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A New Measure of Accessibility
Reflecting Population Distribution

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Abstract

The purpose of this paper is to suggest a new measure of accessibility reflecting population distribution and to examine its availability by applying it to actual data.

The measure of accessibility to child care facilities is well known as that reflecting population distribution although it has the following two significant problems: one is that demand population is likely to be overestimated; the other is that facilities different in size are equivalently treated. In order to solve these problems, this paper developed a new measure and compared it with two previous one using data of child care facilities in Edogawa-ku in Tokyo. As a result of the comparison, we realized that the new measure is sufficiently available.

1. Introduction

The measure of accessibility is a geographical concept that shows a level accessible to adjacent facilities, cities and so on. There are a lot of applied forms in the measure of accessibility and one of them is a measure reflecting population distribution. The measure of accessibility to child care facilities is well known as that reflecting population distribution and has been developed and examined by some geographers (e.g. Harris 2001, Kawabata 2010, 2011). The accessibility to child care facilities is a measure that reflects demand population distributing in the vicinity of such facilities. Subsuming demand population into the measure of accessibility improves availability of that when there is a limit in the amount of supply from facilities.

The accessibility to child care facilities, however, has two significant problems. One is that demand population is likely to be overestimated; the other is that facilities different in size are equivalently treated. Thus this paper suggests a new measure of accessibility reflecting population distribution in order to solve the above two problems.

This paper presents previous and new measures of accessibility in Chapter 2, compares spatial patterns of their measures by applying them to actual data in Chapter 3, and describes conclusion in Chapter 4.

2. Previous and New Measures

2-1. Previous Measures

The basic form of the measure of accessibility is shown in the following equation:

$$A_i = \sum_j \frac{S_j}{d_{ij}^c} \tag{1}$$

Here A_i indicates an accessibility of area i, S_i indicates the size (the accommodation capacity or the amount of supply) of facility j, d_{ij} denotes distance between area i and facility j, and c is constant.

Kawabata (2010) suggested a measure of accessibility to child care facilities by modifying the above basic form (equation (1)) in order to consider demand population distributing in the neighborhood of such facilities. The accessibility is expressed as follows:

$$A_i = \sum_j \frac{S_j \delta_{ij}}{D_j} \quad , \qquad D_j = \sum_k P_k \delta_{jk} \tag{2}$$

Here A_i indicates an accessibility of area i, S_i indicates the amount of supply from facility j, D_j is the amount of demand adjacent to facility j, P_k is the amount of demand in area k, and δ_{jk} is a binary variable showing 1 if $d_{jk} \le d_{\mathrm{L}}$ and showing zero if $d_{jk} > d_{\mathrm{L}}$. Here d_{L} denotes the limit of distance to accessible child care facilities and d_{jk} denotes distance between area j and facility k.

2-2. New Measure

As mentioned above, there are two significant problems in the accessibility of child care facilities (equation (2)). These two problems are written in:

1) when calculating D_j (the amount of demand adjacent to facility j), there is a possibility that P_k (the amount of demand in area k) is double-counted in plural facilities including facility j, and as a result, D_j has a risk of overestimation.

2) when calculating A_i (accessibility of area i), that facilities different in accommodation capacity are equivalently treated even if the capacity is 1 or over 10,000.

In order to solve these two problems, this paper suggests a new measure of accessibility. Equation (3) shows the measure.

$$A_i = \frac{\sum_j S_j \delta_{ij}}{\sum_j D_j \delta_{ij}} \qquad D_j = \sum_k \left(P_k \times \frac{S_j \delta_{jk}}{\sum_l S_l \delta_{kl}} \right) \tag{3}$$

The meaning of every variable in equation (3) is the same as that in equation (2).

The new measure solves problem 1) by dividing P_k into adjacent facilities according to the amount of supply from them (the second term of equation (3)), and solves problem 2) by calculating weighted averages of supply-demand ratios of adjacent facilities when calculating A_i (the first term of equation (3)).

3. Application

This chapter applies the above three measures (equation (1), (2) and (3)) to actual data in order to examine availability of the new measure.

3-1. Data and Method

This paper uses data of accommodation capacity of child care facilities in Edogawa-ku in Tokyo, Japan on April 1, 2011, and uses register-based age-specific population data (only age 0-5) by small area in Edogawa-ku on April 1, 2011. Edogawa-ku is located at the most eastern part of Tokyo. The reason why Edogawa-ku is adopted as a study area is that the area shows the highest TFR of 23 Tokyo Special Wards and that, therefore child care facilities are supposed to be densely distributed in the area.

We can calculate demand population from register-based population by multiplying each population of age 0-5 by the following coefficient: 0.2(age 0), 0.3(age 1), 0.35(ages 2 and 3) and 0.3(ages 4 and 5). These coefficients are determined with reference to values obtained empirically by Kawabata (2009). Furthermore we convert these data into grid-cell data with one side about 250m.

As regards the limit of distance to accessible child care facilities, we utilize a direct distance of 700m, which is about $\sqrt{2}/2$ times as long as 1,000m. This is because a road distance of 1,000m is generally recognized as the maximum distance that we can go to child care facilities five or six days a week (Kawabata 2009), and because Edogawa-ku has a grid road network.

There are 84 child care facilities in Edogawa-ku as of April 1, 2011 and the total number of accommodation capacity of these 84 facilities is 10,077 persons (about 120 persons per facility). The demand population in Edogawa-ku on April 1, 2011 is 11,249 persons (about 16 persons per grid-cell).

3-2. Distribution of Demand Population

Figure 1 shows distribution of the demand population in Edogawa-ku in 2011. Symbol X in this figure indicates locations of child care facilities. According to this figure, eastern and southern parts of Edogawa-ku show high density of demand population. These parts are relatively newly developed areas and this may cause high density of demand population. We can scarcely recognize the correlation between locations of child care facilities and distribution of demand population.

3-3. Spatial Patterns of Three Measures

Figure 2, 3 and 4 show spatial patterns of the basic measure, a previous measure reflecting population distribution and a new measure reflecting it, respectively. Symbol X in these figures indicates locations of child care facilities.

The feature common to three figures is that higher values are observed in areas agglomerating more child care facilities. The basic measure at grid-cells close to the boundary of Edogawa-ku (Figure 2), however, does not show a higher value even if more child facilities lie in the neighborhood of such grid-cells. This is because the basic measure has a tendency of being underestimated at peripheral areas close to the boundary of a study area. The reason why the basic measure has such a tendency is that peripheral areas cannot include nearby facilities in the calculation of accessibility if the facilities being located in the outside of a study area. On the other hand, remaining two measures do not have a tendency of being underestimated at peripheral areas because the measures are derived from a supply-demand ratio and because the measure is not easily influenced by exclusion of nearby facilities.

Spatial patterns of two measures reflecting population distribution are similar to each other although the previous one has a more uneven pattern than the new one. Such a difference may occur because of the difference in form between the two measures, i.e., the previous one is expressed as the sum of supply-demand ratios of facilities; the new one is expressed as a weighted average of supply-demand ratios of facilities. As mentioned above, however, the previous one has irrational properties that facilities different in accommodation capacity are equivalently treated. This fact enables us to realize that the spatial patterns of the new one may be more reliable than those of the previous one and that the new one is sufficiently available.

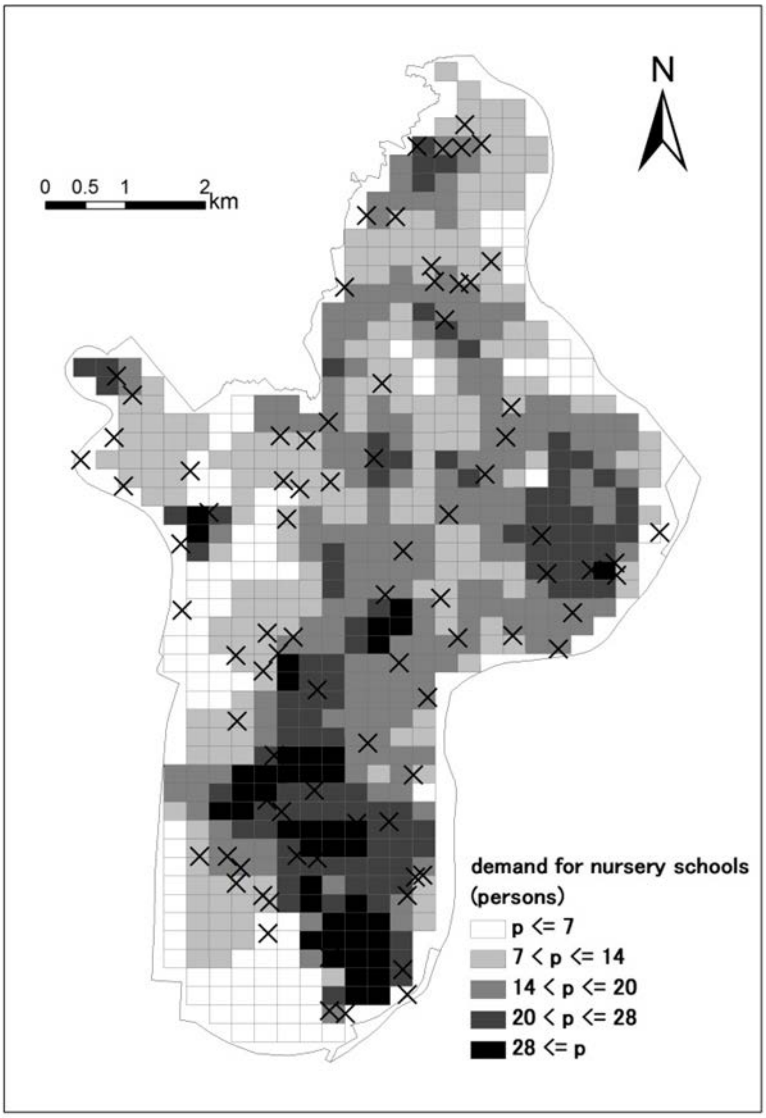

Figure 1 Distribution of Demand Population in Edogawa-ku (2011)

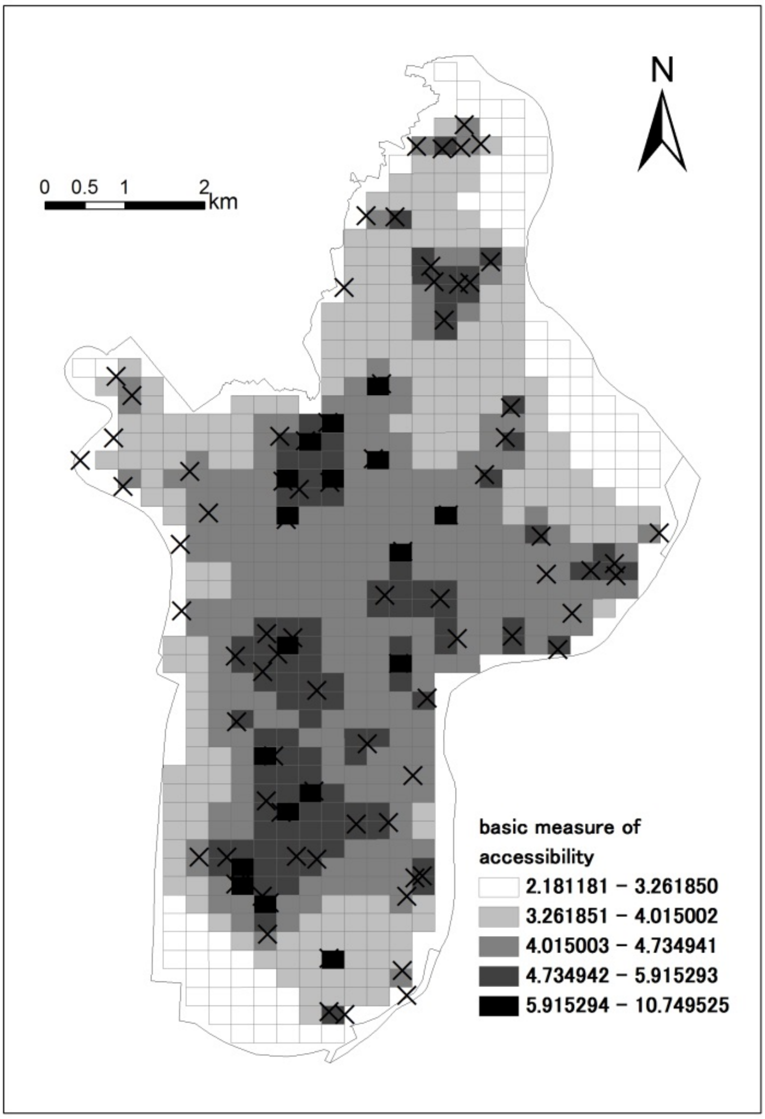

Figure 2　Spatial Patterns of a Previous Measure (Basic Form) of Accessibility to Child Care Facilities in Edogawa-ku (2011)

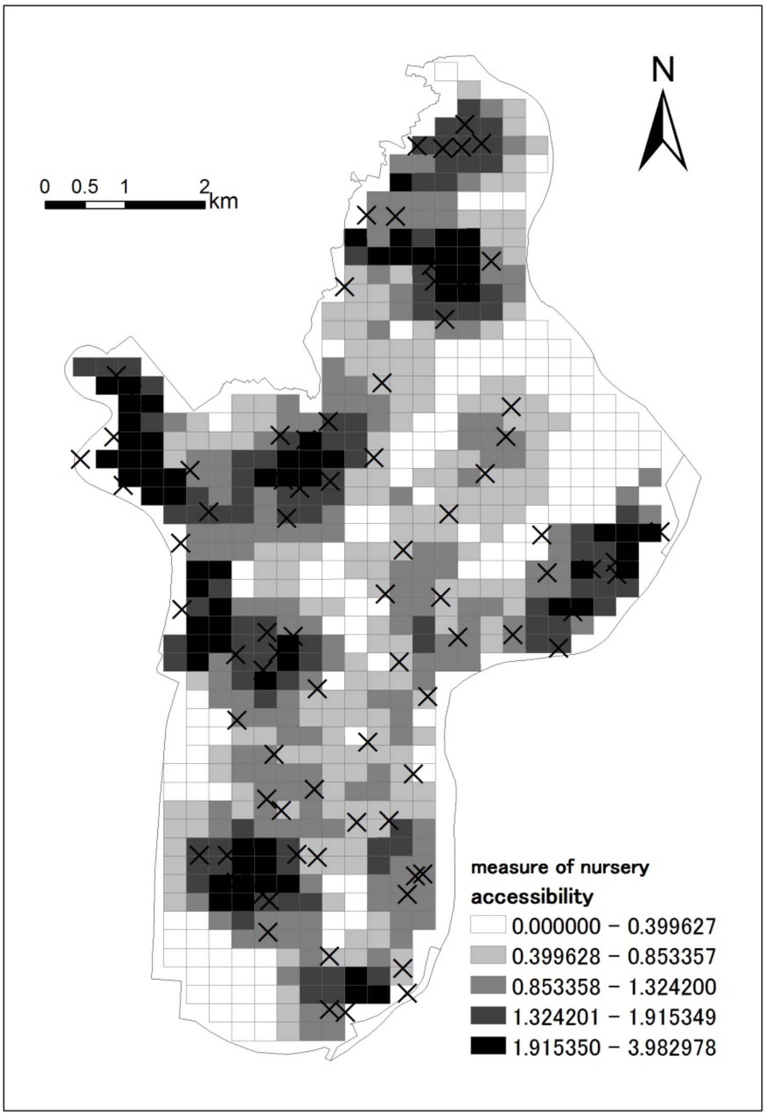

Figure 3 Spatial Patterns of a Previous Measure (Modified Form) of Accessibility to Child Care Facilities in Edogawa-ku (2011)

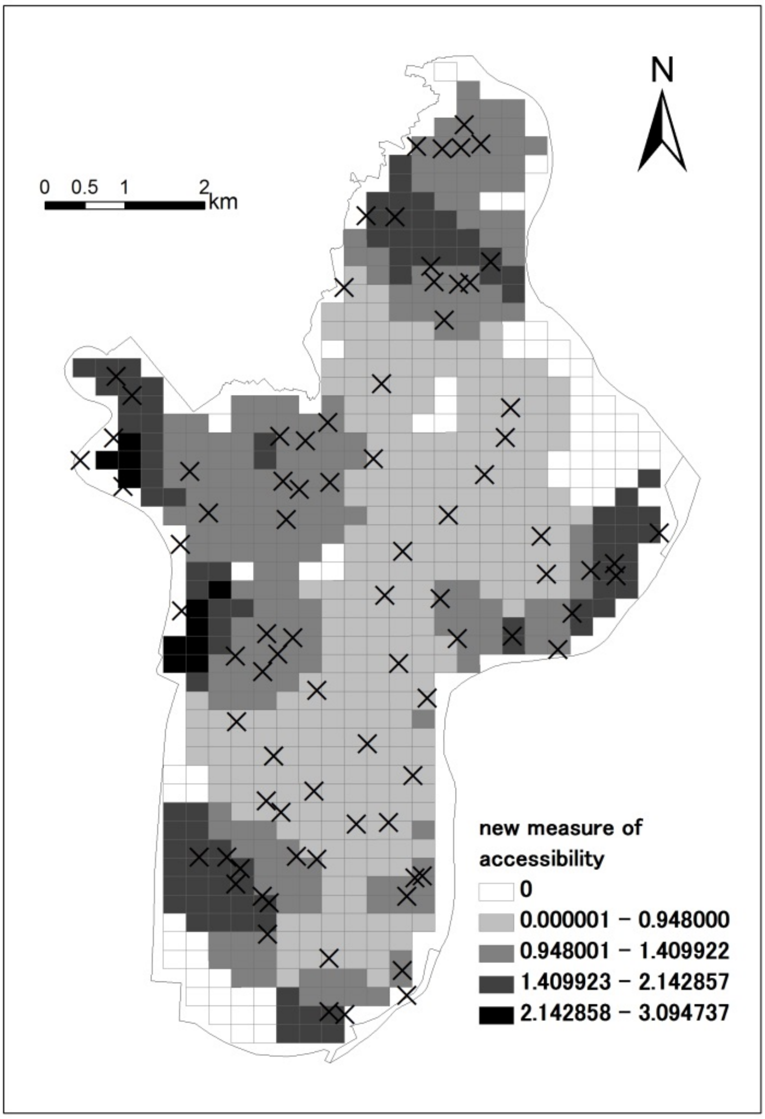

Figure 4 Spatial Patterns of a New Measure of Accessibility to Child Care Facilities in Edogawa-ku (2011)

4. Conclusion

This paper suggested a new measure of accessibility reflecting population distribution (equation (3)) and attempted to examine its availability by comparing with two previous one using data of child care facilities in Edogawa-ku in Tokyo. The results of comparison are summarized as follows:

First, the basic one written in equation (1) has a tendency of being underestimated at peripheral areas close to the boundary of Edogawa-ku. Secondly, spatial patterns of two measures reflecting population distribution are similar to each other although the new one shows a more even pattern than the previous one (equation (2)). Thirdly, if considering that the previous one has irrational properties mentioned in Chapter 2, the above two results enable us to conclude that the new one is sufficiently available.

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References

Harris, B., 2001, “Accessibility: concepts and applications”, *Journal of Transition and Statistics*, Vol.4, No.2/3, pp.15-30.

Kawabata, M., 2009, “Accessibility to Child-Care Centers: A Case Study of Bunkyo City in Tokyo”, *CSIS Discussion Paper*, No.99, pp.1-16.

Kawabata, M., 2010, “Children Awaiting Enrollment in Child-Care Centers and Accessibility to Child-Care Centers: A Case Study of Bunkyo City in Tokyo”, *Journal of Applied Regional Science*, No.15 pp.1-12.

Kawabata, M., 2011, “Spatial Mismatch of Childcare in Tokyo”, *CSIS Discussion Paper*, No.107, pp.1-31.