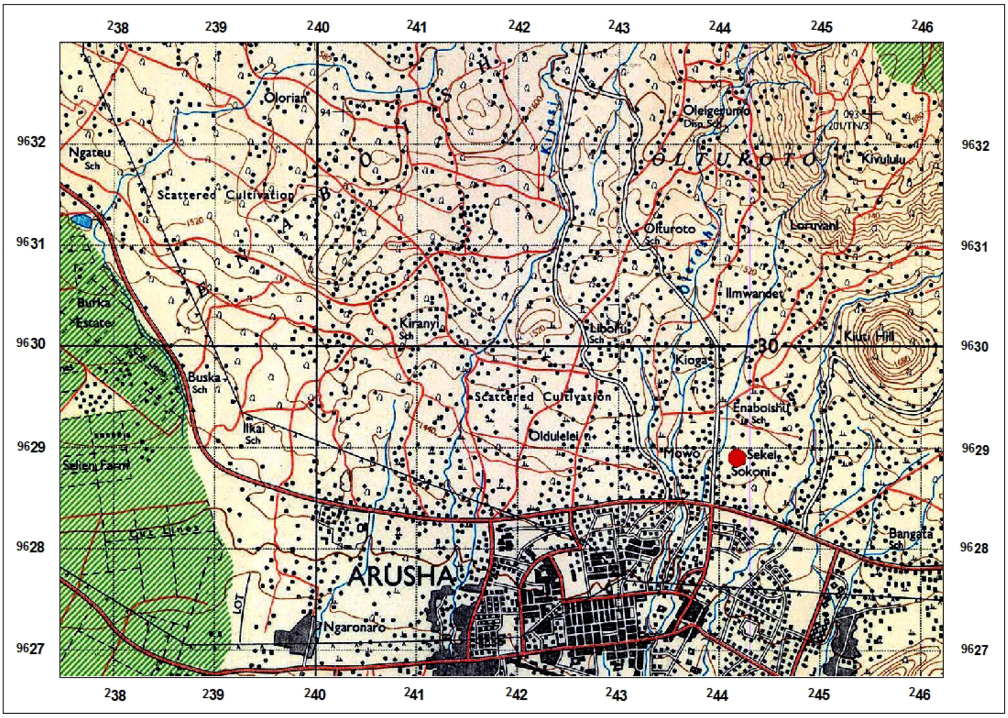
(i) Describe social economic activities of the mapped area.

(j) Identify types of rocks that are predominant in the area.

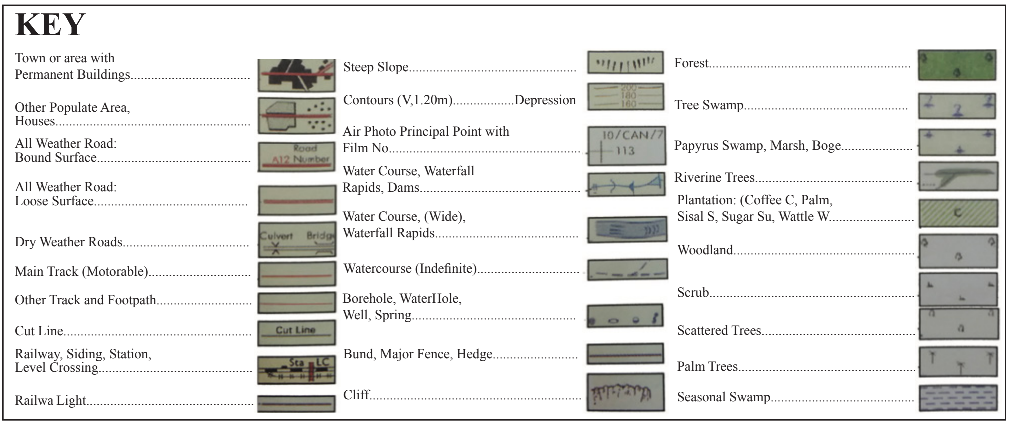
(k) Comment on the population distribution of the area.

(l) With clear evidences from the map, suggest the type of climate and drainage system.

2. Study carefully the map extract of Arusha Sheet 55/3 and answer the question.



Scale 1:50 000



(i) Describe geomorphic activities shaping the land scape.

(ii) Comment on the possible types of soil on the mapped area.

(iii) Describe the relief of the mapped area.

(iv) Provide three reasons for the absence of swamps in the area.

(v) With evidence, provide three criteria which can be used to deduce human activities.

(vi) Outline limitation of contour lines in depicting relief features.

(vii) Name two drainage pattern shown in the map and for each provide at least one factors that determine its formation.

(viii) Describe the nature and distribution of vegetation in the area.

(ix) Comment on factors that have determined the nature of land use in the mapped area.

(x) Briefly explain the strength of marginal information in interpreting the given map.

(xi) Explain the factors which determine the nature of settlement patterns in the mapped area.

Chapter Five

Photograph interpretation

Introduction

Photography interpretation is a skill every person practices every time and everywhere. It is a human instinct to interpret, identify and grasp information portrayed by photographs. For instance, you may have seen friends laughing alone before a photo, picture or television advertisements. Laughs are effects of interpretations given to different phenomena. In this chapter, you will learn about types of photographs, how to make photograph and image interpretations; their characteristics, methods of object identification and how to extract information from photographs. You will also learn the differences between satellite images and normal photograph and their measurements. The competencies acquired from this chapter will enable you to interpret images and photographs or deduce information from them.

Basic concept of photograph, image and sensors for imaging and photography

Geography students, like any other persons, may have faced the contradiction in distinguishing between photographs and images in their common uses. They may have been treated the two equally in some cases. However, photographs and images are different.

The fact that both photograph and image presents geographic information, does not make them identical.The word photography originates from two Greek words, *photos* which means “Light” and *graphein* which means “to draw”. Specifically, photographs are images recorded on a photographic film or storage *chips* of cameras. Many of the photos are recorded within 0.3 micrometer (μm) to 0.9 micrometer (μm) range of visible and reflected infrared wavelengths. Therefore, photographs are images which represent an object. Although the term *“image”* refers to any pictorial representation of a feature or object, a photograph must be an image. All images represent some aspects of objects. Images are categorised based on wavelength of electromagnetic radiation. Names like X-rays pictures, infrared images, radar pictures and photographs (Figure 5.1) are commonly used for differentiation of the images in the environment. They are recorded by cameras or sensors within any wavelength. Therefore, photograph is both a *picture* and an *image,* but not all images are photographs. Photographs are employed in many fields of science, manufacturing and business, film and video production, recreational and mass communication.

Another distinction between photographs and images is based on sensors. All cameras detect a particular wavelength and represent it in their own way. A camera measures the visible part of electromagnetic spectrum and represents the wavelength as a photograph. Yet there are x-ray sensors which detect that part of spectrum and produces x-ray images. Therefore, all cameras are sensors but not all sensors are cameras.

(a) Photograph

(b) Infrared image

(c) X-Ray

Figure 5. 1 *Categories of images under different wave length*

Historical background of photographs

The invention and development of photographs is not only associated with the human struggle to master their surroundings, but also society problems that demanded photogrammetric skills for reference. Photographs were formally invented by Daguerre in 1839 and Niepce in 1927. Since then, photography and photographic fields have been growing with technological development. In the rudimentary stages of photographic technology camera were mounted on birds and wild animals to capture static and moving objects cameras could take a minute or even more to capture image of an object (Figure 5.2).

Figure 5.2: *A camera mounted on a pigeon*

Also, the achievement of pioneering generation made invention of terrestrial and balloon photographing which is now called aerial photograph. The analogue Photogrammetric period marked by introduction of operational airplanes and cameras formed a stand of the aerial survey techniques done today and the surge of stereo plotter to support reading and interpretation of photographs. The invention of computers and its programme and the increase of the photographic adjustment theories marked the analytical phase of history. Recently, with the improvement of storage devices and special microprocessors or chips make easy access and use of digital imagery, instead of photographs.

With the development of technology and increased need for environmental management, photographs are importantly integrated into spatial thinking and Geo-technologies related to global positioning systems (GPS), remote sensing, and geographic information system (GIS). Photographs as source of information in geography are now cheap and freely available from a several sources, including google earth and earth explorer.

Photograph interpretation

Interpretation entails giving analysis to an image. Everyone to a certain extent, is a photo-interpreter. Interpretation, therefore, involves observing objects to recognise and analyse their shapes, alignments and relationship to the environment. Photograph interpretation is a critical examination of the presented photographic object to identify and then judge their significance and meaning.

Photograph interpretation is an interplay of several objects and interpreter's variables. Variables which can also be considered as the principles to objective interpretation, include prior knowledge of the captured area and understanding of the subject matter. Experiences on shapes, sizes, tone, organisation, shadow, texture among others are the key variables to photo interpretation. During photo interpretation, all variables are applied simultaneously to deduce or induce information. For example, looking at Figure 5.3, one recognises that the objects in the photo are lions and not elephants or hyena. This recognition is made by looking at the shape, size, own experience, tone and texture variables such as shadows, shadow point, area of maximum shadow, effects of sun's altitude effects of sunlight.

Figure 5.3: *Lions*

Although shadow is a pertinent element to help photograph interpretation, it can obstruct a feature from identification. Shadow can cover objects and cause difficulty in recognition. There are times when the relief displacement of an object matches exactly with the shadow, thus it cannot be seen. The point where the relief displacement of objects exactly matches with the shadows such that no shadow is visible is termed as *no-shadow point or Hot spot* (Figure 5.4).

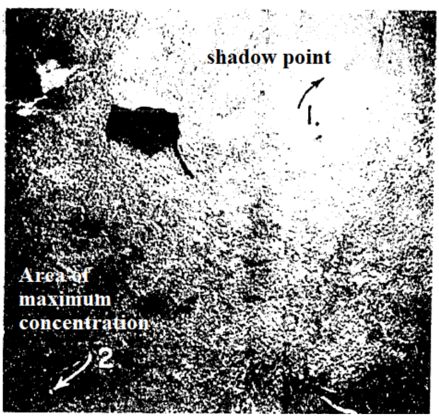


Figure 5.4: *Shadow point*

Also, there are cases where too much brightness hinder identification of features in a photograph. Depending on the time when the photography was taken, a camera records the greatest proportion of shadow accentuated by glare in areas which are away from the sun. The quality of one's interpretation can be affected. On recording or taking picture, the place where the photographer is located determines the shape, size, tone, organization and type of the photograph.

Photographs can be grouped into ground photographs, aerial photographs and satellite images photographs.

Ground photographs as the name suggests, are camera pictures taken horizontally or obliquely from the ground level. They record objects with a camera carried by a person or vehicle which is on the ground. Photographs under this category give a horizontal view of the object recorded. Ground photographs are further categorise into ground horizontal photographs ground close-up and ground oblique photographs.

Ground horizontal photograph

Ground horizontal photographs are taken from the ground perspectives when the axis of the camera is placed horizontally towards the object. Ground horizontal photograph is the most common type of photograph. The main characteristics of all ground horizontal photographs is that, they show side or front view of the objects clearly (Figure 5.5).

Figure 5.5: *Ground horizontal photograph*

Ground close up photograph

Ground close-up photographs also known as ground view photographs are camera pictures taken closer to the object. They are characterized by large objects at fore ground (Figure 5.6). Ground general view photograph shows objects in a progressively decreasing in scale size from the camera tilt angle. The photograph shows objects whose sizes decrease from the foreground to the back ground. The main object to be shown are somehow apart from a photographer. Some of the photographs part include small horizon in their background. The photographs are easily divided into three main parts, namely the fore ground (front view), middle ground (middle view) and back ground (back view). A picture is always clear and does not show the top view .

Figure 5.6: *Ground close up photograph*

Ground oblique photograph

Ground oblique photographs are taken from up heaved land. They can be taken from house roofs, hills or mountain at an angle between 30˚ and 60˚. The pictures can easily be divided into foreground, middle ground and background. The amount of horizon at the background depends on the camera's tilt angle. Objects from the foreground decreased their sizes towards the background. This top part of the object partly seen relative to the camera's angle. This means that, photographs taken at an acute angle greater than 50˚ have their top seen than those taken at 50˚ (Figure 5.7).

Figure 5.7: *Ground oblique photograph*

Advantages of ground oblique photographs

Ground oblique photographs have served a very important role in human social and economic sustainable development. It provide relevant landscape data timely and at the required place. Also, supplements data which cannot be collected by high geotechnologies such as the intensity and extent of flooding or the effect of locusts in a recognisable area on global geotechnologies. Furthermore, oblique photographs can aid field sketching as features are large and can be clearly seen. However, its inability to cover a large area makes it unsuitable for interpreting features on a large area. It can easily be interpreted to provide a conclusion which cannot be generalized as the area covered may not be representative of the whole area under study. However, compared to the ground close-up, ground oblique photograph represents more features. It provides more information that could support land use planning. The relief of a given landscape is much clearer than ground horizontal photographs. It shows top view and side of an object. It is important in producing small sketch maps in the field.

Disadvantages of ground oblique photographs

Ground oblique photographs tend to distort uniformity of the photo since the scale decreases from the foreground to the background. It is difficult to determine the scale of the photograph unless the photographer knows the size of an object. The photograph cannot be used for large area map production. Horizon cannot be seen properly. It is important to note that the main feature of oblique photographs is that they show top and side or front view of the objects.

Ground photography analysis

The basic hints or techniques for ground photograph analysis are as follows:

(i) Identify parts, section or position of photograph that means fore, middle and back ground of photograph and make a note of important features shown;

(ii) Read the caption and look at the position of the feature and draw a simple sketch map of the area. If the objects decrease from left to right hand side, they indicate that the photographer was on the left side. If the objects decrease from right hand side it indicate that the photographer was on right hand side. If the objects decrease from the fore to back ground of the photo they indicate that the photographer was in front of the objects;

(iii) Lay a piece of tracing paper over the photograph and draw a trace diagram showing more important features;

(iv) Write short descriptions of the features shown; and

(v) Describe the process which have led to the formations of any landforms and land scapes.

Several aspects need to be considered in analysing photographs. The effects of perspective objects where objects appear much larger than those further away. Each picture has a fore ground, middle and background section. The clarity of the photograph must also be considered. This varies due to atmospheric conditions and quality of the film. The caption if provided should be considered carefully. The time of day which a photograph was taken is important as long evening may obscure important details.

Activity 5.1

1. (a) Describe the categories of ground photographs.
   (b) As a practical geography student explain what will be the usefulness of ground photograph.
2. Assume your are in the examination room and you are given ground oblique photograph.
   (a) Explain criteria you would use to identify features?
3. Explain aspects to consider before analysing the contents of a ground photograph.
4. Explain techniques for analysing ground photograph.

Aerial photographs

Aerial photograph is another type of photographs taken from above. You should not be confused with the phrases '*Aerial photography*' and '*Aerial photograph*'. The latter is a product and end result of the aerial photography. Since its invention in 1830s, aerial photography has been the most effective photographs used for a map making, showing boundary location, determining road alignment and vegetation delineating among many other activities. This is the essence you should learn about aerial photographs. Aerial photographs are pictorial representations captured by sensors mounted on flying plane such as kites, helicopters and drones (Figure 5.8). Formally, helicopters and airplanes were highly valuable, though recently, drones are out pacing.

Figure 5.8: *Drone*

Classification of aerial photography

On the basis of camera orientation, aerial photographs can be categorised on the basis of several criteria as *orientation of camera axis* (such as, vertical photograph and oblique photograph); angular coverage and emulsion type such as, panchromatic black and white photographs, color photographs, infrared, black and white photographs and false colour composite photographs. In this section, definition of types are based on orientation of camera axis.

Types of aerial photographs

Aerial photographs can be categorised into vertical aerial photographs and oblique aerial photographs (Figure 5.9)

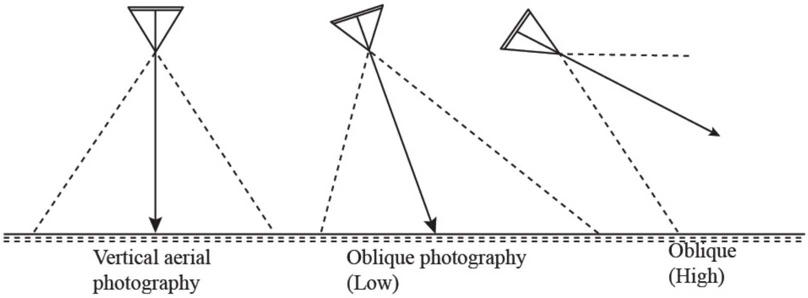


Figure 5.9: *How different types of aerial photographs are taken*

Vertical aerial photograph

Vertical aerial photographs also known as terrestrial photographs are those taken by a camera with its axis perfectly or nearly vertical. Turbulence that shake airplanes and drones can distort the verticality. They are characterised by showing only the top view of objects than side views (Figure 5.10). Extra terrestrial photograph are the picture taken by Satellite at very high altitude.

Figure 5.10: *(a) Flying aircraft taking a vertical aerial photograph*

Figure 5.10: *(b) Vertical aerial photograph*

Vertical aerial photograph cover relatively large area compared to any other type of ground photographs. Though its scale is almost the same especially at the centre, however it decreases sideways the captured area and it is mostly small. The sizes of images are small. The centre of the photograph is known as the principal point.

Oblique aerial photograph

On the other hand, oblique aerial photographs are camera pictures taken at an angle less than 90°. They are taken by a flying object which has its axis directed between the vertical axis and horizontal plane. Oblique aerial photographs can also be divided into low oblique aerial photographs which do not show the horizon and high oblique aerial photograph which show the horizon (Figure 5.11).

Figure 5.11 *(a) Low obliques photograph*

Figure 5.11 *(b) High oblique photograph*

Oblique aerial photographs give a wide panoramic view of a large area. They provide supplementary information to ground low oblique and ground horizontal photographs. They also cover large area than ground photographs. Moreover, it gives a clear picture of the relief of a given landscape. In addition, the scale of the photograph is medium and less uniform compared to vertical scale.

Based on extent of area, high oblique aerial photographs extract more information than ground photographs. High oblique aerial photographs are used to supply instant data of such moving objects as vehicles, ship, train and landslide. It can clearly show layout of the different infrastructure like railway, road and houses render suitable for land use planning. Oblique aerial photography have been very useful in wild animal census, locating archaeological sites, strategic military and civilian surveillance and map making.

Advantages of vertical aerial photographs over maps

Aerial photographs facilitate studies on the previously inaccessible areas and landscapes such as dense tropical forests, desert interiors and swampland. Aerial photographs are significant decision support systems to the world's environment management. They have provided the world with tools to predict the future conditions of our surroundings and set policies and strategies to countermeasure them. By their nature, aerial photographs are raw materials for land use planning, they have also supplied images to be used for planning and mapping. Plans for settlement, infrastructure layout, disaster management and evacuations, and establishment of developmental programs and projects have made an intensive use of aerial photographs. Aerial photographs also serve as raw materials for other land and hydrographic surveys. They are important sources of information for land surveys carried for multiple purposes. They are baseline data for other activities, projects and programme. Moreover, based on their ability to capture and record terrestrial and aerial moving objects, aerial photographs have become the tracking systems of traffic and theft management in a larger part of the world.

Disadvantages of vertical aerial photographs

However, set-backs associated with their production could be a barrier to the utilization of aerial photographs. Aerial photographs, other than those taken by non-commercial firms, have been costly. Their availability for local land use planning for example, is impaired by their cost of availability or production. Again, hindrances from natural weather phenomenon like heavy rain, clouds, fog and mist during acquisition have decelerated the speed at which supply could match the demand. The technological development in geographical information system (GIS) and the emergence of free online geographic data sources such as google earth, earth explorer and many others provide the justification for the deteriorating production of aerial photographs.

The techniques for interpreting vertical aerial photographs

(a) *Tone or colour or shade:* This element considers the darkness and brightness of the objects. Some areas like forest area, large water bodies, including ocean, lake, rivers appear dark in colour because of less reflective capacity. Some features like beach, sandy desert, glaciated area and all weather roads appear bright in color because of high reflective capacity.

(b) *Shape:* Some objects such as rivers and roads can be easily identified in a curved elongated shape. Pitch or stadiums are in oval rounded shape; round about and water tank can be identified with circular shape.

(c) *Texture:* This refers to the roughness and smoothness of object. Some features like forest, residential area and mountainous area are shown with rough texture while features like water bodies, grassland and snow appear smooth in texture.

(d) *Pattern:* This refers to arrangement of the objects, where objects can be in regular or irregular pattern. Normally, urban settlements, planted vegetation appear in regular pattern while natural forest, shanty town, mountainous regions appear in irregular pattern.

(e) *Size:* If the scale of the photograph is known then objects of known size such as football pitches and tennis courts can be identified based on their sizes.

(f) *Site:* This technique enables a photo interpreter to identify a feature according to environment where such features are found. For example, feature cutting a river channel can be a bridge, vegetation along side of the river such as bamboo and in coastal areas can be mangroves.

(g) *Association:* Is the technique of interpreting features from the existing features. For example, building with chimney indicates commercial or industrial area. Forest with wild animals such as Giraffe and Elephant indicates national parks and existence of tourism industry.

(h) *Shadow:* It helps to give an impression of the depth to a vertical air photography. It helps to distinguish objects such as raw of trees or height of building by looking direction of shadow, to the position of the sun and shape of the shadow. It can also be used to estimate the time when the object was photographed.

(i) *Background information:* If all attempt to identify objects have failed the interpreter must then refer to maps and written descriptions of the area.

Exercise 5.1

1. Carefully study the photograph below and answer the questions that follows:

(a) What physical landscapes does the photograph represent?

(b) Describe any two ecological problems that may face the area.

(c) Identify the type of photograph giving at least two evidences.

(d) Briefly describe the mode of its formation for the feature at the photograph.

2. What kind of photograph is mostly used in map making and why?
3. Explain the differences between a vertical aerial photograph and a topographical map.
4. All photographs are images but not all images are photographs. Justify.

The concept of satellite and image

Satellites are just man-made car-like carriers of sensors. They are platforms on which photographic and imaging sensors are mounted. They function like human hands or camera stands we are used to. They are not sensors but they just hold sensors intact and provide support to sensors. There are various satellites in the space, developed and launched by different nations and companies for different purpose (Figure 5.12).

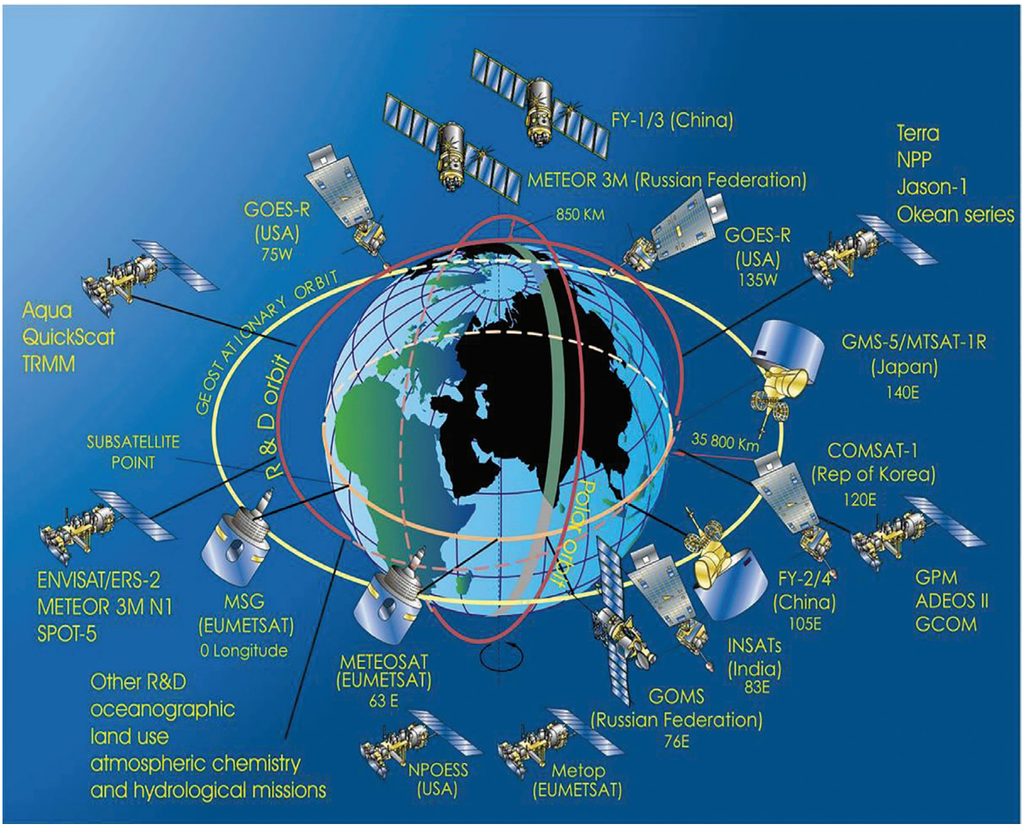


Figure 5.12: *Different satellites and their orbits*

These platforms carry sensors (including camera) which collect images for different purposes. Satellite sensors have supplied billions of free and commercial images which can easily be downloaded and used for all other photographic applications. Some sensors do not produce photograph-like-images rather they provide reflective and emission signatures of the world's resources and conditions. Every earth's object has its unique reflection and or emission signature. This means that the reflective properties of vegetation differ from that of water while the reflective properties of human bodies are different from that of soil. Therefore, satellites provide images which can require different techniques and skills of reading and interpretation.

Satellite images or imageries

Satellites are placed on particular path called an orbit. There are three types of satellite orbits: sun-synchronous satellite (placed at about 500 km - 900 km); geostationary satellites or also called geosynchronous (placed at about 36 000 km) and low Earth orbits. Geostationary satellites carry sensors for meteorological and telecommunication monitoring. Sensors at sun synchronous satellite are generally used for remote sensing studies. Low Earth orbiting (LEO) satellites can be used for spying.

The satellite detect and capture mass of data in a very wide range of wavelengths, including, but not limited to, visible (Figure 5.13), near infrared and mid infrared. Generally, the process of acquisition of information by a recording device that is not in physical contact with the object under study is called remote sensing.

Figure 5.13: *Satelite image*

Satellite sensors produce a multitude of image in these wavelengths which can be called photographs to be interpreted and used for our daily lives. They provide images on meteorology, oceanography, biodiversity conservation, forestry and regional planning. They provide images on which much of decision regarding land use planning, management and mapping can be categorised on the bases of their imaging systems. Table 5.1 summarises imaging systems.

Table 5.1: *Types of imaging systems*

Imaging system	Example	Sensor	Platform
Filming	Aerial photographs	Camera film	Air craft
Scanning	Meteorological satellite	Advanced very high resolution radiometer (AVHRR)	Satellite
	Earth observation satellite (Landsat)	Has different sensors, one is multi-spectral scanner (MSS)	Satellite

Exercise 5.2

1. Basing on its characteristics, briefly explain the concept of satellite image.
2. Explain the importance of satellite in society.
3. Explain any two types of satellite images.

Contribution of satellite images to geographers and community

Satellite imageries and services surround every body's life. Satellites handle our mobile phone operations, radio stations and television broadcasts. They track vehicles and people and make up navigation systems necessary for geotechnologies and geographic information systems. Satellite images provide meteorological data on different aspects including cloud cover, rainfall, hurricanes and oceans tides which can be used for meteorological broadcast and disaster prediction and control. Satellite imagery provides information regarding wildfires, volcanoes, hurricanes, torrents and rainfalls that help to minimise negative impacts on people. Satellite's ability to produce massive images have helped land use planners, map makers, oceanographers and even agriculturalists to utilize them for the betterment of their lives. They supply data used for updating our existing maps.

Difference between aerial photographs and satellite images is summarised in Table 5.2.

Table 5.3: *Difference between aerial photographs and the satellite images.*

Satellite image	Aerial photograph
They cover large area approximately (185 x 185 km^2). This is due to the fact they are situated higher than air crafts.	It covers small area approximately (23 x 23 km^2).
Multi-band aspect that is the satellite images of different objects hence different colour. Satellites record visible and invisible parts of electromagnetic spectrum.	Can record only in the visible light multi-band. This is because sensors which operate in the area of electromagnetic spectrum depend on sunlight to produce photographs.
Difficult to interpret due to low spatial and high spectral resolution (wide range of electromagnetic spectrum).	Easy to interpret due to high spatial resolution and small range of features.
Are taken throughout the year; hence, it is easy to record and detect seasonal changes in the year as it captures different images within a few days.	It is impossible to have repetitive coverage of the whole world.
It shows fewer details due to small scale. That is it has low resolution.	It shows more details due to large scale. That is it has high resolution.

Image and photographs sensors platforms

Though not very pronounced, nature of the vehicle which carries the photographing sensors determine the categories of the photographs. The categorization as ground, aerial and satellite photographs gives an implication of the carrier of the sensor for the purpose. Photography platforms in this context, therefore are the raised surface on which sensors are carried. There are three categories of platforms which carry sensors for photographing; ground-based, airborne and spaceborne (Figure 5.14).

Figure 5.14: *(a) Ground based*

Figure 5.14: *(b) Airborne platform*

Figure 5.14: *(c) Spaceborne*

Ground-based platforms entail all carriers of sensors situated on land. The mobile and common ground vehicle, hand held, towers and balloons are significantly used. They elevate sensors up to 50 meters. They generate data of instant and later use at low altitude. These types of platforms are relatively inexpensive, stable and due to their low altitude, provide high-resolution data.

Airborne platforms are sensor carriers capable of flying up to 50 km of elevation. They provide images containing varieties of data. They can provide images useful for mapping, and can pin-point locations accurately for boundary and other activities, like environmental management. Kites, airplanes, helicopters, high-altitude aircraft and free-floating balloons are examples of airborne platforms.

Satellites are common and known vehicles which carry sensors for imaging and photographing. They are spaceborne vehicles specially made to carry sensors around a particular prescribed path. Satelite carry sensors with ability to measure and detect different wavelengths along the electromagnetic spectrum. Satellites follow a particular path called an orbit.

Photograph and image interpretation

Photograph interpretation is the process of reading, examining and interpreting photographs for obtaining reliable information about natural or cultural features presented. It requires skills and knowledge of many professions. For example, it requires knowledge on types of vegetation to help in analysing climate, types of soil and can be used to identify the possible crops that can grow in the area. Yet, knowledge regarding drainage can help to analyse types of rocks while knowledge on crops and their properties is helpful in analysing the type and nature of soils in the photograph.

Therefore, photograph or image interpretation, as used in this section, is an interplay of interpersonal qualities, environmental knowledge and many others variables. On the other hand, characteristics associated with objects on photographs are equally important in photograph interpretation. Elements such as a shape of an object, size, tone, pattern, shadow, texture, location, height, depth, and site or situation or association have a significant role in analysing relationships between features. All elements are within the object. However, interpreter's elements which help in photograph interpretation include interpreter's knowledge of the area and of the subject.

For example, using the visible photograph (Figure 5.15), you can identify the type of image and the angle of the sensor's axis, identify activities, soil type and many other variables.

Figure 5.15: *Tea production farm*

The photograph in Figure 5.15 shows one part of the area in Tanzania where tea is produced. Therefore, analysis of the photograph will be assisted by prior-knowledge of the areas associated with the cultivation of such crop. Type of crop can support to understand type of soil, climatic conditions provided you already know the characteristics of the crop seen in the photograph. The crop can also help to describe the nature of drainage of the area and the general view of the photo can help to tell the type of photograph.

Exercise 5.3

1. Carefully study the following photograph and answer the questions that follows:

(a) What type of photograph is this ?

(b) With reasons suggest the type of soil that could favour the growth of such crop.

2. What other agricultural crops may be grown in the area where the photograph was taken?

Parts of a photograph

In the process of interpreting images, a number of skills are applied. For example, you may see a hygrophyte or xerophyte plant on a photo and you want to describe it. In that case, you are required to section a photograph. A photograph can be sectioned horizontally into the; *foreground; middle ground* and the *background* (Figure 5.16). At the fore ground features appear to be big and clear. The middle ground is the area in the middle distance away from the camera. At this section the size of the objects appears to be relatively small but moderately clear. The area farther away from the camera with tall trees including the horizons is called the background. At this part features appear to be small and not clear.

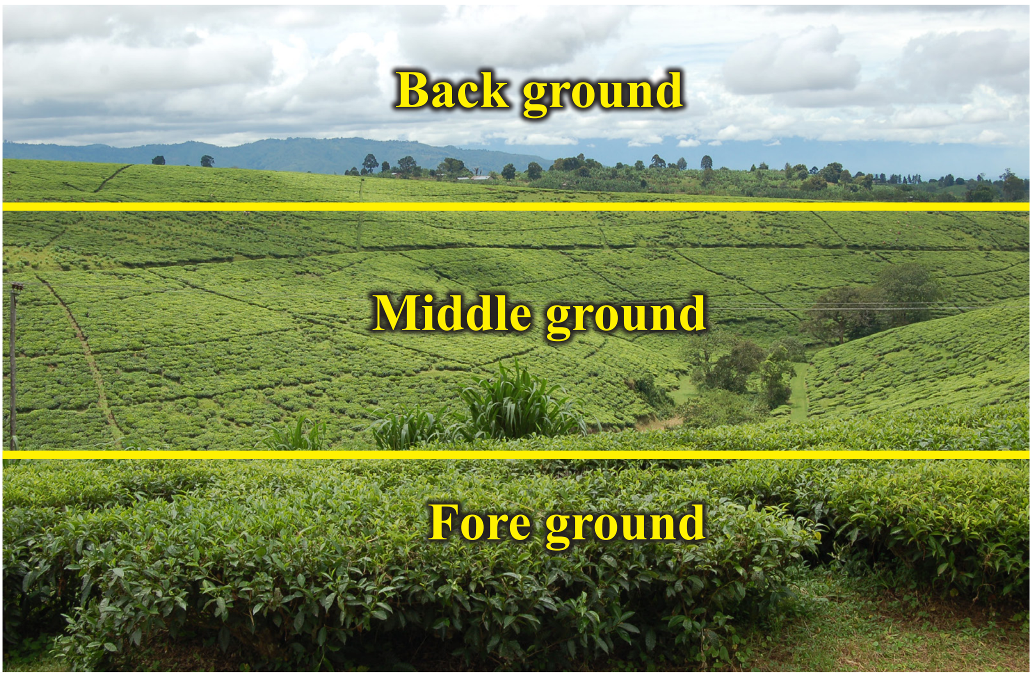


Figure 5.16: *Location of parts of photograph horizontally*

As the need may arise, you can divide photograph further into three equal vertical parts: left, center and right. When describing a side of a particular object, you can then refer them as located to the *left at the foreground centre or background* and to the *right at foreground* (Table 5.4 and Figure 5.17). The centre or back ground term should be used to address the object's location relative to other objects in the photograph. Words like top or bottom, North or East are not recommended in photograph interpretation.

Table 5.4: *Parts of a horizontal photograph commonly used in interpretation*

Left background	Centre background	Right background
Left middle ground	Centre middle ground	Right middle ground
Left foreground	Centre foreground	Right foreground

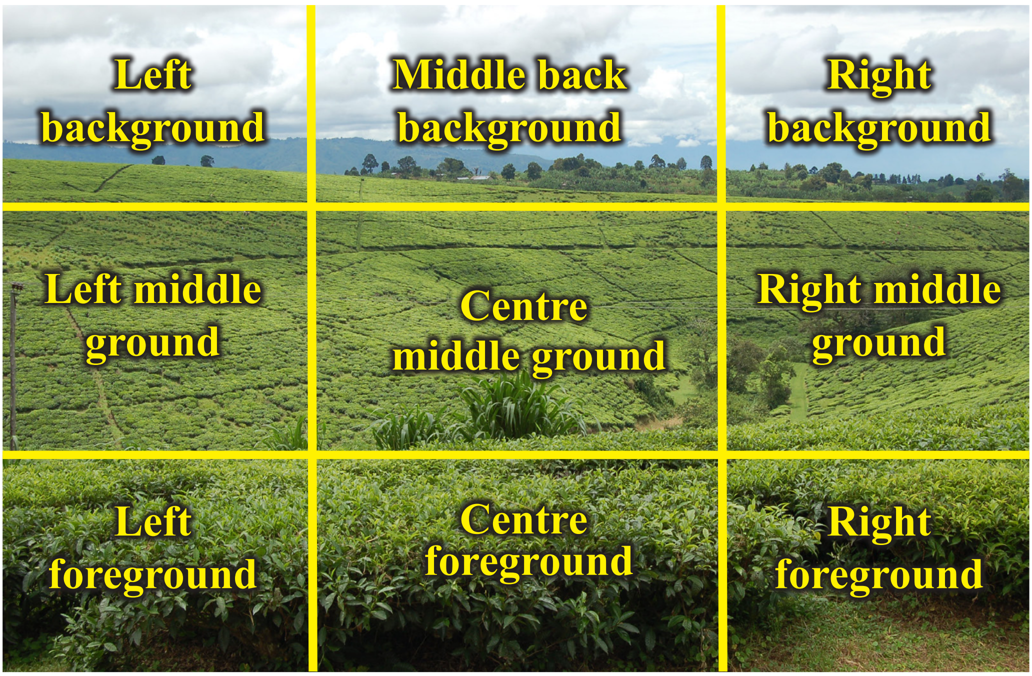


Figure 5.17: *Location of parts of a photograph commonly used in interpretation*

Activity 5.2

1. Carefully study the following photograph and answer the questions that follows

Source: https-//www.derrystrabane.com/strathfoylegreenway.

(a) What type of this photograph?
(b) Section the photograph into nine parts and mention the features found in each part.
(c) What would be the usefulness of having such a photo?
(d) What social activities could be taking place in the area?
(e) At what time of the day was the photograph taken?

Factors which may affect the quality photograph

Nature of camera to be used: Camera focal-lens, film used and filtration capacity are the most important factors. Where, a camera with large focal-lens, high filtration capacity towards different aspects such as cloudcover, dust and fog may produce sharp and good photographs contrary to the camera with small focal-lens.

Knowledge of photographer:
Competence of the photographer on using camera and selecting an appropriate location for the caption also determine the quality of photograph. Whereby, well trained photographer is capable to produce best photograph.

Position of photographer: When a photographer will be near the objects in term of distance and height, the caption may be good as well as angle at which is taken determine the quality of photograph. That is why the ground-level photograph is regarded as the best qualitative photograph.

Nature of the targeted area: Levelled area influences good photograph especially for ground photograph unlike the slope and mountainous area which may influence image distortion.

Weather condition: A good photograph should be taken at the clear day with free from clouds, fog and extream sunlight.

Time at which photograph taken: The best photograph should be neither taken during the night nor sunny noon time.

Limitations to quality photograph interpretation

Efficiency and the accuracy of photo interpretation is subject to some barriers developed from the photographing and imaging sensors. The resolution level of the image, the quality and the clarity of the photograph may affect interpretation. Photograph interpretation is affected by: weather condition at the time when the photograph was taken; for example cloud cover and fog may affect the quality of the photograph. Also, the angle of the sun when the photograph was taken may determine the darkness or brightness of the photographs. Moreover, quality of the camera lens (size) may determine the quality of the photograph and the type of the paper as well as the method used to print the image.

Other additional factors include season of the year, during rainy season when vegetation is green the photograph will appear darker, but during dry season when vegetation is less green the photograph will appear brighter; the position of the camera towards the object, when the photo is taken with a camera which is near the objects, the photograph will appear clearer than when the camera, is a bit far. Colour of the object for example, objects with black colour may not be clear due to their dark tones while bright coloured objects will be clear.

Other general skills for the interpretation of photographs

Apart from the qualities and elements that can help you make a better interpretation of photographs, there are several skills you need to develop for photograph interpretation. The understanding of how you can determine title, estimating time and the season, identify and explain human activities, estimate the size of features, suggest location of the scenery in the place, and estimate direction are pertinently necessary in photo interpretation. These interpretation skills could be achieved in different ways:

Determination of the title can be extracted from photograph information itself. Geographer must be careful in studying the fore ground, middle ground and the background. However, the familiarity of a photographed area can give a clue for suggestion of the title of the photograph. Similarly, time of a day when the photograph was taken can be estimated. This can easily be detected by using direction of shadow of objects. For example, if a photograph was taken during or around noon shadows casted by objects will be short and centred around the object. Shadows are shortest around midday and they are longest early in the morning or late in the afternoon. The time would be morning if the shadows are in the left hand side of the object, if the shadow is on the right hand side of the object the photograph was taken in the evening.

Consistently, it is also possible to determine the hemisphere in which the photograph was taken or the direction in which the camera faced. Beyond the tropics, the sun never gets overhead but the shadow behave similarly to those in the tropics; that is, they are shortest at midday and point pole wards. Bright clear skies with dry vegetation could indicate a dry period or season. On the other hand, luxuriant vegetation, young crops in the field, flowering plants, and clouds in the sky could indicate a rainy period or season. Winter could be indicated by the presence of snow on the ground.

The type of clothing worn by the people can also indicate the temperature at the time when the photograph was taken. Also, the activities shown on the photograph can help to determine the time of the year when the photograph was taken. Activities taking place in the photograph can also enable us judge the time when the photograph was taken. For example, cotton is always harvested during noon hours, tea harvest suggest morning time since the leaves have to be taken to the factory in the evening.

Estimating sizes of features on a photograph may be difficult because unlike in maps where the scale is constant throughout the map, in photograph there is scale distortion; such as images become progressively smaller from the camera towards the middle ground and background. The sizes of objects can also be approximated. First, the size of the familiar object is estimated. For example, a coin or a pen may be placed against the rock or any other feature. The size of the coin or pen can then be used to determine the size of the rock or any other object. Heights of trees and houses, could be estimated using familiar objects in the photograph such as cars or persons. However, comparison should only be done for features or objects which are on the same level and at the same distance from the camera. For example, a person in the foreground will appear bigger than an elephant in the background.

Weather and climate do not appear directly on photographs. Information has to be gathered from the photograph, both on physical features and human activities. Conclusions can be made by judging from this information. The nature of the sky by the time the photograph was taken can tell the weather conditions of that time; presence or absence of clouds. The type of clothes worn by the people in the photograph can also indicate the weather condition experienced at the time.

The types of houses and style of buildings are also indicators of the climatic condition of an area. For example short house with mud roofs in rural areas in Tanzania indicate semi-arid conditions. The type of crops grown in the field and the type of animals kept can also help to determine the climatic condition of the area. For example, presence of sugarcane plantations would mean the area is generally warm, while the presence of tea and coffee plantation indicate cool climate. Tea and coffee also indicate presence of high rainfall (reliable and abundant) which is evenly distributed throughout the year. Sisal is a drought resistant crop; thus it indicates low rainfall in the area. Natural vegetation present on the photograph also can help to determine the climatic condition within the area. For example, dense forests with tall trees suggest that the area receives heavy and reliable rainfall. Bushes and grass land indicate dominance of low and unreliable rainfall. Table 5.5 summarises the interpretation of climatic condition from photographs.

Table 5.5: *Table for interpretation of climatic type from the photograph*

Object and its characteristics	Type of climate or season
(i) Cloud covering the sky, green vegetation and grasses	Wet season
(ii) Plants without leaves (shaded) and dry grasses	Dry season
Nature of crops	
(iii) Sugarcane, cotton, sisal, cloves, maize, wheat, ground nuts, cashew nuts, and maize. Mostly experience high temperature and moderate rainfall.	Tropical climate
(iv) Coffee, tea, rubber, cocoa and palm oil. Survive in area with reliable rainfall.	Equatorial climate or Tropical highland, Montane climate
(v) Millet, sorghum, cassava thrive or survive in low rainfall and high temperature region.	Semi-arid region
Vegetation cover	
(vi) Dense forest with tall trees	In consideration with other factors, this indicates equatorial climate or mountainous climate. Survive better in areas with heavy rainfall
(vii) Scattered trees with tall grasses, baobab and swamps. This mostly thrive in areas with moderate rainfall and moderate temperature.	In consideration with other factors this indicates tropical climate.
(viii) Thicket, scrubs, grasses, thorn trees,cactus and scrubs thrive or survive mostly in area with low rainfall and high temperature.	In consideration with other factors, it indicates semi-arid climate or tropical climate.

Kinds of animals	
(ix) Goat and sheep mostly found in dry condition.	Semi -arid region
(x) Giraffe, elephants, lions, antelope survive in scattered trees and long grasses.	Tropical climate
(xi) Monkeys, gorilla, chimpanzee, leopard mostly found in tall trees and forest.	Equatorial climate
Water body	
(xii) Large inland water body such as lake, River or Dam.	Equatorial climate
(xiii) Water holes, wells, streams indicate an average amount of temperature and rainfall.	Tropical climate/semi arid
(xiv) Oasis	Semi-arid and arid climate

Human activities

There are several activities that can be identified or need to be identified on a photograph. These include farming, transport, fishing, forestry and communication .

1. Agriculture or farming: Agriculture includes crop cultivation and livestock keeping.

   Subsistence crop farming: is characterised by several features such as permanent and temporary houses, the land is segmented into small portions and fields separated by hedges sisal or planted trees. Subsistence farming also use rudimentary tools such as simple hand hoe and machetes.

   Commercial crop farming: is characterised by presence of cash crops such as tea, coffee, sisal. Presence of modern machineries and processing factories also are good evidence. Presence of feeder routes within the farm and facilities of collecting produced goods also can help to determine the type of farming. Size of the farm is large.

   Livestock farming: may be grouped into traditional, ranching and dairying. Traditional livestock keeping is characterized by cattle grazing in natural grassland especially in semi-arid areas. Also, traditional livestock keepers keep large herds of traditional breeds of cattle, sheep and goats for example Zebu cattle.

Ranching can be evidenced by presence of large field divided into paddocks, presence of cow sheds near the farm houses. Presence of windmills and water supplies, for example, water tanks, ponds, water holes, or reservoirs accompanied with cattle dips on the farm also may indicate ranching. Dairying is evidenced by high-grade cows with big udders, milk processing plants and zero grazing units.

Plantation farming is evidenced by a single crop covering extensive stretches of land, for example, sugarcane, tea, sisal and wheat. Storage facilities near the farm also are good evidence. Many laborers in the fields for example, picking tea or coffee and nucleated settlement within the farm meant for workers can tell a lot about plantation farming.

There are two aspects to consider on describing the scale of production, these are:

Small scale production: it is suggested by presence of food crops cultivation, use of local tools such as hand hoe, axes and machete (panga), uses of family labour force and size of the farm should be small in size.

Large scale production: it is suggested by cash crop production, use of modern tools such as harvesters and area of the farm should be large and well mechanised.

2. Tourism**:** it is indicated when photograph show large water body, forest, wild animals, hills, coast, caves, historical sites or mountains.
3. Trade: this may be evidenced by the presence of town and shop malls.
4. Fishing: is indicated by the presence of boat, large water body such as ocean, rivers, lake, dams and net drying yard.
5. Lumbering: is evidenced by the presence of forest, saw mills, chain saw and timber or logs.
6. Industrial manufacturing: is indicated when the photograph shows industry, ginnery or large plantation of sisal, tea or coffee. These crops require processing industry within the farm.
7. Mining: in a photograph is indicated by the presence of quarry or quarries.

Studying physical features on photographs

The landscape is formed by a several features. The common features we expect to find on photographs include relief, settlements and drainage.

Relief

Relief features are many and varied in nature:

(i) Flat landscape

These can be found in both lowlands and uplands. In the lowlands, flat landscape is called a plain. They are normally less than 500 m above mean sea level and are associated with meandering rivers. Flat areas in uplands (above 500 m above mean sea level) are called plateaus. Plateaus always have steep sloping edges.

Sometimes flat lands can be identified by the type of crops grown in the area. For example, sugarcane and rice growing are practised on flat lands. Activities such as irrigation also indicate that the area is relatively flat.

(ii) Mountainous landscape

Is an elevated landform of more than 2000 m above mean sea level is referred to as mountainous. It is characterised by steep slopes on an individual block of land or an extended mountainous range. Crops grown in an area can also be used to deduce the altitude of an area. Crops such as pyrethrum, tea, wheat and coffee are highland crops. For example, tea is grown in the Southern highlands in places such as Mufindi (Iringa) and Rungwe (Mbeya) in Tanzania.

Settlements

Settlement can be divided into two major types: rural and urban. Rural settlement can be evidenced by simple architectural designs of semi-permanent houses. The dwellings are also not planned and unevenly distributed. There can also be evidence of farming or fishing activities. Urban settlements can be indicated by permanent buildings, regular street patterns, buildings with several stores, industrial areas and warehouses, high population density, port facilities such as docks, cranes, containers, and a well-developed communication network (Figures 5.18).

Figure 5. 18: *(a) Urban settlements*

Figure 5. 18: *(b) Rural settlements*

Drainage

Drainage is the natural or artificial flow of water from an area by streams to the rivers and draining water from the land to the lakes or oceans. However, drainage may include features such as swamps, water holes, ponds and reservoirs. Water features are easily recognisable in all types of photographs. Deep waters in lakes and ocean appear darker while shallow water in rivers and continental shelves appear brighter. Presence of waterfalls and rapids indicates that the river is flowing along a steep region or landscape. River meanders show that the river is in the middle or old stages. A river delta can be identified by presence of many channels or dis-tributaries before the river enters the lake or ocean. In aerial photographs river patterns, for example dendritic, trellis and radial can easily be recognised.

Activity 5.3

Study the following photograph then answer the questions that follows:

1. With reasons name the type of photograph.
2. Describe the given photograph according to its divisions.
3. With evidence identify the time when the photograph was taken.

Exercise 5.4

1. Describe types of photographs.
2. Account for the uses of photographs in social and economic activities.
3. Explain factors which affect the quality of a photograph.
4. Briefly describe the criteria for categorising the settlement patterns of an area and give reasons for each.
5. Mention the type of settlement and give the reasons for each.
6. Refer to the photograph in Activity 5.2 and answer questions that follow:
   (a) How does this type of photograph differ from a satellite image?
   (b) With evidence(s) from the photograph in Activity 5.2 comment on the following
      (i) Relief and drainage.
      (ii) The time when the photograph was taken.
      (iii) Economic activities carried out in the area.
      (iv) Giving reason, identify environmental problems which are likely to face the area.
      (v) Explain ways to overcome those problems.
      (vi) With evidences from the photograph describe sections of the photography.
7. Ajmal is a new Geography student at Chimbe chimbe Secondary school. He wanted to interpret a ground photograph but he did not know how to begin. Give him hints on how to interpret his photograph.

Photographic scale

The scale of a vertical aerial photograph is a function of the camera's focal length (f) and the altitude or height from which the exposure is made or of air craft.

$$S = \frac{f}{H}$$

Where:

f = Camera' focal length

H = Flying height of the aircraft

S = Scale

Note: This formula is used when the photograph is taken on a flat surface.

Vertical aerial photographs present a true record of angles. However, the horizontal distances are subjected to wide variations due to the flying height of the aircraft and the focal length. Flying height of the aircraft usually is taken from a specified elevation above mean sea level. Focal length of aerial camera varies according to specified need and purpose. In Tanzania the most common used focal lengths are the f = 152 mm and 132 mm.

Note: If one knows the focal length used and the altitude of the aircraft then it is possible to calculate an approximate scale.

However, when the photograph is taken on a rough surface, the following formula is used compute the scale.

$$S = \frac{f}{H - h}$$

Where;

h = Average elevation of the photographed area.

New line scale average is applicable when the altitude of the aerial photographs is unknown or not given. In such cases scale may be determined as shown in the following example.

Example 1

A camera in an aircraft at an altitude of 3 300m was used to take a photograph. Determine the focal length of the camera if the scale of the photograph is 1:25 000.

Solution

Formula

$$S = \frac{f}{H}$$

Data given

Height of the plane (H) = 3300 m

Scale of photo (S) = 1:25 000

f = ?

$$\frac{1}{25\,000} = \frac{f}{33\,000\text{ m}}$$

$$25\,000 \times f = 33\,000\text{ m} \times 1$$

$$25\,000f = 3\,300 \times 1\,000\text{ mm}$$

$$\frac{25\,000f}{25\,000} = \frac{3300\,000\text{ mm}}{25\,000}$$

Therefore the focal length = 132 mm

Example 2

Calculate the flying height of an aircraft which produced a vertical aerial photograph at the scale of 1:20 000 whose mean ground height was 500 m above mean sea level with focal length of 152 mm

Solution:

$$S = \frac{f}{H - h}$$

Given data

h = 500 m

f = 152 mm

S = 1: 20 000

H = ?

$$\frac{1}{20\,000} = \frac{152\text{ mm}}{(H - 500) \times 1000\text{ mm}}$$

$$20000 \times 152\text{ mm} = 1\,000\text{ mm H} - 500\,000\text{ mm}$$

$$3\,040\,000\text{ mm} = 1\,000\text{ mm H} - 500\,000\text{ mm}$$

$$3\,040\,000\text{ mm} + 500\,000\text{ mm} = 1000\text{ mm H}$$

$$\frac{3\,540\,000\text{ mm}}{1\,000\text{ mm}} = \frac{1\,000\text{ mmH}}{1\,000\text{ mm}}$$

3540m = H

Therefore, flying height of an air-craft is 3540 m

Example 3

Find the scale of the photograph when two land marks shown on the photograph can be located on 1:20 000 scale of topographical map. The measured distance between the land mark is 50 mm on the map and 20 mm on the photograph.

Solution:

$$PS = \frac{DP}{DM} \times MS$$

Where:

DP = Distance between two known points of photograph

DM = Corresponding distance on the map

MS = Map scale

PS = Scale of the photography

Data given:

DP = 20 mm

DM = 50 mm

MS = 1: 20 000

PS = ?

The scale of photograph is

$$PS = \frac{20}{50} \times \frac{1}{20\ 000} = \frac{1}{50\ 000}$$

Therefore, the scale of photograph is 1:50 000

Example 4

Calculate the average scale of vertical air photograph taken by an aircraft flying at 19 000 ft with the focal length of 6 inches. The surface has an average elevation of 100 ft.

Solution:

$$S = \frac{f}{H - h}$$

Data given

focal length (f) = 6 inches

flying height (H) = 19 000 ft

Height of the surface (h) = 100 ft

Scale of photo (S) = ?

$$\frac{6 \text{ inches}}{19\ 000 \text{ ft} - 100 \text{ ft}}$$

$$\frac{6 \text{ inches}}{18\ 900 \text{ ft}}$$

To change foot to inches

1 ft = 12 inches

18 900 ft = ?

$$\frac{12 \text{ inches} \times 18\ 900 \text{ ft}}{1 \text{ ft}}$$

= 226 800 inhes

$$\text{Scale} = \frac{6 \text{ inches}}{226\ 800 \text{ inches}}$$

$$\text{Scale} = \frac{1}{37\ 800}$$

Therefore,the scale of photograph is 1:37 800

Revision exercise 5

1. If distance between village A and B is 12 cm on a photograph. Find the scale of the photograph when the corresponding map distance is 24 cm and the map scale is 1: 200 000
2. An air craft flying at height of 5000 m above mean sea level took a photograph of the land at 1200 m using a camera with 152 mm focal length. Calculate the scale of the photograph.
3. What guidelines should be considered in making interpretation of vertical aerial photography? provide six points.
4. Assuming the scale 1: 25 000. Calculate the height of an area shot by a camera whose focal length is 152 mm, mounted on aircraft which is flying at 10500 m above the sea level.
5. With the aid of diagram, briefly describe the way aerial photographs are classified into main types depending on the position of camera optical axis.
6. Briefly explain the way satellite images and extraterrestrial photogram influence socio-economic activities of human being.
7. Illustrate the strength of photographs over maps in obtaining field information.
8. Carefully study the photograph provided and answer the questions that follows;


Source: https://www.nashulai.com/covid19

(a) Name the type of photograph.

(b) Explain the main physical features found in the area.

(c) State the main activity of the area.

(d) Name the scale of activity stated in 8(c) and support your answer by providing three reasons.

(e) At what time the photograph was taken?

9. (a) How can the scale of vertical photograph be determined?

   (b) Identify factors affecting the scale of photograph.

10. Differentiate between:

    (a) Vertical photograph and oblique photograph.

    (b) Vertical aerial photograph and maps.

11. Explain eight characteristics of aerial photograph.

12. Examine six elements of aerial photograph interpretation.

13. Give a critical classification of aerial photograph.

14. Examine eight factors affecting the quality of aerial photographs.

15. The side of the building measures 20 cm on the photograph taken by a 160 mm focal length camera. If the same side measures 4.25 cm on the 1: 50 000 map. Calculate the flying height of the aircraft above the ground.

16. The garden measures 24.4 cm and 34.5cm on a 1: 25 000 map. Determine the measurement of the garden in the photograph if the photo scale is 1: 20 000.

17. Bishara and Grace are best Geography students. Bishara was taking vertical aerial photograph while Grace was drawing the map of the same area.

(a) What hints should Bishara use in making the interpretation of such phenomina? Provide six points.

(b) Describe main characteristics of the phenomenon taken by Bishara.

Glossary

Bench mark	a reference mark of known elevation cut or set in stone, concrete or other durable and used in the determination of altitudes.
Data	information or facts about a particular phenomenon.
Database	an electronic memory.
Electromagnetic	consisting of electromagnetism.
Multi spectral	operating in or involving several parts of the electromagnetic spectrum occurring or recurring simultaneously.
Parameter	a descriptive property of the population while statistic is a descriptive property of a sample.
Population	a group of people, events, things, or other phenomena that you are most interested in; it is often the "who" or "what" that you want to be able to say something about at the end of your study. The set of all elements that share one or more characteristics which we wish to make an inference.
Radar	an instrument which discovers the position or speed of objects such as aircraft or ships when they cannot be detected, by using radio signals.
Radiometer	instrument for the detection or measurement of radiant energy
Sample	a smaller (but hopefully representative) collection of units from a population used to determine truths about that population in a research process.
Satellite	object which has been sent into space in order to collect information or to be part of a communication system.
Scan	examine it using a machine that can show or find things inside it that cannot be seen from the outside.
Sensor	instrument which reacts to certain physical conditions or impressions such as heat or light, and which is used to provide information.
Spectrum	a range of different colours which is produced when light passes through a glass prism or through a drop of water.
Trigonometric station	a fixed surveying station, used in geodetic surveying and other surveying projects in its vicinity
Variable	is any characteristic, number or quantity of a person, object or phenomenon that can be measured or counted.
Wavelength	distance between a part of a wave of energy such as light or sound.
X-rays	a type of radiation that can pass through most solid materials.

Bibliography

Abeedulah, J. (1993). *Fundamentals of photointerpretor and photogrammetry*. Islamabad: Winrock International.

Agor, A. (2015). *A Text book of surveying and levelling*. New Delh: Khana publishers.

Alan Strahler /Arthur Strahler (2006). *Introducing physical geography.* United States of America: John Willey and sons, Inc.

Burt, J. S. Barber, G. M & Rigby, D. L. (2009). *Elementary statistics for Geographers* (3rdEd), The Guilford Press A. New York: Division of Guilford Publications, Inc.

David, P. P. & Kisser J.D. (2012). *Aerial photography and image interpretor* (3rdEd). New Jersey Canada: John Willy & Sons, Inc.

Durra, S.E. (1990) *Map reading, photograph interpretation and elementary survey.* Dar es salaam: General publications Ltd.

Durra, S.E. (2003). *Map reading, photograph interpretation and elementary survey for secondary level*. Dar es salaam: General publications Ltd.

Ferguson, A. G. & Ngau, P. M. (1981). *Fieldwork and data analysis in geography*. Nairobi: Macmillan.

John, S. & Roger, K. (2008): *AQA Geography.* UK: Nelson Thomas Ltd Delta Place

Lodha, R. M. (2010). *Academic dictionary of geography*. New Delhi: India Publishers.

Mc Master, D. N. (1970): *Map reading for East Africa.* London: Longman Group Ltd.

Mc Master, D. N. (1971). *Map reading for East Africa.* London: Longman Group Ltd.

Murry, A. (1967): *Africa: The study map notes books.* London: Collins Clear Press.

Paul, P. (1979): *Longman dictionary of contemporary English.* Bath Great Britain: Pitman Press.

Prichard, J. M. (1979): *Practical geography for Africa.*Hongkong: Longman Group Ltd.

Pritchard, J. M. (1990). *Practical geography for Africa*. Hongkong: Longman Group Ltd.

Richard White (1984): *Africa in focus, A physical human and economic Geography*.

Speak, P. & Carter, A.H. (1964). *Map reading and interpretation*. Long man Group Limited

Truran, H. C. (1975). *Apractical guide to statistical maps and diagrams.* Nairobi: East Africa Publishers Ltd.

United Republic Tanzania (2017). *National environment statistics report,* 2017 Tanzania Mainland, NBS.

United Republic Tanzania (2018). *National environment statistics report,* (NERSR, 2017)-Tanzania Mainland,Dar es salaam,Tanzania Mainland.

United Republic Tanzania (2019). *Dodoma region investment guide*.

United Republic Tanzania (2019). *Songwe region investment guide*.

Index

O

P

Q

R

V

W

Practical Geography for Advanced Secondary Schools Student's Book Form Five & Six

ISBN 978-9987-09-400-4