

# PUBLICATION OF LAND PRICE INFORMATION THROUGH THE COMPARISON OF INTERPOLATED APPRAISED PRICES AND TRANSACTION PRICES

R. Inoue<sup>a,\*</sup>, W. Nakanishi<sup>b</sup>, A. Sugiura<sup>c</sup>, T. Nakano<sup>c</sup>, S. Yoneyama<sup>d</sup>

<sup>a</sup> Dept. of Civil and Environmental Engineering, Tohoku University, 6-6-06 Aoba, Aramaki, Aoba, Sendai, Miyagi 980-8579 Japan - rinoue@plan.civil.tohoku.ac.jp

<sup>b</sup> Dept. of Civil Engineering, University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-8656 Japan - nakanishi@trip.t.u-tokyo.ac.jp

<sup>c</sup> Ogata Appraisal Corp., 3-2-6 Akasaka, Minato, Tokyo 107-0052 Japan - (sugiura, nakano)@ogata-office.co.jp

<sup>d</sup> Yoneyama Corp., 3-3-22 Komagome, Toshima, Tokyo 170-0003 Japan - shig@yone.dp.u-netsurf.ne.jp

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## ABSTRACT:

The Japanese are becoming increasingly aware of the significance of the disclosure of in-depth land price data with regard to establishing land markets with a high level of transparency and fairness. Presently, both the Public Notice of Land Prices, which essentially comprises values that are appraised by Japan's Ministry of Land, Infrastructure, Transport and Tourism, and transaction prices, which have been open to the public since 2005, play a major role in land pricing in Japan. However, these datasets alone do not provide adequate information for all market participants, not only because both are limited in number but also because they are specific to the situation in Japan: the appraised prices are always shown to be cheaper than the actual transaction prices, to a certain degree, and the important information with transactions such as the precise point in space and time is not completely open to the public owing to privacy protection. Furthermore, it is difficult to compare these two prices in a simple way as their distribution of points is different. In this paper, we propose the publication of valuable land price information by interpolating appraised prices to every transaction point by using the kriging method, comparing actual transaction prices with them, and drawing a map that allows us to understand the trend of land prices easily. Moreover, we build the experimental WebGIS service using which anyone can easily search the interpolated appraised price of the land of their interest and the related land price history and market conditions.

## 1. INTRODUCTION

With the national government of Japan promoting the realization of "effective land use" through market mechanisms, it has become increasingly recognized that the disclosure of in-depth land price data is significant with regard to establishing land markets with a high level of transparency and fairness. Until now, the Public Notice of Land Prices, which essentially comprises values that are appraised by Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT), has played a major role in land pricing in Japan. Furthermore, in recent times, transaction prices, which have been open to the public since 2005, have come to play an equally important role.

However, these datasets, the appraised and transaction land prices, alone do not provide adequate information for all market participants; the appraised prices are limited in number due to budget constraints, thus the number of transaction prices is also limited.

Moreover, land price information exhibits several other problems that are specific to Japan. The main problem with appraised prices is that to a certain degree, they are always known to be cheaper than the actual transaction prices. In addition, they do not

provide short-term market trends, since the publication cycle is half a year long and the period from appraisal to publication spans three months. The problem with transaction prices is that owing to privacy protection reasons, their attributes such as the precise points in space and time are not completely accessible to the public. Even though detailed attributes of each transaction are published, it is quite difficult to compare transaction and appraised prices in a simple way and to collectively understand the long-term market trends from the appraised prices and the short-term trends from the transaction prices. On the one hand, the appraised prices are that of the typical land lots in their neighborhood and distributed evenly in space and time. On the other hand, the transaction prices include information about land lots in poor conditions, such as those with irregular shapes, and are unevenly distributed in space and time. As a result, these two types of land price information have not been adequately utilized. Therefore, it would be helpful if comparison information of these two land prices is available to all market participants, including the non-professional general public.

In this paper, we propose to publish valuable land price information by interpolating appraised land prices into every transaction point by kriging, a geostatistical model that deals with spatio-temporal correlations, and comparing the actual transaction prices with them. We confirm the accuracy of interpolation by

kriging and then use the precise data of the transaction point in space and time from the Tokyo Association of Real Estate Appraisers. Finally, we create the experimental WebGIS service, with which anyone can easily search for the interpolated appraised price of the land of their interest, information about the land price history, and related market conditions. Such a publication of market trend information is an effective tool for sharing land price information with all market participants and thus for improving the transparency of the real estate market in Japan.

## 2. INTERPOLATION OF APPRAISED PRICES BY A LAND PRICE MODEL

### 2.1 Kriging

We use kriging to interpolate land prices in this paper. Here, we briefly explain the kriging model and its applications.

The kriging model deals with spatio-temporal correlations. It assumes second-order stationarity between the observations of a random field and computes the best linear unbiased predictor (BLUP) of unobserved values at any location (Cressie, 1990).

Kriging is applied not only to environmental datasets but also to socio-economic and real estate price data. For example, Dubin (1988, 1992, 1998) and Basu and Thibodeau (1998) applied kriging to house price data. They compared predicted values by kriging with the predicted values by ordinary least squares (OLS), and concluded that prediction using kriging outputs more accurate land prices than prediction by applying OLS when the residuals of OLS are spatially autocorrelated.

Because land price has a spatial and temporal correlation (neighborhood land lots share local amenities, and short-term land prices are influenced by the prevailing economic conditions), interpolation that considers spatio-temporal correlations should be expected to output more accurate land prices than other methods. In fact, Inoue et al. (2008) demonstrated the high applicability of kriging to land prices using the appraised land price data in Tokyo's 23 wards area over 34 years.

### 2.2 Land Price Models and Spatio-temporal Correlation Model

The land price dataset in this study was sourced from "the Public Notice of Land Prices" (in Japanese, *Kōji-Chika*) compiled by MLIT. The dataset is available to the public annually, and it is one of the most significant land price indices in Japan. The land prices are appraised on January 1 under the assumption that the land lots are in the best condition and used optimally. Our target area in this study is Tokyo's 23 wards, which is in the central area of Tokyo. The time period considered is from 2000 to 2009 (10 years). The number of assessed land prices differs according to the year: 1,811 points in 2008 and 18,528 points in total. However, we use 17,966 points, as we omit the points corresponding to industrial areas.

Land Price Models	Explanatory Variables		
	Common Factors	Regional Factors	Individual Factors
Residential Zone (less than 300m <sup>2</sup> ) (9,342 points)	Mortgage rates (%) <sup>*1</sup>		Distance to nearest station (m) Area of land lot (m <sup>2</sup> ) Width of front road (m) Aspect of front road (dummy) <sup>*2</sup>
Residential Zone (over 300 m <sup>2</sup> ) (1,553 points)			Distance to nearest station (m) ln (Area of land lot (m <sup>2</sup> )) Floor area ratio (%) Aspect of front road (dummy) <sup>*2</sup>
Neighborhood Commercial Zone (2,093 points)	Yearly average of Nikkei 225 average stock index (JPY)	Average travel time to five major stations (minutes)	Distance to nearest station (m) ln (Area of land lot (m <sup>2</sup> )) Width of front road (m) Adjacency to station plaza (dummy)
Commercial Zone (4,978 points)			Distance to nearest station (m) ln (Area of land lot (m <sup>2</sup> )) Width of front road (m) Floor area ratio (%) Adjacency to station plaza (dummy)

\*1 sourced from [http://www.jhf.go.jp/customer/yushi/kinri/suji\\_zaikeiyushi.html](http://www.jhf.go.jp/customer/yushi/kinri/suji_zaikeiyushi.html)

\*2 one if south, southeast, and southwest, otherwise zero

Table 1. Land price model and explanatory variables

### 2.2.1 Land Price Model and Spatio-temporal Variogram:

We formulate the land price model from the aspect of real estate appraisal. Real estate appraisal usually classifies pricing factors into three types: common, regional, and individual factors. Similarly, it classifies consumer groups. For analyzing land prices, it is important to consider the orientation and the trend of supply and demand of consumer groups.

On the basis of the above, we formulate four land price models with different components of land price formation. First, we set three zones: residential, commercial, and neighborhood commercial zones according to the land use zoning designated by urban planning act. Then, considering the different consumer groups, we divide the residential area into two types: land lots whose area is less than 300 m<sup>2</sup> and otherwise; the consumer group for the former is expected to comprise end users and that for the latter is expected to comprise real estate companies.

Finally, we choose the components of land price formation as the explanatory variables for each model if the significance level satisfies 5%, and the sign condition is reasonable if regressed by OLS. We use the logarithmic value of the explained variable, the land price: ln(JPY/m<sup>2</sup>). The explanatory variables of four models used in this study are shown in Table 1.

We now provide a detailed explanation of the explanatory variables. Since a high proportion of commuters use rail transport in the Tokyo metropolitan area, it is often said that the distance to the nearest train station and travel time to the central business district (CBD) by rail transport have a high impact on land prices. Therefore, we consider the average travel time to five major train stations and the distance to the nearest station as accessibility indices. The five major stations near the CBD were selected according to the number of passengers recorded by the 2000 Transportation Census of Urban Cities, conducted by MLIT. The average travel times are calculated, weighted by the number of passengers.

An additional explanatory variable, the yearly average of the Nikkei 225 stock average index, is used for land price estimation as a common factor. Since changes in the Nikkei 225 stock average index can generally be correlated to changes in land prices, this data is used to explain the economic environment in Japan.

The land price model and spatio-temporal variogram used in this study are represented by equation (1) and (2), respectively.

$$y_i = \beta_0 + \sum_j \beta_j x_{ij} + \varepsilon_i \quad (1)$$

where  $y_i$ : the land price data of land lot  $i$   
 $x_{ij}$ : an explanatory variable of attribute  $j$  at land lot  $i$   
 $\beta_j$ : parameters  
 $\varepsilon_i$ : an error term at land lot  $i$ .

$$\gamma(\mathbf{h}, u | \theta) = \tau^2 + \sigma_1^2 Sph(\|\mathbf{h}\|, \theta_1) + \sigma_2^2 Sph(|u|, \theta_2) \quad (2)$$

Land Price Model	Difference between Interpolated Value and Examined Appraised Price			
	Within $\pm 1\%$	Within $\pm 2\%$	Within $\pm 5\%$	Within $\pm 10\%$
Residential Zone (less than 300 m <sup>2</sup> )	12%	23%	50%	77%
Residential Zone (over 300 m <sup>2</sup> )	15%	29%	59%	81%
Neighborhood Commercial Zone	20%	37%	70%	91%
Commercial Zone	9%	17%	38%	63%

Table 2. Distribution of accuracy of interpolation

$$\text{where } Sph(d, \theta) = \begin{cases} \frac{3}{2}\% - \frac{1}{2}(\%)^3 & \text{if } 0 < d \leq \theta \\ 1 & \text{if } d > \theta \\ 0 & \text{if } d = 0 \end{cases}$$

$\mathbf{h}$  : vector between points in space

$\|\mathbf{h}\|$  : length of vector  $\mathbf{h}$

$u$  : time interval

$\theta_1, \theta_2$  : range of space and time, respectively

$\sigma_1^2, \sigma_2^2$  : sill of space and time, respectively

$\tau^2$  : nugget

## 2.3 Parameter Estimation and Validation of Interpolation

**2.3.1 Parameter Estimation:** First, we set variables  $\theta_1$  and  $\theta_2$ , which are the range that the self-correlation of spatio-temporal correlation model affects. Considering that the longest distance between two appraisal points is about 30 km, we decide  $\theta_1$  as 15 km, half of the longest distance, and  $\theta_2$  as 4 years. We then estimate the parameters for each model. Thus, every parameter but the “floor area ratio” of the residential zone (over 300 m<sup>2</sup>) satisfies the sign condition. This is because the input of the “floor area ratio” of the residential zone (over 300 m<sup>2</sup>) is only 6 values with a small variance, from 80% to 400%, and the effect of “floor area ratio” might be explained by the spatial correlation model.

**2.3.2 Validation of Interpolation:** The results of the 10-fold cross validation are shown in Table 2. This table shows the difference between interpolated values and the examined appraised prices obtained from each point. The ratio that interpolated values are within 10% of the examined appraised price is 77% for residential zones less than 300 m<sup>2</sup>, 81% for residential zones over 300 m<sup>2</sup>, and almost 91% for neighborhood commercial zones. Here, we check the high accuracy of this interpolation. However, we could not obtain a favorable result for the commercial zone model for which only 63% are within a difference of 10%. The reason behind this might be that the prices of land lot in commercial zones have a strong individual, gradual trend that explanatory variables cannot clearly explain differences among them. Therefore, we henceforth use the other three models and points in these three zones for the publication of land price information.

### 3. PUBLICATION OF LAND PRICE INFORMATION THROUGH COMPARISON OF TWO PRICES

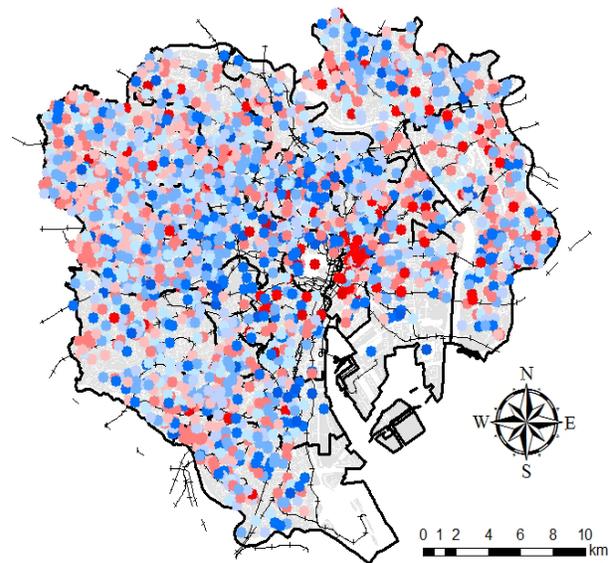
In this section, we propose examples for providing land price information through the comparison of interpolated appraised price and transaction prices. This will enable people to know the variances and temporal fluctuation of transaction prices, which is not possible if only appraised prices are available.

#### 3.1 Preparation

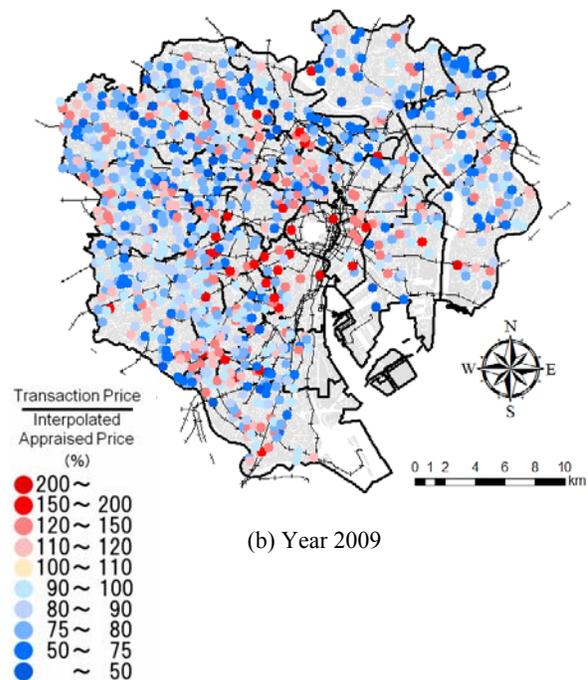
First, we choose the appropriate transaction data to suit our purpose. The target area in this case is Tokyo's 23 wards with appraised prices and the period spans from 1999 to 2009. We use the transaction of lots with regular shapes and no buildings or with inexpensive buildings (less than 5,000 JPY/m<sup>2</sup>) whose prices are considered to be included in the land price. Therefore, the transaction data used for information comprise 17,310 points for residential zones less than 300 m<sup>2</sup>, 2,251 for residential zones over 300 m<sup>2</sup>, and 2,285 for neighborhood commercial zones. Second, we interpolate the appraised price of every transaction point at the time of transaction. For this purpose, we set the variables corresponding with explanatory variables of the model proposed in the last chapter. Some of them, such as "Distance to nearest station" and "Area of land lot," can be directly obtained from the transaction data. Since only mailing addresses are available for the point in space, we use a geocoding service provided by the Center for Spatial Information Science, the University of Tokyo. This geocoding service converts the mailing addresses into values of latitude and longitude in a geographic coordinate system with high accuracy.

#### 3.2 Information from Individual Data

Here, we regard the interpolated appraised price of the transaction point as the "standard price" of the transaction. Then, each transaction acquires information on how expensive or cheap the actual transaction price is, compared to the "standard price," and we call this the information "transaction price level." The transaction price level is a percentage value, simply calculated as the "transaction price" divided by the "interpolated appraised price." Figure 1 shows the examples of this information in Tokyo's 23 wards in the years 2000 and 2009. Thus, people can grasp how the "transaction price level," the number and the point in space of transaction and the variance of transaction prices change over time. It should be mentioned that this information also has an advantage in terms of privacy protection, as it does not directly display the transaction prices.



(a) Year 2000



(b) Year 2009

Figure 1. Information of transaction price level

#### 3.3 Information from Aggregated Data

We also propose another manner to provide this information by aggregating data. First, Figure 2 shows the ratio of the transaction price level aggregated by each year. This reveals that a slight change occurred from 1999 to 2001; the level was extremely high around 2006 and 2007. In contrast, in 2009, the level below 100% became more than half for the first time in the last 11 years. The land price trend before and after the Lehman Shock can be clearly

seen in this figure. Second, Figure 3 shows a part of the result of aggregation by each ward. It reveals that the transaction price level in central Tokyo, such as in Chiyoda and Chūō wards, has constantly remained at a high level over the past 11 years, while the transaction price level to the northeast of Tokyo is relatively lower than the southwest. The fact that Setagaya and Ōta wards are popular residential zone, which have some “stockbrokers belt” may heighten the transaction price levels in these areas.

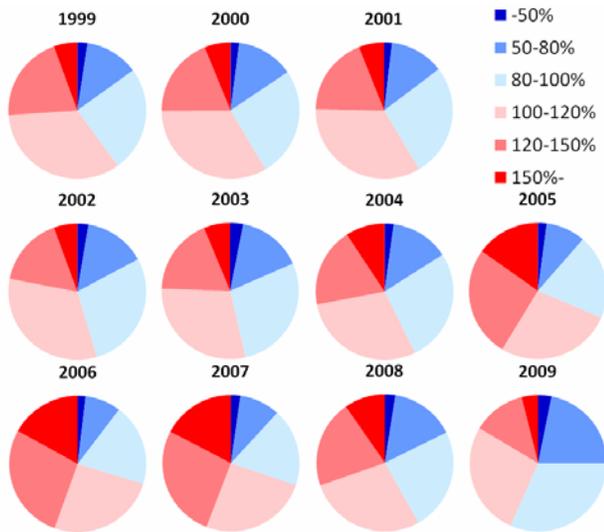


Figure 2. Transaction price level in each year

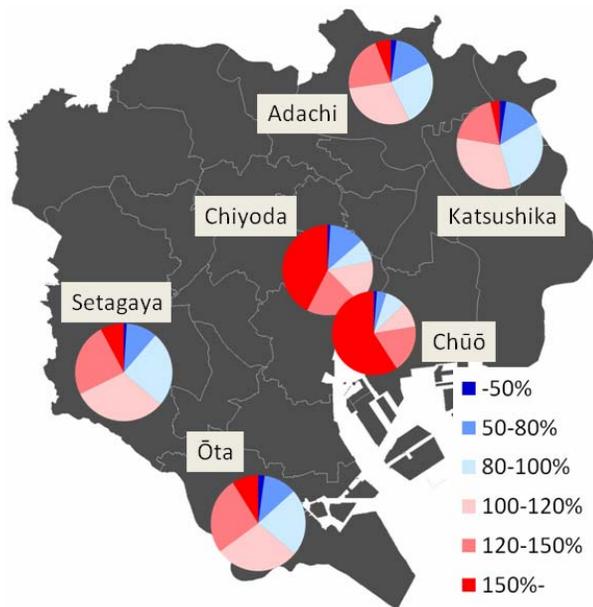


Figure 3. Transaction price level in each ward

#### 4. PUBLICATION OF LAND PRICE INFORMATION THROUGH EXPERIMENTAL WEBGIS SERVICE

#### 4.1 Outline

On the basis of the results so far, we create the experimental WebGIS service that provides land price data for any location within the target area. This service also provides information about the land price history of the location and related land market conditions. The environment used for implementation is given as follows:

- Web server – Apache2.2.14
- Database server – MySQL 5.1.41
- C++ compiler – Intel C++ compiler 11.0
- Mapping, Geocoding – Google Maps API ver.2

#### 4.2 Features of the Service

Here, we explain how users employ this service. First, users input the address of the location whose land price they are searching for. The system then translates the address input into latitude and longitude coordinates of the World Geodetic System using Google Maps API and plots a marker on the map. Referring to the data of coordinates of the centroids of every city block in the target area, which were calculated from the city block data in “Digital Map 2500 (Spatial Data Framework),” distributed by the Geographical Survey Institute of Japan, the system chooses the city block closest to the result from Google Maps API. Then, information on the nearest station and the distance to the nearest station is prepared for each city block in advance and displayed on the screen.

Figure 4 illustrates the example. When a user inputs the address, for example, “東京都千代田区三番町 6 番 2 3 (6-23 Sanban-chō, Chiyoda-ku, Tokyo),” the result shows the nearest station is “半蔵門 (Hanzō-mon station)” and the distance to Hanzō-mon station is “750m.” Next, the system lets users input detailed land lot information. Users choose the zoning, floor area ratio, and width of front road from the drop-down menu and input the area of the land lot and the width of front road directly by value. When users click the button “地価を計算 (Calculate the land price),” the system interpolates the land price data from the information, and outputs the land price as of January 1, 2010. For this location, the interpolated land price is 1,831,000 JPY/m<sup>2</sup>.

Furthermore, the service provides information on the land price history of this land lot from 2000 to 2010 (Figure 5), the transaction price distribution within 2000 m from 2000 to 2010 (Figure 6), and the transaction price distribution from June 1, 2007 to June 1, 2009 (Figure 7). Users can set the condition of the space and time range from certain alternatives. If the number of transactions is less than 10, under certain conditions, the system returns an error message.



Figure 4. Input screen

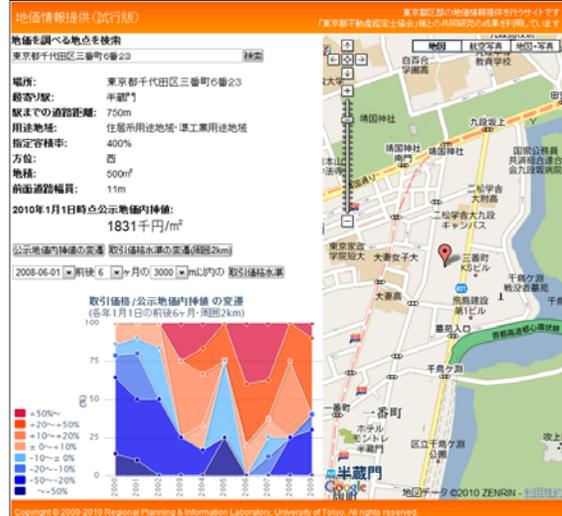


Figure 6. Market conditions around the location



Figure 5. Interpolated land price and its history

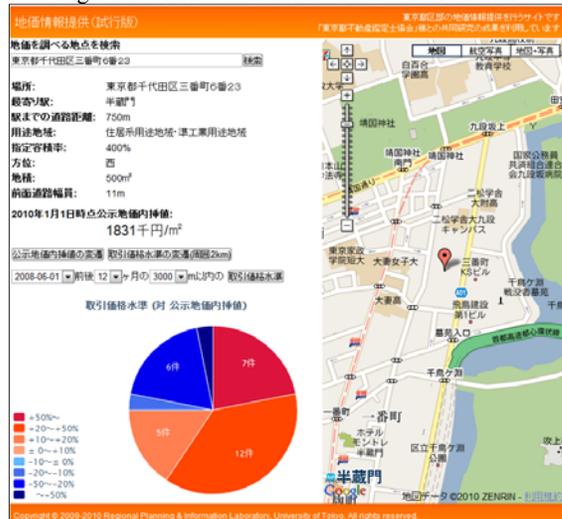


Figure 7. Market conditions around the location

## 5. CONCLUSION

In this study, we proposed several ways to ensure the availability of valuable land price information to the public in Japan. Since it is difficult to compare appraised prices with transaction prices directly, we interpolated appraised prices to the point where transaction existed, and then compared both the prices. Subsequently, we formulated the land price models from the aspect of real estate appraisal and then employed the kriging model to estimate parameters and interpolate the appraised land price to any location with a high accuracy. After interpolation, we calculated the “transaction price level” by comparing actual transaction prices with interpolated appraised prices. Finally, we proposed a technique for the publication of land price information on static maps and also by using the experimental WebGIS system. User-friendly static maps provided users with visual and

easily comprehensible information on the annual or area wise transaction trends. Furthermore, the WebGIS system allowed users to easily search for the interpolated appraised price of the land of their interest along with information about related market conditions. In these publications, we ensured the protection of privacy of information on transactions by avoiding a direct display of the transaction prices. Such publication of land price information would be effective for sharing information regarding real estate market trends and would thereby improve the transparency of the real estate market in Japan.

The following topics can be examined by future studies. First, the land price model can no longer satisfactorily explain the prices in the commercial zone. Hence, we should consider other factors that may affect the land price. For example, it is likely that “liveliness” is important for the commercial zone. However, we have to somehow define such factors as variables. Second, although the visualization on static maps is effective for intuitive understanding, it provides only qualitative information. Therefore, we intend to apply point pattern analysis to transaction data in order to obtain quantitative analysis results that can provide us more in-depth information. Thirdly it is not easy to handle transaction data appropriately. For example, we should define “what is a unique transaction,” as some land lots are being continuously purchased and sold by real estate companies. Finally, the WebGIS system should be further developed at some point. For example, users do not always have information on “zoning” and the “floor area ratio” of the land lot; therefore, instead of them having to manually input this information, we should prepare an environment in which the database automatically inputs such information after the address is input. Moreover, dealing with the opening of new railways and stations is important for land price history, as many railways and stations have opened (or closed) in the past several decades.

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