Assessing Public Transportation Accessibility Based on Topological Structure

Chulmin Jun[*], Young-Ook Kim[**], Seungjae Lee[*] & Seungil Lee[*]

* The University of Seoul, Seoul, Korea
** The Sejong University, Seoul, Korea

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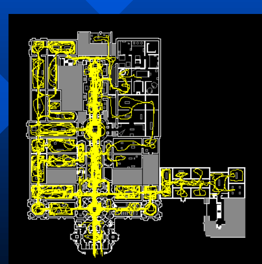
Introduction

- Public-oriented transportation policies
- Unbalanced supply due to less systematic route planning and operations
- Unbalanced accessibility causes inequalities in time, expenses and metal burden of users.
- Need robust methodology to assess the accessibility or serviceability of the transport routes.

Introduction

- Space syntax is the technique to analyze the connectivity of urban or architectural spaces.
- Has been applied to analyzing movement in indoor spaces or pedestrian paths (not in transport network).
- The study proposes a method to evaluate accessibility of public transport network based on its topological structure.

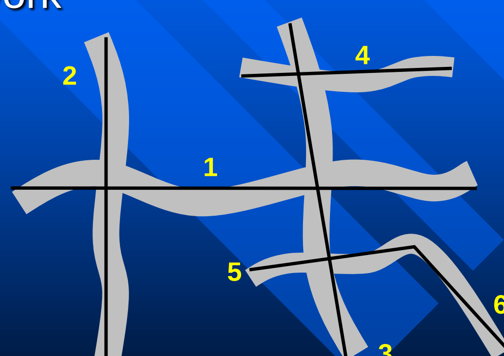


Hierarchical Network Configuration

- Movement can be described in an abstracted form using its topology.
- Topological description helps focus on the structural relationship among units.
  - For example, pedestrian movement can be described using network of simple lines without considering the details such as sizes of forms, number of people and speed of movement.

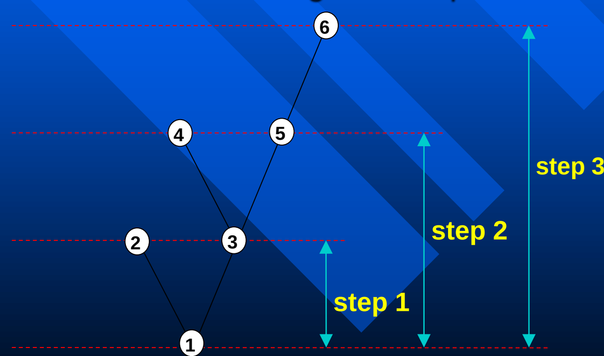
Hierarchical Network Configuration

- Topological description of streets network



Hierarchical Network Configuration

- Hierarchical structure of a street
  - Representing each component with a node and a turn with a link connecting their respective nodes



Hierarchical Network Configuration

- This relationship is described thought a variable called *depth.*
  - Depth of one node from another can be directly measured by counting the number of steps (or turns) between two nodes.

Hierarchical Network Configuration

- Total Depth(TD)
  - $TD_1 = 1 \times 2 + 2 \times 2 + 3 \times 1 = 9$

$$TD_i = \sum_{s=1}^{m} s \times N_s$$

TD_i : the total depth of node *i*
s : the step from node *i*
m : the maximum number of steps extended from node *i*
N_s : the number of nodes at step *s*

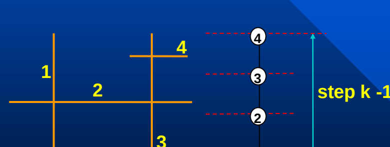
Hierarchical Network Configuration

- Mean Depth(MD) = TD / (k-1)
- Normalized Depth(ND)

※ k : the total number of nodes

a. completely symmetrical network

$$MD = \frac{k-1}{k-1} = 1$$



b. completely asymmetrical network

$$MD = \frac{1+2+...+(k-1)}{k-1} = \frac{(k-1)k/2}{k-1} = \frac{k}{2}$$

$$1 \le MD \le \frac{k}{2}$$

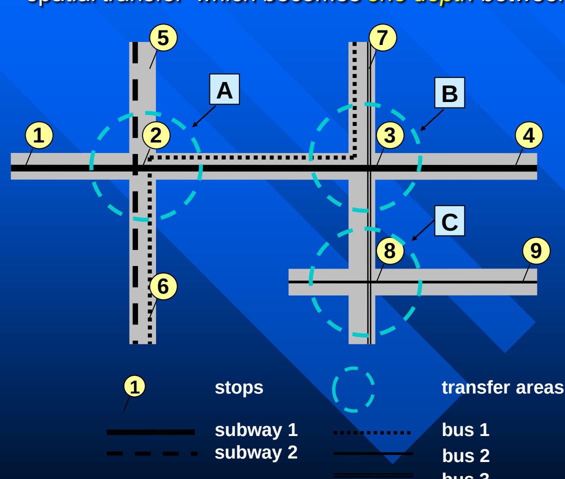
$$0 \le \frac{2(MD-1)}{k-2} \le 1$$

Applying to Public Transportation

- Hierarchical network structure focuses on turns of spaces while the public transportation entails transfers between vehicles.
  - » In hierarchical network description, the deeper the depth from a space to others, the more relatively difficult it is to move from that space to others.
  - » In public transportation, cost generally increases as the number of transfers between different modes increases.

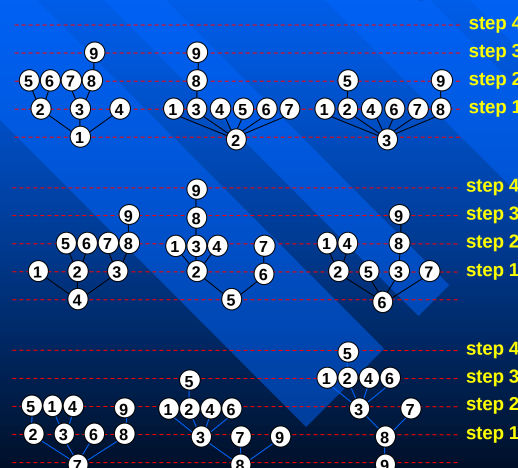
Applying to Public Transportation

» *One transfer* from a transportation mode to another is the 'spatial transfer' which becomes *one depth* between spaces.



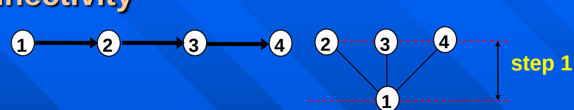
Applying to Public Transportation

- Mapping schematic route connectivity onto a graph

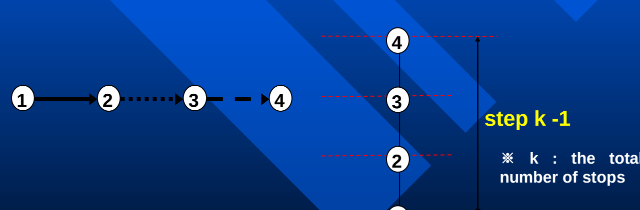


Applying to Public Transportation

- Symmetry and asymmetry of the route connectivity



a. complete symmetry of the route connectivity



b. complete asymmetry of the route connectivity

Applying to Public Transportation

- Computing depth from each stop

Stop No.	TD	MD	ND	ND^{-1}
1	14	1.750	0.214	4.67
2	11	1.375	0.107	9.33
3	10	1.250	0.071	14.00
4	14	1.750	0.214	4.67
5	17	2.125	0.321	3.11
6	13	1.625	0.179	5.60
7	12	1.500	0.143	7.00
8	14	1.750	0.214	4.67
9	21	2.625	0.464	2.15

Applying to Public Transportation

- Iterative procedure for computing TD

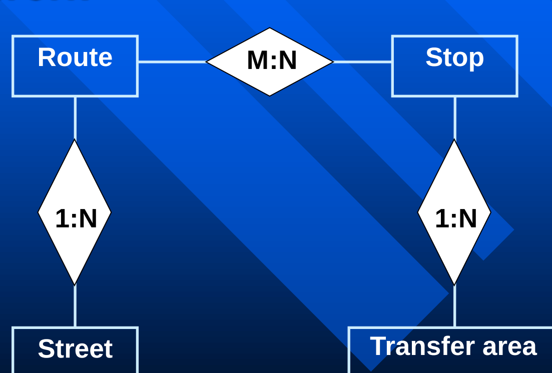
1.For i=1~k stops
  1.1 For all routes that share stop i
    1.1.1 Step = i
    1.1.2 Find all stops except for stop i and accumulate TD
    1.1.3 For all transfer areas found
      1.1.3.1 Find all stops in current transfer area
      1.1.3.2 For each stop
        1.1.3.2.1 for each route
          Step++ and go to 1.1.2

Integrating into GIS

- Typical GIS data structure alone can not capture the complex relationship in public transportation.
- The relationship among streets, routes, stops and transfer areas can be abstracted into an entity-relationship model in a relational database.

Integrating into GIS

- **E-R diagram for public transport network**

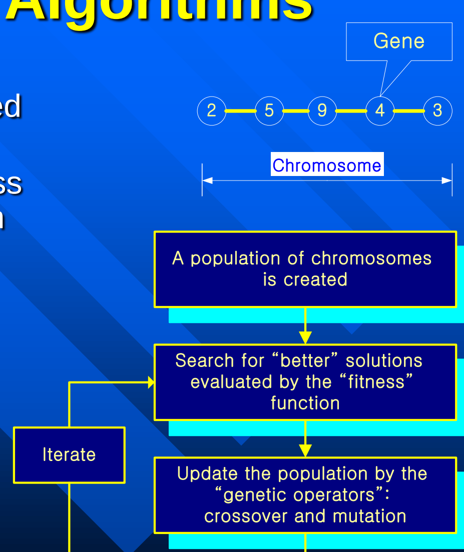


Generating Paths using GA

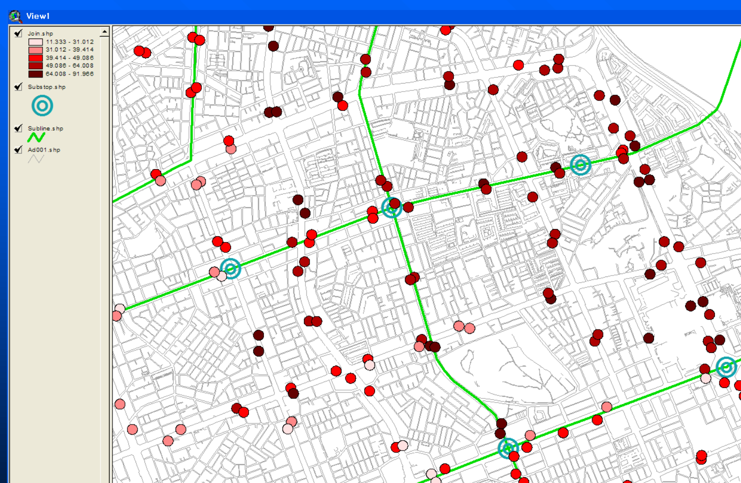
- Computing depth of a stop requires finding paths from that stop to all others, each of which being the minimum-cost path.
- In this study, the minimum-cost path is the one having the minimum number of transfers between the O-D.

Genetic Algorithms

- Use the terms borrowed from natural genetics
- A global search process on a certain population of chromosomes by gradually updating the population
- Exploiting the best solutions while exploring the search space



Applying to the CBD of Seoul



- Integration(ND-1) for bus stops in the CBD of Seoul.

Concluding Remarks

- A method to assess accessibility of public transport network was proposed by defining the network relationship onto a graph.
- An analogy between the concept of depths in pedestrian network and the accessibility of network of transport routes was used.
- An algorithm to automate the computing process was developed.
- If the procedure is applied to a city, we can quantify the difference in the serviceability of city areas based on the public transportation.


Thank You!