Measures of Nodal Accessibility

(By Total Matrix)

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- ***Accessibility*** *is the measure of* ***the capacity of a location to be reached by, or to reach different locations****.*
  - *Therefore, the capacity and the arrangement of transport infrastructure are key elements in the determination of accessibility.*

Or

node – linkage association*.*

- Due to inequalities, all locations are not equally accessible. Thus, accessibility represents spatial inequalities.

- Well-developed and efficient transportation systems offer high levels of accessibility, while less-developed ones have lower levels of accessibility.
- Thus, accessibility is linked with an array of economic and social opportunities, but congestion can also have a negative impact on mobility.

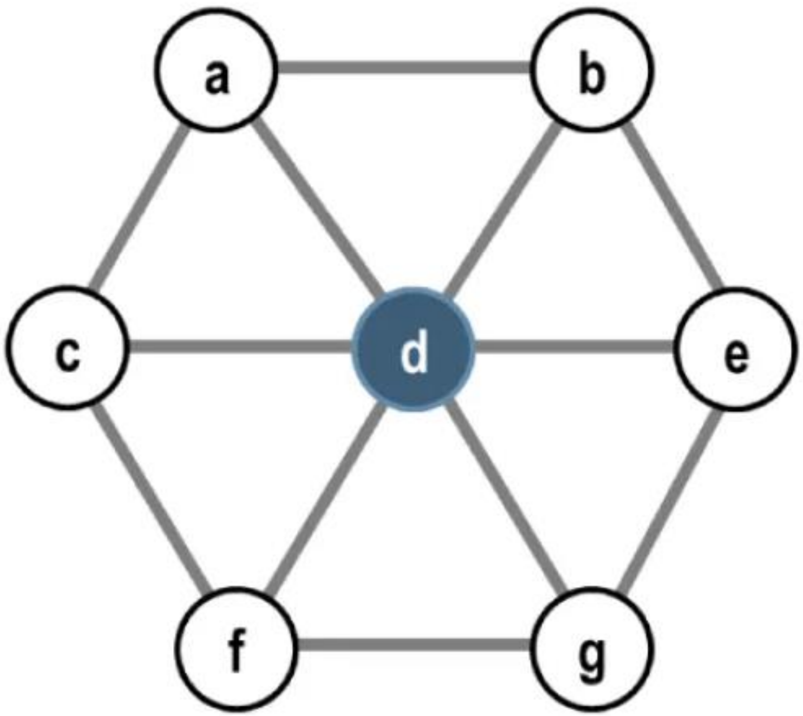
- Accessibility is a determining factor behind the availability of opportunities (jobs, customers, suppliers, etc.) and if they can be realized or not.
- In a high accessibility setting, an individual will have access to a wider array of goods and services, employment as well as additional social interactions. The same applies to a business with potentially more customers and suppliers.
- Keeping **accessibility constant**, density is also a factor impacting on opportunities.
  - In a high density setting, a distance will confer more opportunities than the same distance on a low density setting.

- The notion of accessibility consequently relies on two core concepts:-

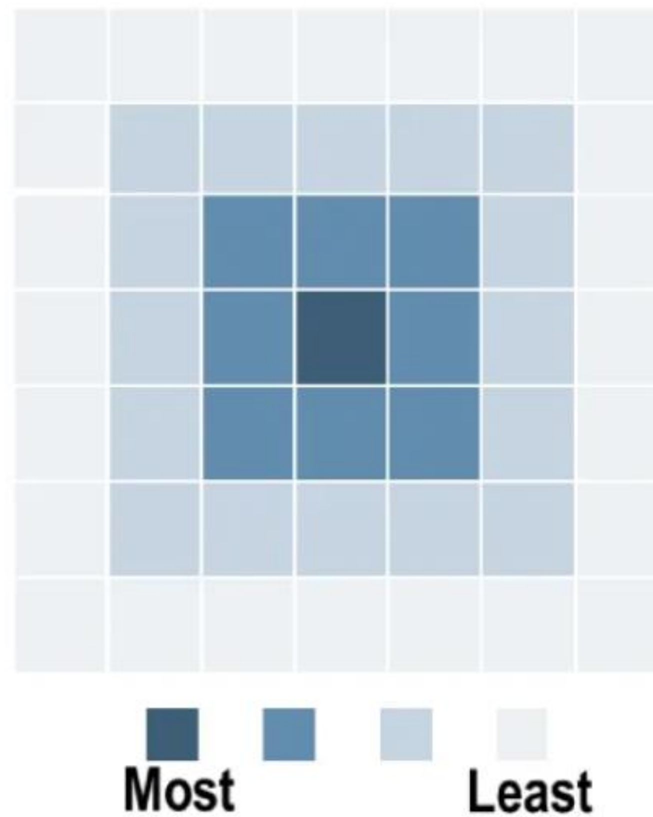
- The first is **location,** where the relativity of space is estimated in relation to transport infrastructures since they offer the means to support mobility. Each location has a set of referential attributes, such as its population or level of economic activity.
- The second is **distance**, which derived from the physical separation between locations. Distance can only exist when there is a possibility to link two locations through transportation. It expresses the friction of distance and the location which has the least friction relative to others is likely to be the most accessible.

- There are two categories of spatial accessibility, which are interdependent:
- **Topological accessibility** :
  - It is related to measuring accessibility in a **system of nodes and paths** (a transportation network).
  - It is assumed that accessibility is a measurable attribute significant only to specific elements of a transportation system, such as terminals (airports, ports or subway stations).
- **Contiguous accessibility:**
  - It involves measuring accessibility **over a surface**.
  - Under such conditions, accessibility is a cumulative measure of the attributes of every location over a predefined distance, as space is considered in a contiguous manner. It is also referred to as **isochrone accessibility.**
- Last, accessibility is a good indicator of the underlying spatial structure, since it takes into consideration **location** as well as the **inequality conferred by distance to other locations**.

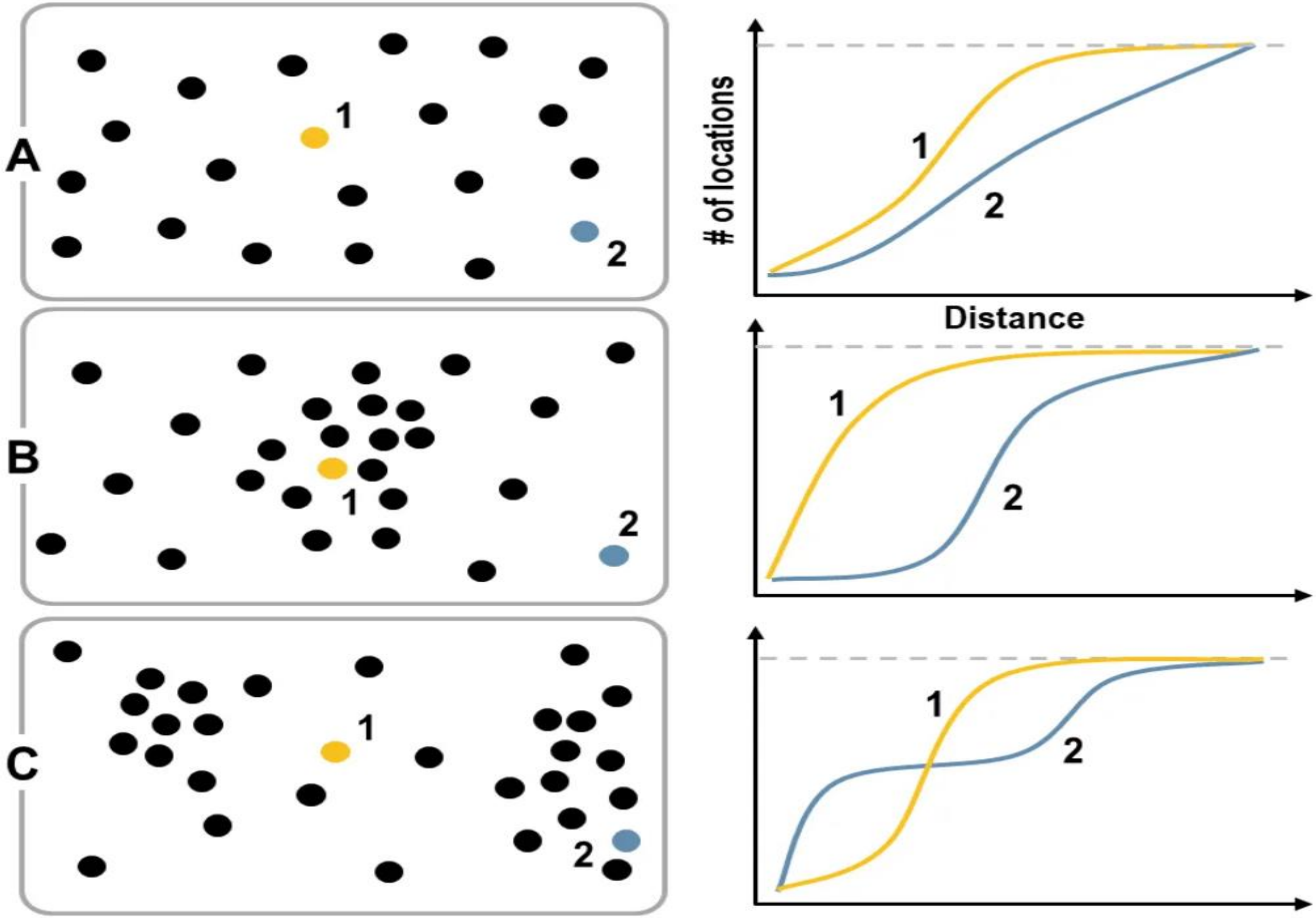
Topological



Contiguous



Accessibility and Spatial Structure



Due to different spatial structures, two locations of the same importance can have different accessibility levels.

(A) Uniform distribution. For a spatial structure where locations are uniformly distributed, locations 1 and 2 have different accessibility levels, with location 1 being the most accessible. As distance (Euclidean) increases, location 1 has access to a larger number of locations than location 2. To access all locations, location 2 would require about double the traveled distance than location 1.

(B) Clustering in central area. In this case, the number of locations that can be reached by location 1 increase rapidly and then eventually peaks. Location 1 has a clear accessibility advantage over location 2.

(C) Clustering in periphery. Although the number of locations that can be reached from location 2 initially increases faster than for location 1, it catches up and is actually the most accessible, but by a lesser margin.

Topologically, accessibility can be measured in three ways:

- **(1) By shortest path matrix (Shimbel Index or D Matrix)** – the number of arcs used in the shortest path between all possible pairs.

or

It indicates the number of arcs needed to connect any node with all the other nodes in the network by the shortest path.

- **(2) By the associated number** – the number of arcs needed to connect a node to the most distant node from it; and

Connectivity and Accessibility

- Any node which is well connected to other nodes in a network is said to be accessible.
- The most basic measure of accessibility involves **network connectivity -** where a network is represented as a connectivity matrix (C1), which expresses the connectivity of each node with its adjacent nodes.

How to construct Connectivity Matrix:

- In a matrix, number of columns and rows in this matrix is equal to the number of nodes, present in the transportation network.
- Each cell entry in the matrix may be used to record some information on the relationship between a pair of nodes.
- A value of 1 is given to the cell, where pair of node is connected directly.
- A value of 0 is given to the cell, where pair of node is non-connected.
- The summation of this matrix provides a very basic measure of accessibility, also known as the **degree of a node**:

Total Matrix:

- Any node which is well connected to other nodes in a network is said to be accessible.
- The summation of this matrix provides a very basic measure of accessibility, also known as the **degree of a node**.
- But the degree of a node has serious limitations as a measure of accessibility. For surface modes of transport, accessibility involves more indirect connections than the direct connection between a pair of nodes.
- The indirect connections, i.e., a linkage between a pair of nodes which passes through one or more intermediate are also important, therefore, a suitable measure should take into consideration for both direct and indirect connections.

The total accessibility matrix (T) is obtained from the following procedure:

1. Construct the connectivity matrix (C1).

- It is a matrix where for each cell a value of 1 or 0 is used to denote in a connection exists between two node pairs.

2. Construct the second order (two-linkages paths) connectivity matrix (C2).

- The total number of two-linkages paths (matrix C2) equals to C1 x C1.
- Each cell in the C2 matrix is the result of the summation of the product of each corresponding row and column in the C1 matrix.

3. Repeat the construction of the Nth order connectivity matrices:

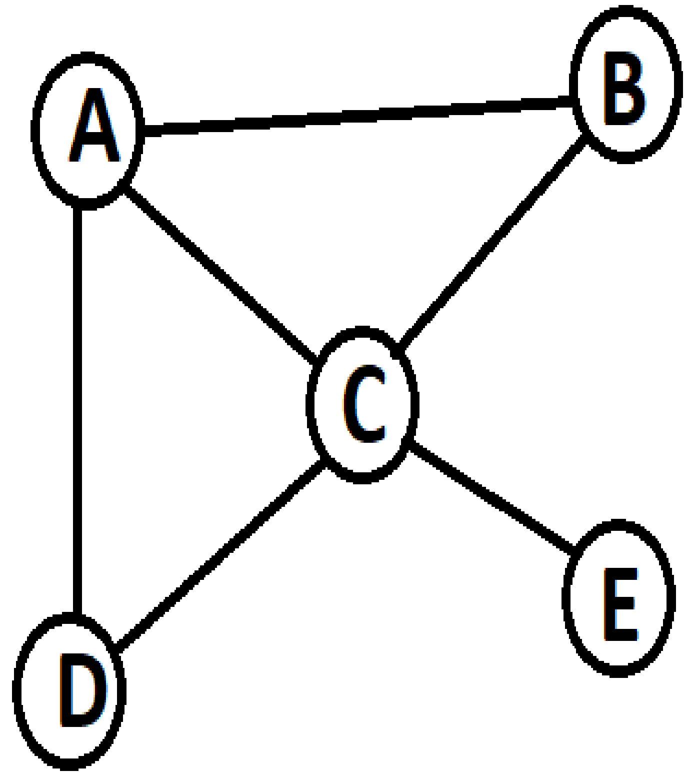
- Connectivity matrices are repeated until the number of Nth-linkages paths is equivalent to the diameter (path between most distant nodes) of the network.
- A 3rd order connectivity matrix (C3) would be equal to C1 x C2.
- For instant, a network that has a diameter of 4 would require the construction of 4 matrices (C1 to C4).
  - C1 matrix = C x C
  - C2 matrix = C1 x C1
  - C3 matrix = C1 x C2
  - C4 matrix = C1 x C3

4. Construct the total accessibility matrix (T):

- The matrices as c, c^2, c^3 and c^4 are summed to give a matrix T that enumerates the total of all direct and indirect connections of a sample network.
- The higher the value of the row sum the greater the accessibility of the node.

Connectivity Matrix (C1):

	A	B	C	D	E
A	0	1	1	1	0
B	1	0	1	0	0
C	1	1	0	1	1
D	1	0	1	0	0
E	0	0	1	0	0
Total	3	2	4	2	1



- On the above network node C is having the highest degree, which is the sum of all the connections this node has **4.**

$$C1 = \sum_{j}^{n} C_{ij}$$

C1

	A	B	C	D	E
A	0	1	1	1	0
B	1	0	1	0	0
C	1	1	0	1	1
D	1	0	1	0	0
E	0	0	1	0	0

X

C1

	A	B	C	D	E
A	0	1	1	1	0
B	1	0	1	0	0
C	1	1	0	1	1
D	1	0	1	0	0
E	0	0	1	0	0

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C2

	A	B	C	D	E
A	3	1	2	1	1
B	1	2	1	2	1
C	2	1	4	1	0
D	1	2	1	2	1
E	1	1	0	1	1

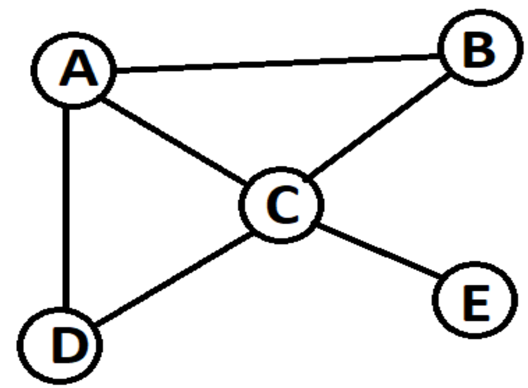
A X A = {(0.0)+(1.1)+(1.1)+(1.1)+(0.0)} = 3

A X B = {(0.1)+(1.0)+(1.1)+(1.0)+(0.0)} = 1

A X C = {(0.1)+(1.1}+(1.0)+(1.1)+(0.1)} = 2

A X D = {(0.1)+(1.0)+(1.1)+(1.0)+(0.0)} = 1

A X E = {(0.0)+(1.0)+(1.1)+(1.0)+(0.0)} = 1



- For instance, cell A-B in C2 matrix indicates that there is only one possible ***two-paths link*** between node **A** and **B** (A-C-B).
- There are two possible two-linkages paths between **C** and **A** (C-B-A and C-D-A).

C 1 Matrix

	A	B	C	D	E
A	0	1	1	1	0
B	1	0	1	0	0
C	1	1	0	1	1
D	1	0	1	0	0
E	0	0	1	0	0

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C2 Matrix

	A	B	C	D	E
A	3	1	2	1	1
B	1	2	1	2	1
C	2	1	4	1	0
D	1	2	1	2	1
E	1	1	0	1	1

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Total Matrix

	A	B	C	D	E	∑
A	3	2	3	2	1	11
B	2	2	2	2	1	9
C	3	2	4	2	1	12
D	2	2	2	2	1	9
E	1	1	1	1	1	5
∑	11	9	12	9	5	46

- This network has a diameter of 2, only two matrices, C1 (1st order connectivity) and C2 (2nd order connectivity), need to be constructed.
- The summation represents for each node the total number of paths. For this network, there are thus **46** possible paths, with **node C** having the largest number (12).

THANK YOU