Publication of Comparison Information between Interpolated Appraised Land Prices and Transaction Land Prices

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Abstract— There is a growing awareness 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 in Japan. Now 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 because not only that both are limited in number but also particular situation to Japan: The appraised prices are always pointed out to be cheaper than actual transaction price in some degree, and the important information with transactions such as the precise point in space and time are not fully open to public for privacy protection. Furthermore, it is difficult to compare these two prices in a simple way, for the distribution of points is different from each other. In this paper, we propose the publication of the valuable land price information by interpolating appraised prices to every transaction point using the method kriging, comparing actual transaction prices with them and drawing a map which allows us understand the trend of the land price easily. Furthermore, we build the experimental WebGIS service with which anyone can easily search the interpolated appraised price of the land where they are interested, and also the land price history and market conditions around there.

Index Terms— Land price information, spatio-temporal interpolation, appraised land prices, transaction land prices.

1 Introduction

There is a growing awareness 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 in Japan, since the national government of Japan promotes the realization of "effective land use" through market mechanisms. 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, transaction prices, which have been open to the public since 2005, have come to play an equally important role recently.

However, these datasets, the appraised and transaction land prices, alone do not provide enough information for all market participants; the appraised prices are limited in number due to the budget constraint, and the transaction prices are also limited in number naturally.

Moreover, the land price information has several other problems that are particular to Japan. The main problem of appraised prices is that they are always pointed out to be cheaper than actual transaction prices in some degree. Addition to that, they do not provide the short-term market trends, since the time cycle of publication is half a year, and the length of time spent from appraisal to publication is three months. The problem of transaction prices is that their attributes such as the precise points in space and time are not fully open to public now, due to the privacy protection reason. Even though the detailed attributes of each transaction are published, it is quite difficult to compare these two prices in a simple way, and understand the long term trend of market from the appraised prices and the short term trend from the transaction prices together; on the one hand, the appraised prices are the price of the typical land lot in its neighbourhood, and distributed evenly in space and time, however, on the other hand, the transaction prices include information of land lots in poor condition such as irregular shape and are unevenly distributed in space and time. As a result, these two types of land price information have not been fully utilized enough. Thus, it would be helpful if it is possible to provide comparison information of these two land prices to all market participants, including non-professional general public.

In this paper, we propose to publish the valuable land price information by interpolating appraised land prices to every transaction point by kriging, a geostatistical model that deals with spatio-temporal correlations, and comparing actual transaction prices with them. We confirm the accuracy of interpolation by kriging and then use the precise data of transaction point in space and time which Tokyo Association of Real Estate Appraisers possesses. Finally we build the experimental WebGIS service with which anyone can easily search the interpolated appraised price of the land where he/she is interested, with the information about the land price history of the location and the market condition around there. Such a publication of market trend information is effective for sharing land price information with all market participants and as a result improving the transparency of the real estate market in Japan.

2 Interpolation of Appraised Prices by a Land Price Model and Spatio-Temporal Kriging

2.1 Kriging

We use kriging to interpolate land prices in this paper. Here we explain briefly about kriging and its application.

Kriging is the model that deals with spatio-temporal correlations. Kriging 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.

Kriging is applied not only to environmental datasets, but also to socio-economic data 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 to predicted values by ordinary least squares (OLS), and concluded that prediction using kriging outputs more accurate land prices than applying OLS when the residuals of OLS are spatially autocorrelated.

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

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2.2 Land Price Models and Spatio-Temporal Correlation Model

The land price datasets in this study were sourced from “the public notice of land prices” (in Japanese, Kōji-Chika) complied by MLIT and “the land price survey” (in Japanese, Chika-Chōsa) by prefectural governments. The datasets are available to the public annually, and it is one of the most significant land price indices in Japan. “The public notice of land prices” is appraised on January 1st, and “the land price survey” is appraised on July 1st, under the assumption that the land lots are in the best condition and at their highest use. Our target area in this study is Tokyo’s 23 wards, which is in the central area of Tokyo.

2.2.1 **Land Price Model and Spatio-Temporal variogram**:

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

Based on the above, we formulate four land price models with different components of land price formation. First we set three zones: residential, commercial and neighbourhood commercial zones according to the zoning of the city planning law. Then we divide the residential area into two: the area of land lot is less than 150 m^2 and otherwise, considering the difference of the consumer groups; the parties to sales for the former land scale is expected to be end-user, and the parties to sales for the latter land scale is expected to be real estate companies.

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

We explain more detail about the explanatory variables. Since a high proportion of commuters utilize 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 use the average travel time to the 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 1995 Transportation Census of Urban Cities, conducted by MLIT. The travel times to the five major stations are weighted by the number of passengers in 2000.

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 is equation (1) and (2), respectively.

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

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

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

where $$Sph(d,\theta) = \begin{cases} \frac{3}{2}\frac{d}{\theta} - \frac{1}{2}\left(\frac{d}{\theta}\right)^3 & if \;\; 0 < d \le \theta \\ 1 & if \;\; d > \theta \\ 0 & if \;\; d = 0 \end{cases}$$

$\mathbf{h}$: vector between points in space
$\|\mathbf{h}\|$: length of vector $\mathbf{h}$
u : time interval
θ_1, θ_2 : range of space and time, respectively
σ_1^2, σ_2^2 : sill of space and time, respectively
τ^2 : nugget

Table 1. Land price model and explanatory variables

<table>
<tr><th rowspan="2">Land Price Models</th><th colspan="3">Explanatory Variables</th></tr>
<tr><th>Common Factors</th><th>Regional Factors</th><th>Individual Factors</th></tr>
<tr><td>Residential Zone
(less than 150m^2)
(6,609 points)</td><td>Mortgage rates (%)*1</td><td rowspan="4">Average travel time to
five major stations (minutes)</td><td>Distance to the nearest station (m)
Area of land lot (m^2)
Width of front road (m)
Aspect of front road (dummy)*2</td></tr>
<tr><td>Residential Zone
(over 150m^2)
(10,367 points)</td><td rowspan="3">Yearly average of Nikkei 225
average stock index (JPY)</td><td>Distance to the nearest station (m)
ln (Area of land lot (m^2))
Floor area ratio (%)
Aspect of front road (dummy)*2</td></tr>
<tr><td>Neighbourhood
Commercial Zone
(3,550 points)</td><td>Distance to the nearest station (m)
ln (Area of land lot (m^2))
Width of front road (m)
Adjacency to station plaza (dummy)</td></tr>
<tr><td>Commercial Zone
(8,204 points)</td><td>Distance to the nearest station (m)
ln (Area of land lot (m^2))
Width of front road (m)
Floor area ratio (%)
Adjacency to station plaza (dummy)</td></tr>
</table>

*1 sourced from http://www.jhf.go.jp/customer/yushi/kinri/suji_zaikeiyushi.html
*2 one if south, southeast and southwest, otherwise 0

2.3 Parameter Estimation and Validation of Interpolation

2.3.1 Parameter Estimation

First we set the variables θ_1 and θ_2, which are the range that self-correlation of spatio-temporal correlation model affect. Considering that the longest distance between two appraisal points is about 30 km, we decide θ_1 as 15 km, half of the longest distance, and θ_2 as 4 years. Then we estimate parameters for each model. As a result, every parameter but "floor area ratio" of the residential zone (over 150m^2) satisfies the sign condition. This is because the input of "floor area ratio" of the residential zone (over 150m^2) is only 6 values with small variance, from 80% to 400%, and the effect of "floor area ratio" might be explained by spatial correlation model.

2.3.2 Validation of Interpolation

The results of the 100-fold cross validation are shown in Table 2. Table 2 shows the difference between interpolated value and examined appraised price got from each point. The ratio that interpolated value are within 10% from examined appraised price is 96% for residential zone (less than 150m^2), 92% for residential zone (over 150m^2) and reaching 91% for neighbourhood commercial zone. Here we check the high accuracy of this interpolation. However we couldn't get the good result of the commercial zone model for which only 46% are within 10% difference. This might be because the prices of land lot in commercial zone have a strong individual trend one by one that explanatory variables cannot explain differences among them well. Thus from now we use 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 the examples how to show land price information through the comparison of interpolated appraised price and transaction prices. People can know the variances and temporal fluctuation of transaction prices, which they cannot in case only appraised prices are available.

3.1 Preparation

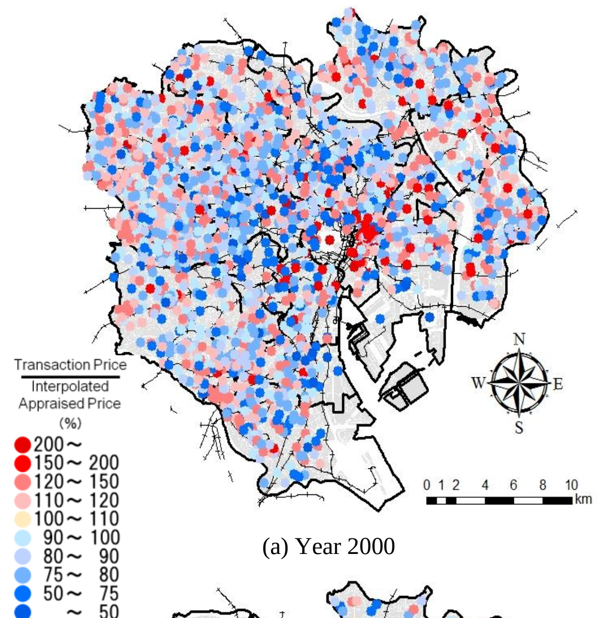
Firstly we should choose the appropriate transaction data which meet our purpose. The target area here is Tokyo's 23 wards as with appraised prices and the period is from 1999 to 2009. Among them we use the transaction of lots in regular shape with no building or with inexpensive buildings (less than 5,000 JPY/m^2) whose price are regarded as the land price only. As a result, transaction data used for information are 17,310 points for residential zone (less than 300m2), 2,251 for residential zone (over 300m^2) and 2,285 for neighbourhood commercial zone. Secondly we interpolate the appraised price of every transaction points at the time of transaction. For this we should 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 got from transaction data. Since only mailing addresses are available for the point in space, we use a geocoding service provided by Center for Spatial Information Science, the University of Tokyo. This geocoding service converts the mailing addresses into the values of latitude and longitude in geographic coordinate system with high accuracy.

3.2 Information from Individual data

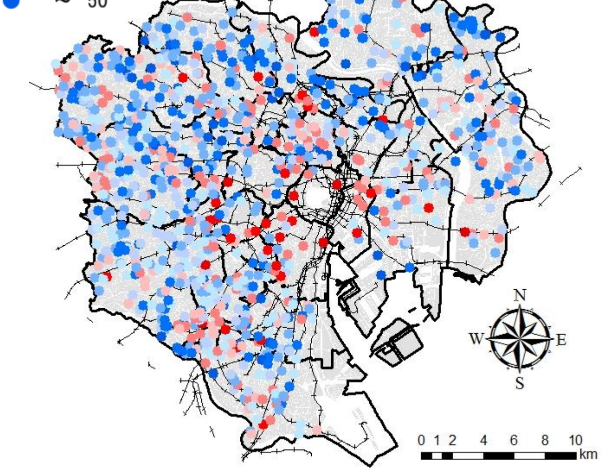
Here we regard the interpolated appraised price of the transaction point as the "standard price" of that transaction. Then each transaction has information how expensive or cheap compared the actual transaction price with the "standard price" and we call this information "transaction price level". "Transaction price level" is the percentage value simply calculated as "transaction price" divided by "interpolated appraised price". Figure 1 is the examples of this information in Tokyo's 23 wards in year of 2000 and 2009. Like this people can grasp how "transaction price level", the number and the point in space of transaction and the variance of transaction prices changes over time. It should be mentioned that this information has an advantage also in terms of privacy protection, for it does not directly show transaction prices themselves.

Table 2. Distribution of accuracy of interpolation

Land Price Model	Difference between Interpolated Value and Examined Appraised Price			
	Within ±1%	Within ±2%	Within ±5%	Within ±10%
Residential Zone (less than 150m^2)	25%	48%	83%	96%
Residential Zone (over 150m^2)	19%	38%	74%	92%
Neighbourhood Commercial Zone	19%	37%	74%	92%
Commercial Zone	4%	9%	24%	46%



(a) Year 2000



(b) Year 2009

Figure 1. Information of transaction price level

3.3 Information from Aggregated Data

At the same time we propose another way to show this information by aggregating data. Firstly Figure 2 shows the ratio of "transaction price level" aggregated by each year. This reveals that slight change occurred from 1999 to 2001, the level was extremely high around 2006 and 2007 and contrary in 2009, the level lower than 100% became more than half for the first time in this 11 years. The land price trend before and after the Lehman Shock can be clearly seen in this figure. Secondly Figure 3 shows the part of result of aggregating by each ward. This reveals that the "transaction price level" in central Tokyo such as Chiyoda and Chūō ward is always at high level over past 11 years and that of northeast Tokyo is relatively lower than southwest. The fact that Setagaya and Ōta ward are popular residential zone which have some "stockbrokers belt" may heighten the "transaction price level" in these area.

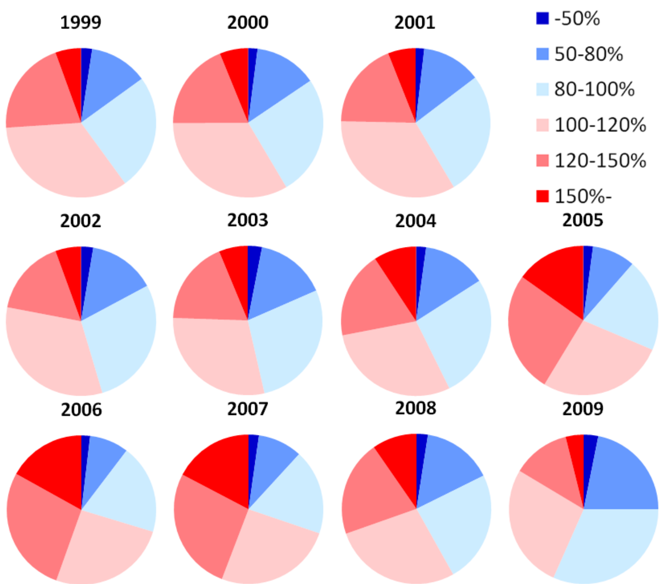


Figure 2. Transaction price level in each year

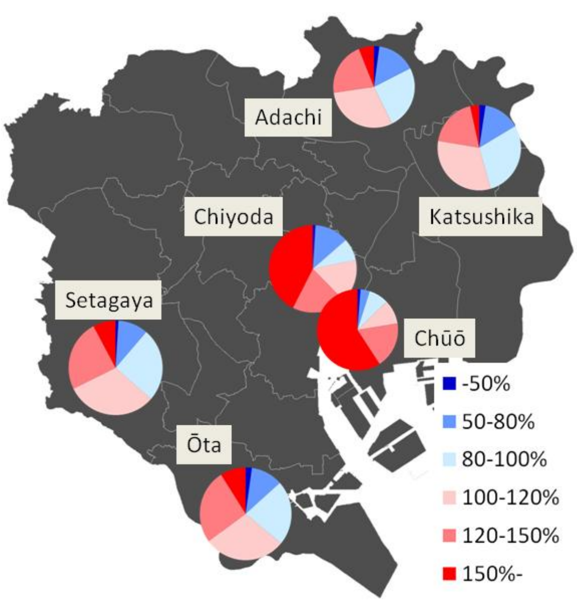


Figure 3. Transaction price level in each ward

4 Publication of Land Price Information Through Experimental WebGIS Service

4.1 Outline

Based on the result so far, we build 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 the land market conditions around there. Environment used for implementation are as follows:

Web server – Apache2.2.14
Database server – MySQL 5.1.41
Mapping, Geocoding – Google Maps API ver.3

4.2 Features of the Service

Here we explain how to use this service according to users. Firstly, users input an address where they would like to know the land price. 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 centroids of every city block in the target area, which were calculated from the city block data in the "Digital Map 2500 (Spatial Data Framework)", distributed by the Geographical Survey Institute of Japan, the system chooses the closest city block to the result from Google Maps API. Then information of the nearest station and the distance to nearest station prepared for each city block in advance appear on the screen.

Figure 4 shows the example. When user inputs the address "東京都千代田区三番町6番23 (6-23 Sanban-chō, Chiyoda-ku, Tokyo)" for example, the result is that 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, the floor area ratio and the 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 of January 1st 2010. At this location, the interpolated land price is 1,831,000 JPY/m^2.

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

Due to the license of transaction price data, we are not able to show this website to the public at the moment.

Figure 4. Input screen

Figure 5. Interpolated land price and its history

Figure 6. Market conditions around the location

Figure 7. Market conditions around the location

5 CONCLUSION

This study proposed several ways to provide the valuable land price information 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 two prices each other. Here we formulated the land price models from the aspect of real estate appraisal and then applied the method kriging to estimate parameters and interpolate the appraised land price to any location with high accuracy. After interpolation, we calculated the "transaction price level" by comparing actual transaction prices with interpolated appraised prices. Finally we proposed the way of publication of land price information on static maps and also by experimental WebGIS system. Static maps provided us information about the trend of transaction in each year or each area visually and are easy to understand. Also WebGIS system allowed users to search easily the interpolated appraised price of the land where they are interested, with the information about the land market condition around there. In these publications we satisfied the protection of privacy information of transaction by avoiding showing transaction prices directly. This kind of publication of land price information would be effective for sharing information regarding real estate market trends and thus improving the transparency of the real estate market in Japan.

The following are topics that may be examined in future studies. Firstly land price model now cannot explain the price well in commercial zone. We should consider other components that may affect the land price. It is likely that "liveliness" is important for commercial zone for example, but then we have to set such components into variables somehow. Secondly indeed the visualisation on static map is effective for intuitive understanding, that provides only qualitative information. Therefore we are planning to apply point-pattern analysis to transaction data, for the result of quantitative analysis would give us more in-depth information. Thirdly it is not easy to handle transaction data appropriately. For example we should define "what is the unique transaction", for some land lots are continuously bought and sold quickly by real estate companies. Lastly WebGIS system should be improved at some point. For example, because users don't always have information of "zoning" and "floor area ratio" of the land lot, we should prepare the environment in which the database automatically input such information instead of users after the address is input. Also dealing with opening of new railway and station is important for land price history, for there were many railways and stations opened (or closed) past several decades.

REFERENCES

Basu, S. and Thibodeau, T.G., 1998. Analysis of spatial autocorrelation in house prices. *Journal of Real Estate Finance and Economics*, 17, pp. 61-85.

Dubin, R.A., 1988. Estimation of regression coefficients in the presence of spatial autocorrelated error terms. *Review of Economics and Statistics*, 70(3), pp. 466-474.

Dubin, R.A., 1992. Spatial autocorrelation and neighborhood quality. *Regional Science and Urban Economics*, 22(3), pp. 433-452.

Dubin, R.A., 1998. Predicting house prices using multiple listings data. *Journal of Real Estate Finance and Economics*, 17(1), pp. 35-60.

Inoue, R., Shimizu, E., Yoshida, Y., Li, Y. (2008) Analysis of spatial distribution of and temporal change in land prices in Tokyo 23 wards using spatio-temporal kriging, *The 2nd World Conference of the Spatial Econometrics Association*, CD-ROM.

ACKNOWLEDGEMENTS

This research was supported by a joint research project with Center for Spatial Information Science, the University of Tokyo.