Application of Quantitative Indices for Urban Environment Analysis in the Consideration of Remote Sensed Imagery: Accessibility and Connectivity

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Abstract: In this study, uses of remote sensed imagery in urban environment analysis are represented with the actual processed results with newly implemented programs running under ESRI ArcView-GIS to extract secondary information about mainly urban transportation environment. Implemented programs are about Accessibility index and Connectivity index. Accessibility index and Connectivity index are composed of four types of different algorithms and three types of algorithms such as alpha, gamma, and shimmel index. As show applied examples, tried to find out how remotely sensed imageries can be effectively utilized at actual processing in the direct or indirect ways in these algorithms.
Keywords: *Accessibility index, ArcView-GIS, Connectivity index, High-resolution imagery, Urban Transportation Analysis*

1. Introduction

Pixel-based and visual oriented analysis functionality, multiple level information from low to intermediate resolution and linkage methodologies with other information system were limitation in using remotely sensed imagery in the past. However in the commercialized use of high-resolution imagery, these kinds of limitation can be gradually overcome. In this study, uses of remote sensed imagery in urban environment analysis are represented with the actual processed results with newly implemented programs running under ESRI ArcView-GIS to extract secondary information about mainly urban transportation environment. This program contains several quantitative information extraction programs which are Accessibility index and Connectivity index. Accessibility index and Connectivity index are composed of four types of different algorithms and three types of algorithms such as alpha, gamma, and shimbel index In fact, most algorithms in this extension program were originally designed in analytical functions in the field of GIS-T (GIS for Transportation), but remotely sensed imageries can effectively utilized at actual processing in the direct or indirect ways in these algorithms. In this study, a small-sized local area, Guri-city and Namyangju-city, nearby Seoul are chosen as AOI (Area of interests), and some additional databases such as road centerline and administrative boundary also are built, and KOMPSAT-EOC and IKONOS imagery are processed. With this program, new quantitative information to characterize an urban environment can be easily obtained, and it is expected that after further analysis with these results, practical problems solving in transportation planning process or urban planning is partly possible. As well, in near future, it is thought that this kind of approach is populated in application fields dealing with the spatial information.

2. Accessibility Index

The conception about accessibility analysis is method to get quantitative index information which regards attractive element correspond to mass in natural science and distance element as variable in TAZ (Traffic Analysis Zone). Figure 2 represents the conception of accessibility. It is important that attractive Factor of each place is influenced from other place as mass in natural science.

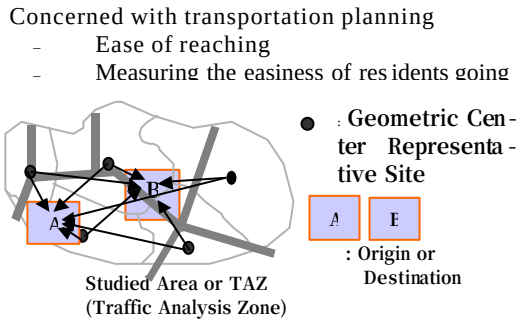

Figure 1. Basic Concept of Accessibility.

Accessibility index that is based upon traffic gravity model systematized by Ma and Pun-Cheng(2000) and some types that apply in this research are as following. A_i represents accessibility of node I, and S_2 represents size of the activity in zone2 and T^x_{1-2} is travel time or

distance with an exponent of the effect of the travel time between the zones in Hansen model. A_{ij} represents Relative accessibility at the point j at point i in Ingram model. A_i represents Accessibility by mode k to residents in zone i , e_j is job opportunities in zone j and T_{i-j} is Average time to reach the nearest M activities from zone i in CTS model. T_{ij} represents Travel time by public transport between zone i and zone j and M_j is Mass of the destined centroid in Gutierrez and Gomez model.

Hansen Model (1959)

$$A_i = \frac{S_2}{T^x_{1-2}}$$

Ingram Model (1971)

$$A_i = \sum_{j=1}^{n} a_{ij}$$

CTS Model (1976)

$$A_i = \left[\frac{1}{M} \sum_{j=1}^{k} E_{ij} T^x_{i-j} \right]^{1/x}$$

Gutierrez & Gomez

$$A_i = \frac{\sum_{j=1}^{n} T_{ij} M_j}{\sum_{j=1}^{n} M_j}$$

Figure 2. Accessibility Index.

Figure 3 is the case of extraction of accessibility index by Ingram Model and the applied area is Nam-yangju city, which is located nearby Seoul.

Representative point of administrative division unit is selected optional point of digitized map. Optional point can be selected according to user's various purposes. Administrative division is linked with database and it automatically extracts the all node in each administrative division. After that automatic distance measuring from optional point to other points or other processing process is handled automatically.

Figure 3. Application of Accessibility index: Examples.

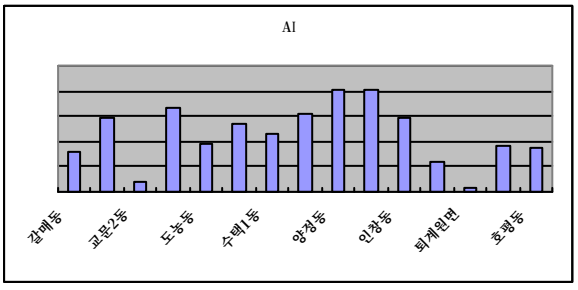

Figure 4. Applied result of Accessibility index: Ingram Model.

Figure 4 is the graph of accessibility index for change of relative accessibility index.

Figure 5 represents one of actual application cases using accessibility index in Ingram model with overlay GIS Layer and KOMPSAT EOC imagery. Figure 5 (a) ~ (b) show accessibility index of each administrative division by Ingram model. Figure 5 (b) also shows accessibility index difference by each administrative division.

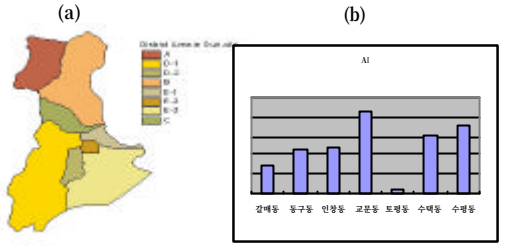

Figure 5. Accessibility index using Administrative boundary: Ingram Model case.

3. Connectivity Index

Figure 6 represents concept of connectivity. That's importance is not attractive factor of each place but how transportation node is connected well.

As time goes by, it shows how the road system is developed by connectivity analysis.

Alpha Index is defined as the ratio of actual circuits to the number of maximum circuits. This is useful in comparing different networks to differentiate their levels of connectivity.

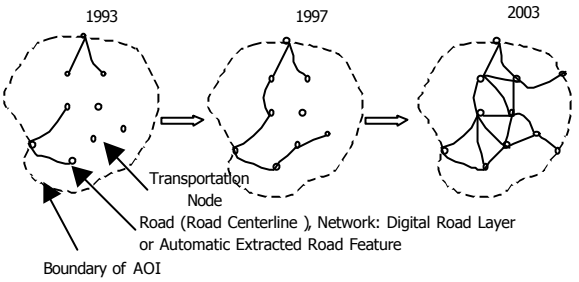

Figure 6. Meaning of Connectivity Concept.

Gamma Index is defined as the ratio of the actual number of edges to the maximum possible number of edges in the network. This is useful for comparing two or more networks.

Shimbel Index is defined as computation of shortest path distances among all points (vertex and node). This is useful in evaluating concentrated levels of transportation networks.

Formulation of these concepts is summarized in figure 7.

$$\alpha = \frac{e - v + 1}{2v - 5} \qquad \gamma = \frac{e}{3(v - 2)}$$

$$D(G) = \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij}$$

e: Edge, *v*: Vertex,
d: distance to i point to j point

Figure 7. Connectivity Index.

Figure 8 represents implementation result of Connectivity analysis's user interface with IKONOS imagery. After determining target layer in step 1, selected area that wish to analyze in administration area unit, rectangle, polygon shape. It shows selected name, coordinate, area. If selection of "Extract Road node" button in step 3, edge(e) and vertex(v) are abstracted automatically. Finally, alpha, gamma, Shimbel index are calculated by "Calculate index" button control.

Figure 9 represents applied result to the area which is same with figure 3.

Figure 8. User interface of extraction extension program of Connectivity index with IKONOS imagery.

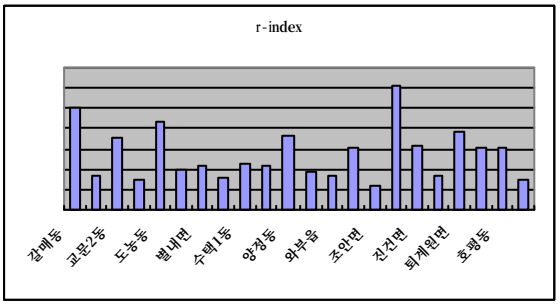

Figure 9. Extracted results of Connectivity index: Gamma index.

4. Conclusions

This study tried to examine possibility of high-resolution satellite imagery information in traffic field practical use and it purposes are addressing of accessibility and connectivity index with remotely sensed imagery, application of satellite imagery information and carrying out case examples.

Extraction of accessibility index needs input basis information according to user's application purpose and database information is linked internally. However, extraction of connectivity index does not need user's input. Required GIS databases in this program are two layers: road and administration boundary.

Quantitative index information that is abstracted as application result can be used displaying urban traffic environment for analysis target area as quantitative. If use satellite imagery, can correct and update database. Also it gives sense for the real of analysis target area.

Various practical uses for traffic field of satellite imagery information are thought to be possible more if is applied connecting with GIS-T techniques.

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