❖ Introduction :-

- Although locating objects, in many cases we will want to know :
  - ✓ **how far** and **how large** they are and
  - ✓ The **distance among them**.
- This sets a stage for more advantage analysis known as measurement.
- For each them they can latter be compared within a single theme or to those of other theme.

- **Distance between objects can be measured as a :**

  1. ***Euclidean Distance*** *(Simple Distance)* : In other cases we will define our distances incrementally, adding the distance of one leg of our journey to another to produce a total distance.
  2. ***Least-Cost Distance*** : This Least-Cost, we will search for batter path and less arduous terrain, seeking always the easiest.

- This Least-Cost distance may be from point to point or from single point to all other point in our terrain.

❖ Measuring a length of Linear Object :-

- Three basic cartographic object types :
  - ✓ Points are assume to have a Zero Dimensions.
  - ✓ Lines a Single Dimension of Length.
  - ✓ Areas has two dimensions : Length and Width.
- Because Points have Zero dimension, there is no appropriate measure for them aside from magnitude attribute values.
- Although these magnitude values are important for analysis, they require no formal calculation.

- **Method for measuring Length of Line :**

  - ✓ As we have seen, line lengths can be used as search criteria. In vector when locational data are recorded on a globe, we use *trigonometric formulas* to calculate great circle distance.
  - ✓ Within a planer reference system, the traditional distance equation *based on Pythagorean Theorem*, takes advantage of X and Y coordinate systems for vector measurements of distance.
  - ✓ Through the digitization process, each line segment is a straight line, and its distance can therefore be calculated on the basis of distance equation.
  - ✓ By adding each of these distance measures, we can easily determine the total length of any line.

- **Problem for measuring Length of Line :**

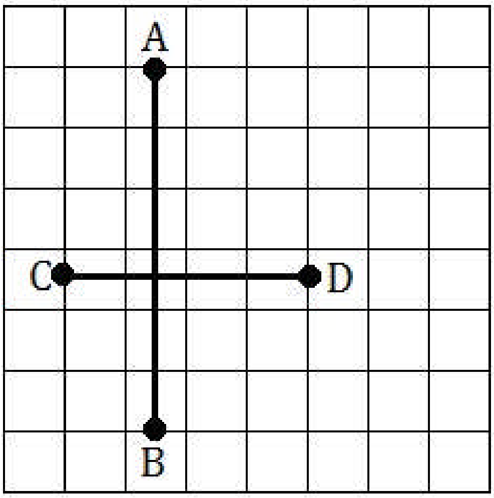
  - ✓ Problem with calculating line distance is that of line whose length extend over a range of elevational distance.

- ✓ **For Example**, a map may show that the road distance from one point to another is somewhat less then what an odometer might show. This typically happen when a vehicle traveling up and down **topographic slope**.

➢ Calculating the Line Length in Raster

- ➢ It is a matter of adding the number of cells together to achieve a total. Working with straight line entity in grid format that occurs as a set of vertical or horizontal (**Orthogonal**) grid cells.

- ➢ **To measure a length of an orthogonal line:**



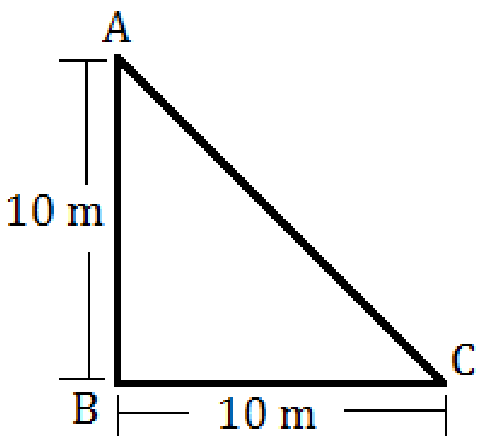
8 X 8 Grid Cells = Total 64 Cells.
Resolution = 10 km per cell

$\boxed{\text{Length} = \text{No. of Cells X Resolution}}$

SO,
$\overline{AB}$ = 6 Cells X 10 = 60 kms.
$\overline{CD}$ = 4 cells X 10 = 40 kms.

- ➢ **To measure a length of an orthogonal line :**

- ➢ But suppose that a line is perfectly diagonal.
- ➢ What do we do if the cells are connected to each other along a corner?
- ➢ Most modern raster systems are able to calculate the diagonal distance between each cell in a diagonal line of grid cells through the use of simple trigonometry.



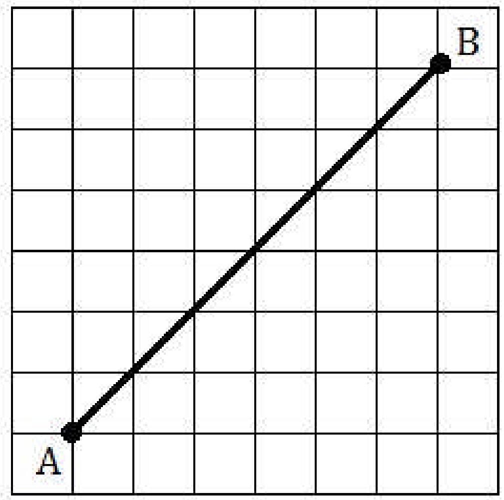
Pythagorean Theorem :

$$AC^2 = AB^2 + BC^2$$

$$AC^2 = 100 + 100$$
$$= 200$$

$$AC = \sqrt{200} \qquad \boxed{AC = 14.14}$$

Diagonal Line is 1.414 Times then the Orthogonal line
10 X 1.414 = 14.14



8 X 8 Grid Cells = Total 64 Cells.
Resolution = 10 km per cell

Length of Diagonal Line = No. of Cells X Resolution X 1.414

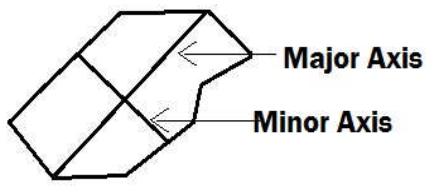
AB = 6 X 10 X 1.414
= 84.84 kms

➢ Calculating the Line Length in Vector

- ***Why to use Vector Data Model to calculate the length of line?***
- Depending on the resolution and the irregularity of the line entity's path, whole loop can be represented by a single grid cell, in this case the length of the line can not calculated in a raster data model. So that it is best to use vector data model.
- To calculate a length along a vector line entity is computationally more exhaustive, but the results are more accurate.
- **Requirement for Vector Data Model :**
- For each straight line segment in a linear object, software will have stored a set of coordinate pairs.
- **How to calculate the length of line in Vector Data Model?**
- The distance between members of each coordinate pair can be calculated through the Pythagorean Theorem.
- Simply adding line segment lengths will produce a relatively accurate measure of the total or accumulated line length.

❖ Measuring Polygons :-

- Orientation of polygonal features will at times be important to the GIS users.
- Conceptually, the idea of polygon orientation is quite simple. It is merely a matter of determining the direction of the longest axis.
- In vector, the on of the solution is to calculate the lengths of **each pair of opposing polygon vertices**, much as we did with the line entity.

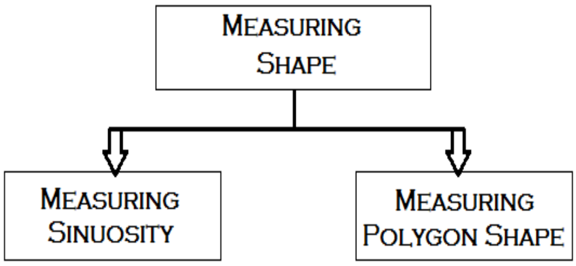


Length of Polygon

- A comparison of these vertices will then show which line is the longest.
- GIS analyst will not searching for a orientation of polygon, rather they are searching for a relationship between the major axis and minor axis.
- The ratio of major axis and minor axis provides a simple measure of shape of polygon called as **elongation**.

- When calculating major and minor axis of a polygon, it is easier to work with the polygon convexity.

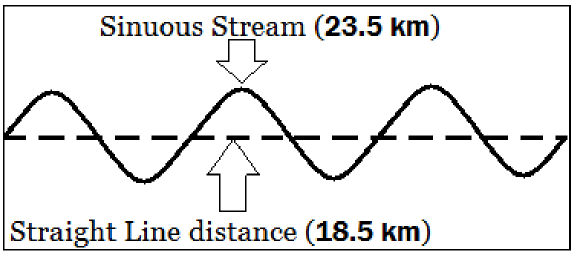
❖ Measuring Shape :-



- **A close relationship between shapes:**
  - ✓ Measuring perimeter
  - ✓ Measuring area of polygon
  - ✓ Length for linear object.
- **For Example :**
  - ✓ Stream Sediment (નિક્ષેપ) Load, Slop.
  - ✓ Amount of Water Flowing in Stream.
- **Functional Relationship have much to do with whether he stream is:**
  - ✓ **Grade** (Balance with stream Input and Output)
  - ✓ **Aggrading** (Building up a Sediment Load)
  - ✓ **Degrading** (Down cutting)
- These values are useful in overall analysis of conditions in a region.
- In Polygon the relationship between perimeter and area.
- Therefore it is important to have at least basic understanding to what these measures are and how they might be perform in GIS.

➢ Measuring Sinuosity :-

- Two simple measures of sinuosity can be used as a measure of a linear shape.
- Straight Line distance
- Actual Linear distance
- The ratio of **Straight Line distance** and **Actual Linear distance** is closer to 1, the less **sinuous** the line.
- There is often need to know more about the shape of curve along the sinuous linear object.



$$\text{Sinuosity} = \frac{\text{Straight Line Distance}}{\text{Actual distance}} = \frac{18.5}{23.5} = 0.787$$

If the Answer is Close to 1, Less the Sinuosity

➢ Measuring Polygon Shape :-

- There are two fundamental aspects of measuring the shape of individual polygon.
  1. Base on the idea of perforated and fragmented region called as **Spatial Integrity**.
  2. Based on the **Boundary configuration**, more closely related to area a perimeter relationship.
- The second measurement allows each individual contagious polygon to be separated from polygon with same attribute value.

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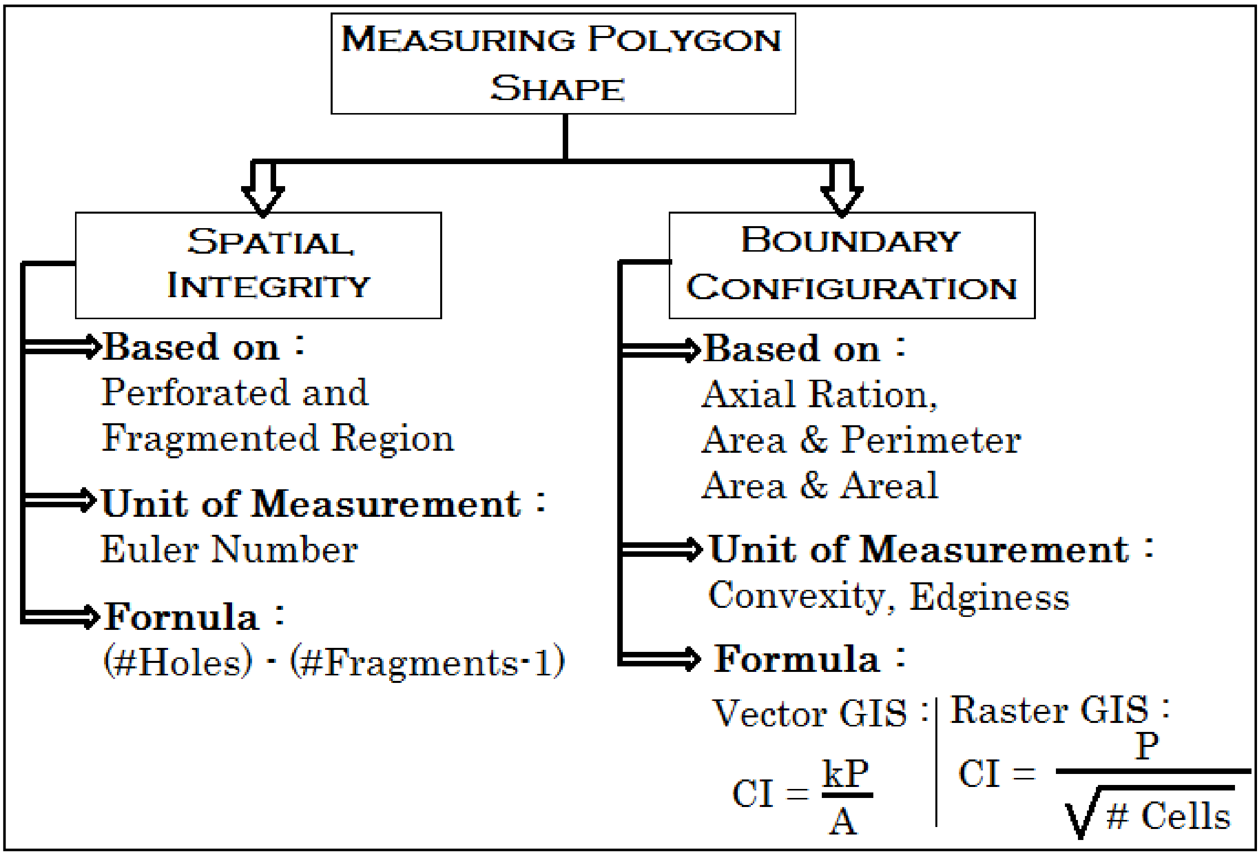
- <u>We can measure each polygon's boundary configuration in isolation from rest of the possible fragmented region, rather than the overall size of the region made up of individual polygons</u>.

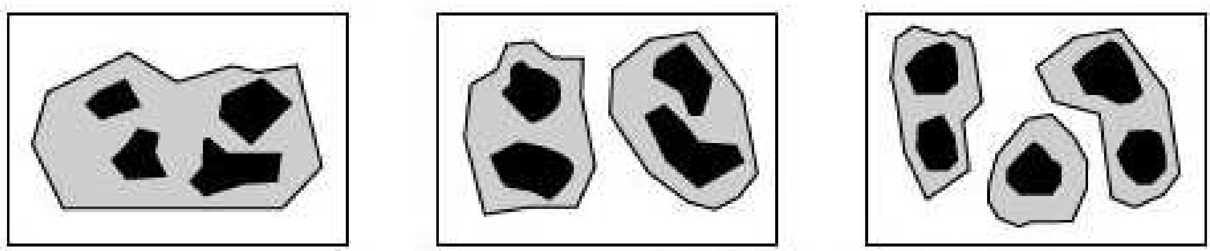


- **<u>Spatial Integrity</u> :**

  - It is the measure of **<u>amount of perforation</u>** in perforated region.
  - The most common measure of the Spatial Integrity is called ***<u>Euler Function</u>***; it is a numerical measure of the *<u>degree of fragmentation</u>* as well as the *<u>amount of perforation</u>*.
  - The Euler function describes this function with the single number, called **<u>Euler Number</u>**.
  - Euler Number is defined by following equation.

Euler Number = (#holes) – (#fragments – 1)

Where,
#holes :- is a number of self-contained polygon perforation in the outside polygon.
#fragments :- is the number of polygons in the fragmented region.



(a) Euler = 4 (b) Euler = 3 (c) Euler = 3

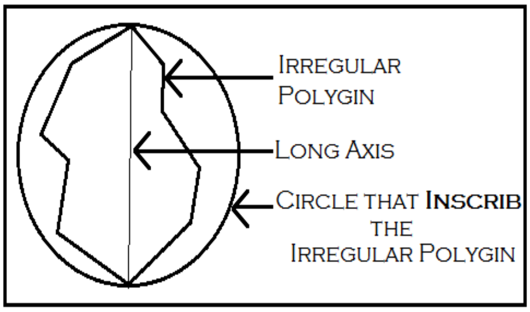
- Euler Number for figure (a) :
  (4) – (1 – 1) = 4 – 0 = 4
- Euler Number for figure (b) :
  (4) – (2 – 1) = 4 – 1 = 3
- Euler Number for figure (c) :
  (5) – (3 – 1) = 5 – 2 = 3

➢ **Boundary Configuration :**

- Among the more prevalent are those based on the axial ratio, those based only on areas, those based on area and aerial lengths, and those measuring the circularity mean side and variance of side.
- Most of these measures are strongly related to the ratio of parameter to area.
- ***The parameter/area ratio itself can be considered to be a measure of polygon shape***.
- For this we most often compare the polygon shapes we encounter to more familiar shapes we can easily describe.
- *Because we use the circle as the comparative shape*, we can say that this measure of the shape is also a measure of the ***convexity*** or ***concavity*** of the polygon.
- A circle has perfect convexity because no portion of its surface is concave or indented.
- This is why *the circle is a most compact geometric shape* and why we use it to measure the shape of other polygons.
- **The general form of the convexity formula in vector GIS** :
  Where,
  Ci = Convexity Index
  k = a Constant
  P = Perimeter
  A = Area

$$\boxed{ci = \frac{kP}{A}}$$

- The constant is based partly on the size of circle that would inscribe the irregular polygon.

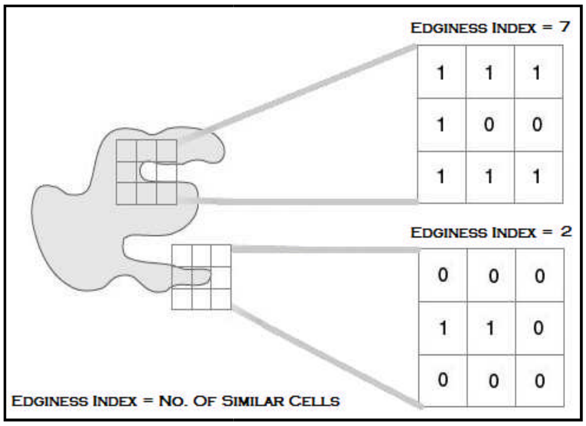


- It is design to provide a range of positive values from 1 to 99.
- Where 100 indicate the 100 % similarity to a circle. (**A Perfect Shape**)
- A perfect circle thus has a value of 100.
  CI = 1, means Total Convexity
  CI = 100, means Total Perfect Shape
- ***In Raster*** the formula is based on the exact same concept, but the area is now recorded as the number of cells, and its square root is used to provide the same 1 to 99 range of similar values.
- Therefore, the general form of formula for calculating convexity in a raster GIS is

$$\boxed{CI = \frac{P}{\sqrt{\#Cells}}}$$

Where,
CI = Convexity Index
P = Perimeter, $\sqrt{\#Cells}$ = Area in Raster Format

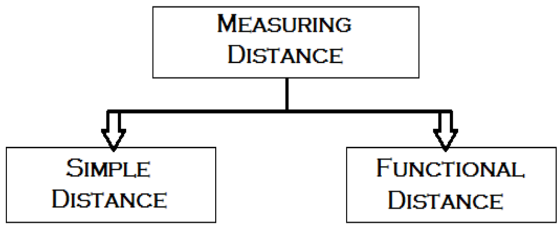
- **Edginess :**

  - This scenario suggest a another measure of boundary configuration called ***Edginess*** that uses a device called **Roving Window**, also known as a **Filter**.
  - *Roving Window is a matrix of numbers* of a preselected size that can be moved across the database either or examine what is there or to modify the grid cell values.
  - In remote sensing, two fundamental tasks for which the filter is used are **Edge Enhancement** and **Edge Smoothing**.

❖ Measuring Distance

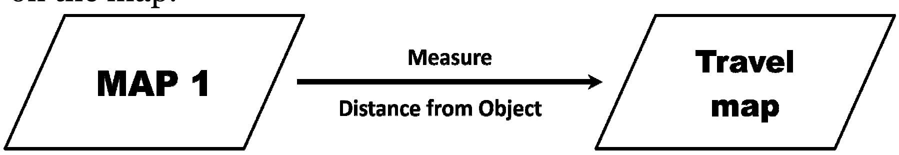
- **Importance for Measuring Distance :**

  - The distance along and among features is important not only in later analysis of the relationship but also it provide a means of *estimating travel to, from and around them*.

Simple Distance :-

- *"Distance can be measure in simple terms where its calculation is based on the absolute physical distance between places on map called **Simple Distance**."*
- Calculating Simple Distance known as ***Euclidean Distance***.
- ***In Raster***, the method is to add the column and row distance in grid cell units, then multiply the number of grid cells by their grid cell resolutions whether Orthogonal or Diagonal (*Diagonal Distance is **1.414** times then the Orthogonal distance*).
- *However this limits our analysis of our distance*.
- **For Example** we may want to know the between a single point location on a mp and all other possible locations.
- ***In Vector***, this is done by producing a series of concentric rings, one grid cell in diameter, around a series of grid cells.
- The result of such a distance measure, assuming the surface is completely uniform, is called an ***isotropic surface***.
- It is not always necessary to measure a distance across a surface starting with a point as the origin.
- We may wish to measure the distance from a linear or polygonal object to all other locations on the map.



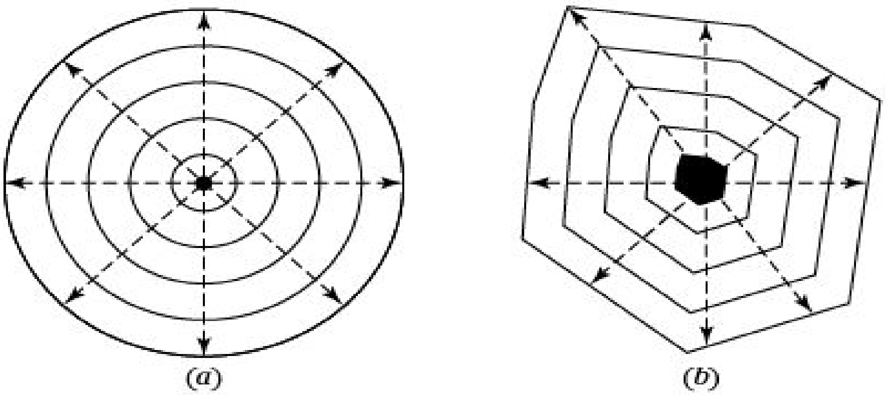


Figure 9.10 Isotropic surfaces around a point (*a*) and a polygon (*b*).

➢ Functional Distance :-

- *"Distance can be measured to include cost incurred while travelling, the cost of travel specifically along network rather then off-road, or difficulties involving barriers that restrict or prevent movement. These approaches to measuring distance are called **Functional Distance**."*
- **The purpose** to calculating the Functional Distance is to estimating the cost for traveling on totally isotropic surface.
- We need to consider *two basic concept* while looking functional distance:
  1. **Friction Surfaces.**
  2. **Barriers.**
- Both involves some form of impedance or ***friction values***, which is measurable that imposes the ***cost of movement***.
- Topography, itself a continuous variable, may imposes a ***friction value*** based both on surface roughness and the variable cost of moving up or down hill.
- In other cases rather isolated conditions or discrete obstacles called ***barriers*** interface with movement across a surface.
- Types of barriers :
  1. **Absolute Barriers.**
  2. **Relative Barriers.**

- **Absolute Barriers :**
  - It will prevent or deflect the movement.
  - Two characteristics of Absolute Barriers.
    - *Preamble* (Prevent the movement)
    - *Impermeable* (Restricted Access such as bridge across the river)
  - (E.g. Cliffs, Fenced Area, Lakes etc…)

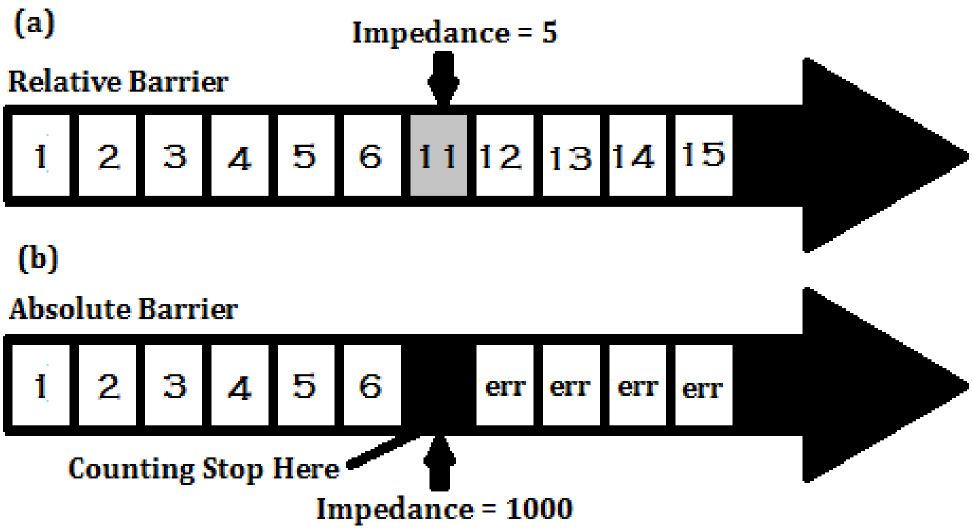
- **Relative Barriers :**
  - Such a barriers might be exemplified by narrow bridges of hilly terrain, shallow streams that are passable for off-road vehicles, or patches of forest *that restrict but no prevent completely*.

➢ How to modify Simple Distance to Functional Distance?

- Whether you are employing friction surface or barriers, it is common practice to employ both on original map layer without friction or barriers and another layer with friction or barriers.
- In such a cases you are modifying your measurement of Euclidean distance by Functional map layer.
- So movement across the topographic surface or through forest will modify the speed of movement.

➢ Raster Modeling of Barriers and Friction :

- If, on an isotropic surface, the GIS adds one grid cell for each unit of travel, each additional ring of an isotropic surface is recorded as 1+ the row before it.
- We want to show travel distance as a functional distance from left to right across the map. To create a barrier, we place values and will not allow the coding of another cell beyond it until it has counted beyond the highest value codes for the barrier.
- **For Example**: if we used the impedance value 5 for our barrier and began counting from left to right, it would continue to increase the next grid cell by a value of 1, until it reached the barrier.
- *It then must add impedance value before it can continues*.
- Such a barrier is consider Relative Barrier because once it has continued five additional numbers, it will continue to move along, adding one number to each additional grid cell.
- *To make a barrier an **absolute barrier***, we assign it a weighting factor sufficiently high that it will exceed either some maximum number designated by GIS or what should be the maximum number for grid cell in the GIS coverage.
- So if we have a raster coverage that is *100 grid cells wide*, we might put a barrier value or *impendent value of 1000* to ensure that the process of moving and counting the grid cell stops before it pass the barrier.



- **Additional Characteristic of Distance :**

  - **Incremental Distance / Cumulative Distance.**
  - ✓ It simply measure each unit, or increment, traveled, adding the second to the amount distance traveled in the first, and so on. In other words, the incremental distance measure shortest path between two places without adding any friction or impendence values along the way.
  - ✓ If incremental distance is measured for an entire surface, the result is **Shortest-Path Surface**.
  - ✓ The purpose for calculating the functional distance on a friction surface is to find the **Least-Cost-Distance**.