Comparative Analysis of Measures for Land Use Mix

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Abstract

This study reviews measures of urban land use mix in order to understand their difference focused on individual parcel based measures. We then apply several of these measures to evaluate land use patterns considering three relationships, and ascertain distributional characteristics of these patterns. We found that measurement values of different land use pair showed low correlation for all measures. As a result, desirable mixed land use pattern varies by perspective of spatial relationship and land use pairs, and the trade-off was observed between measures.

1. Introduction

The need for greater land use mix has been adopted as the conventional wisdom among urban planners as well as public health professionals. Also the concept of mixed land use is considered essential to achieve a compact city. Thus, several land use mix measures have been proposed from the past (Cervero, 1997; Miyazaki, Itamoto and Nakazawa, 2001; Manaugh and Kreider, 2013; Koide, 1997). These measures have been applied as evaluation indices for explaining effects of mixed land use on the formation of community based on walking, on the reduction of automobile dependence, and on utilization of infrastructure.

However, we cannot assume that these measures are organized in a systematic manner. Furthermore, effects of mixed land use have been evaluated from limited perspectives by limited measures. These are thought to be the main reason of ambiguous definition and structure of mixed land uses. In this study, we: (a) Review various land use mix measures and compare these measures based on land use patterns, and (b) Evaluate land use patterns based on several measures and ascertain their distributional characteristics.

2. Review of Measures for Land Use Mix

The concept of urban land use mix implies that nearby land uses or activities have an influence over each other across a limited space range. Song, Merlin and Rodriguez (2013) suggested that urban mixed land use measures contain two concepts implicitly or explicitly; distance and quantity. However, spatial relationship between different land uses cannot be defined by only distance due to the continuity of urban space. Thus we categorized measures of land use mix into three groups; diversity (quantity), proximity and adjacency.

Land use mix measures can be categorized by their spatial unit for calculation into integral measures which are calculated based upon an area's land use distribution as a whole, and divisional measures which make use of subdivisions (Song, Merlin and Rodriguez, 2013). As the geographic information system develops, however, measures based upon individual parcel

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or mesh also has been used in these days (Cervero and Kockelman, 1997; Manaugh and Kreider, 2013). They are expected to grasp spatial inter-mixing at a fine grain. Thus in this study, we focus on these individual parcel based measures. The measures we have selected for analysis are average count of different use within limited range (*ANC*), nearest distance (*ND*) and average distance (*AD*) to different use, and average number of adjacent different use (*ANA*) as Table 1.

Table 1. Definition of mix land use measures

Category	Measures
Diversity	$ANC_{lk} = \frac{1}{N_l}\sum_i^{N_l}\sum_j^{N_k-1} x_i^l x_j^k$, $d_{ij} \le r$ $x_i^k = \begin{cases} 1 & \text{if the use of mesh } i \text{ is } k \\ 0 & \text{if the use of mesh i is not } k \end{cases}$ d_{ij}: manhattan distance between mesh i and j
Proximity	$AD_{lk} = \sum_i^{N_l}\sum_j^{N_k-1} x_i^l x_j^k d_{ij} \,/\, \sum_i^{N_l}\sum_j^{N_k-1} x_i^l x_j^k$, $d_{ij} \le r$ $ND_{lk} = \frac{1}{N_l}\sum_i^{N_l}\sum_j^{N_k-1} min \quad x_i^l x_j^k d_{ij}$
Adjacency	$ANA_{lk} = \frac{1}{N_l}\sum_{i=1}^{N_l}\sum_{j=1}^{4}\frac{x_i^l L_{ij}}{4}$ $L_{ij} = \begin{cases} 1 & \text{if use of adjacent mesh } j \text{ is } k \\ 0 & \text{if use of adjacent mesh } j \text{ is not } k \end{cases}$

3. Relationship between Land Use Measures

We made 10×10 grid land use patterns (torus pattern) with 4 land uses (residential, commercial, green, and industrial use). We set 3 kinds of land use proportions (r:c:g:i = 40:20:20:20, 25:25:25:25, 30:30:20:20) and created 1,000 random patterns randomly for each proportion. Distances between meshes were calculated with the Manhattan distance, and *ANC* and *MD* were calculated by considering only meshes within *d*=5 from each mesh. Measures were calculated for all six pairs (r-c, r-g, r-i, c-g, c-i, g-i).

Correlation analysis and factor analysis were conducted using each measurement value. Measurement values of 6 pairs in the same measure showed low correlation (-0.33~0.28), whereas same pair's measurement values of *ANA*, *AD*, *MD* showed relatively strong correlation. As a result of factor analysis, each pair of measures except *ANC* was categorized into the different factor, and same pairs of *ANA*, *AD*, and *MD* were categorized into the same factor (i.e. factor 1: ANA_{rc}, AD_{rc}, ND_{rc}).

Even though one of pairs of *ANA* is fixed, it does not mean that the result has the fixed land use pattern. Neither does *AD* and *ND*. Thus, it is required to consider multiple measures and pairs in order to accomplish the desirable structure of mixed land. However, high correlations between the same pair of *ANA*, *AD*, and *MD* do not necessarily suggest that these measures can be used interchangeably. In real urban neighborhoods, adjacency to commercial uses can cause negative externality effects such as noise or light at midnight, while good accessibility to commercial uses can improve convenience of residents.

4. Evaluation of Land Use Patterns

In this section, we evaluated land use patterns using several measures as criteria. There are complex relationships which have connection with positive and negative effects of mixed land use. However we restricted our evaluation here to three relationships for the purposes of simplicity and clarity of comparison.

(1) Proximity to commercial and green uses (ND_{rc}, ND_{rg}) improves convenience.
(2) Proximity between residential and industrial use (ND_{ri}) causes negative effects.
(3) Adjacency between residential and commercial use (ANA_{rc}) has negative effects.

Evaluation 1 considered only the first relationship, and evaluation 2 added the second relationship. At last, evaluation 3 extracted land use patterns considering all relationship based on the Pareto optimal method. Figure 1 shows average measurement values of extracted land use patterns by 3 kinds of evaluations.

Land use patterns which were extracted by evaluation 1 showed shorter average ND_{rc} than all land use patterns. However they are worse than all patterns in respect of ND_{ri} and ANA_{rc} as expected. In case of proportion 1 and proportion 2, land use patterns satisfying evaluation 2 became better in terms of ND_{rc}, ND_{rg}, ND_{ri} compared to all patterns, even though they showed higher ANA_{rc} a little bit. Extracted patterns applying evaluation 3 showed lower ANA_{rc} than other land use patterns, but other measures did not show improvement.

We observed at least one more significant improvement of measurement value in proportion 1 and 2 by three kinds of evaluations. However, results of evaluations in proportion 3 showed little difference compared to all patterns. We examined specific land use patterns satisfying each evaluation (Figure 2). In the land use pattern applying evaluation 1, residential meshes are decentralized to shorten distance to commercial and green mesh, and industrial meshes are decentralized too. When we consider ND_{ri} (evaluation 2), industrial meshes tended to cluster together. Lastly, we observed that all land uses clustered with same land uses (decentralized concentration) in evaluation 3.

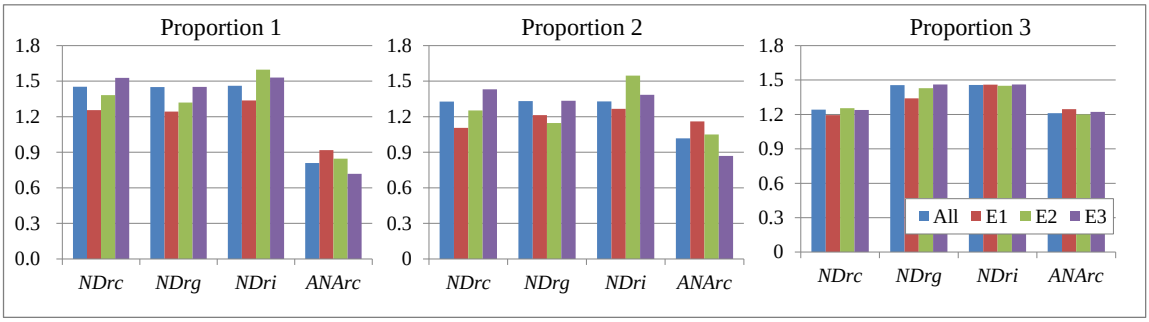
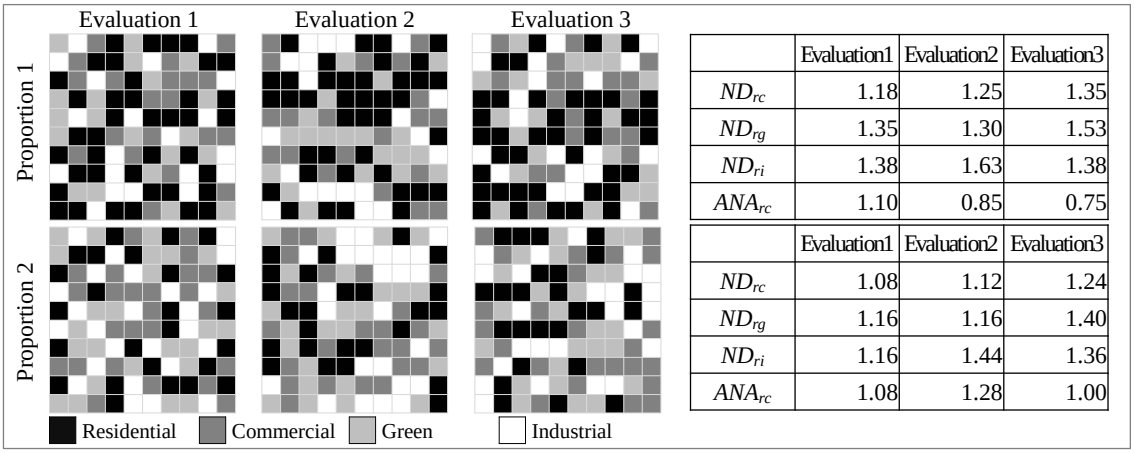


Figure 1. Average measurement value for each evaluation



	Evaluation1	Evaluation2	Evaluation3
ND_{rc}	1.18	1.25	1.35
ND_{rg}	1.35	1.30	1.53
ND_{ri}	1.38	1.63	1.38
ANA_{rc}	1.10	0.85	0.75

	Evaluation1	Evaluation2	Evaluation3
ND_{rc}	1.08	1.12	1.24
ND_{rg}	1.16	1.16	1.40
ND_{ri}	1.16	1.44	1.36
ANA_{rc}	1.08	1.28	1.00

Figure 2. Example of land use patterns

5. Conclusion

We categorized land use mix measures into three groups and analyzed their relationships. Also we evaluated land use patterns based on four measures. These results suggest that desirable mixed land use pattern varies by perspectives of spatial relationship and land use pairs, and there is the trade-off relationship among measures. Furthermore, it is necessary to examine thoroughly how each measure effects to resident's behavior in real urban space.

Keywords : *urban land use mix, diversity, adjacency, proximity*

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