A Multilevel Model Based Hedonic Analysis of 3D Visibility: an Empirical Case Study of Yokohama Baycity.

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Abstract

This study empirically tests whether or not "visibility" is capitalized into condominium prices using hedonic approach in Yokohama city, Japan. Because of the problems in data availability and technical constraint, economic value of visibility in urban area is not significantly discussed until recently and therefore it is still unclear. In addition to the value of goodness of visibility (open view), this paper examines the value of green view (visibility of green spaces) and ocean view (visibility of ocean). The first, land cover of individual building and green spaces are derived by classifying spatially fine aerial photo (0.5m), then visibility from each floor in each condominium is analyzed using viewshed analysis. The hedonic analysis is conducted with a multilevel model, which considers the hierarchical structure (room/building) of a condominium. The result suggests that the green view does not have statistically significant effect, while ocean view has significant effect in our test site city Yohokama which face the Tokyo bay.

1. Introduction

The objective of this study is evaluating the economic value of various types of visibility of view in an urban area. One of the typical ways of evaluating economic value of non-market goods including view is the hedonic approach (Rosen 1974; Tyrvainen and Miettinen 2000; Irwin 2002; Morancho 2003; Tajima 2003; Kong et al. 2007; Cho et al. 2008). So far, numerous hedonic studies have established that view plays a significant role in the market price of a dwelling. Jim and Chen (2009) and Damigos and Anyfantis (2011) compactly summarized important literatures.

In the large amount of studies, visibility was measured using a dummy variable which takes '1' if a focused object is visible. For example, McLeod (1984) found that river views are particularly important being valued at 28% of average selling price in Western Australian case study. Benson et al. (1998) found that the highest-quality ocean views are found to increase the market price of ancomparable home by almost 60%; the lowest-quality ocean views are found to add about 8%.

Some other studies are based on field investigations. For instance, Tyrvainen and Miettinen (2000) found that dwellings with a view onto forests are on average 4.9 % more expensive than dwellings with otherwise similar characteristics, by a field investigation to get the window view information. Luttik (2000) found that a pleasant view can lead to a considerable increase in house price, particularly if the house overlooks water (8–10%) or open space (6–12%). In this work, the information on environmental and other location factors was drawn from maps, and complemented by specific detailed information on the locality gathered by visiting each house in the sample.

Both the dummy variables based approaches and the field investigation based approaches have problems. The former, which did not consider the quality of a view, may have been underestimating the premium for a high quality view while over estimating the premium for a low quality view (Beherer 2010), and the latter, which relies on the investigation, is time consuming and difficult to implement if the number of samples are very large.

On the other hand, owing to the development of Geographical Information Systems (GIS), now 3D-visibility analyses can be conducted using the system (Bartie et al. 2010). Then, in recent years, a number of hedonic studies of 3D view have discussed (e.g., Peterson and Bolye 2002; Cavailhès et al. 2009). However, on urban area, such hedonic studies are still limited. One of the reason is difficulty of expressing complex 3D geometry of urban form using raster data while study area must be expressed using a raster data when 3D view is analyzed (Lliobera 2003; Yang et al. 2007).

In accordance with the recent development of the remote sensing technology, studies of analyzing 3D view on urban spaces increases gradually. For instance, Yu et al. (2007) evaluated the ocean view of condominiums in the urban area in Singapore using hedonic approach, and clarified that unobstructed sea view will add an average premium of 15% to the property price. Sander and Polasky (2009) verified that goodness of view, visibility of wetlands, and visibility of water inflate property values in USA. On the contrary some studies have demonstrated insignificance of view (e.g., Peterson and Boyle 2012), and thus, consensus about the effects of visibilities is not necessarily obtained.

On the other hand, when condominium prices are analyzed, multilevel structure of the condominiums should be considered. Ignoring such a multilevel structure could induces serious biases on standard errors of regression coefficients (Hox 1988). However, as is summarized in Behrer (2010), most of hedonic studies of visibility have used the standard linear model that cannot consider the multilevel structure of condominiums (e.g., Peterson and Boyle 2002; Yu et al. 2007; Jim and Chen 2009; Sander and Polasky 2009; Jim and Chen 2009; Behrer 2010).

Present study evaluates economic values of various types of 3D views using a model called multilevel model that can capture the multilevel structure of condominiums (e.g., Goldstain, 2011). To achieve it, various types of view from condominiums are evaluated using the 3D structural information of the vegetation and buildings obtained by LiDAR data (high-resolution raster data), and subsequently, values of views are evaluated applying two types hedonic models: the standard linear regression model and the multilevel model. Note that this is a simple analysis corresponding to the first stage of the hedonic analysis of Rosen (1974).

The rest of the sections are organized as follows. Section 2 discusses our visibility analysis, and constructs the indexes of visibility. Section 3 precedes the hedonic analysis that evaluates the values of visibilities, and our discussion is summarized in section 4.

2. Outline of our analysis

2.1. Target area and dataset

This study evaluates the effect of visibility from condominiums that are completed between 1993 and 2008. Our study area is the central part of the bayside of Yokohama city, which is the second largest city with a population of over three million in Japan (figure 2). This baycity Yokohama is located less than thirty minutes south of the Tokyo CBD by train. Data of attributes of condominiums, including prices, were provided by Marketing Research Center Co. Ltd. These price data were based on registration (salser' pricing) and not transaction (actual traded price). The descriptive statistics of the condominium prices is given in table 1, and geographical distributions of the observations are given in Figure 3.

Fig. 1. Yokohama city and our study area

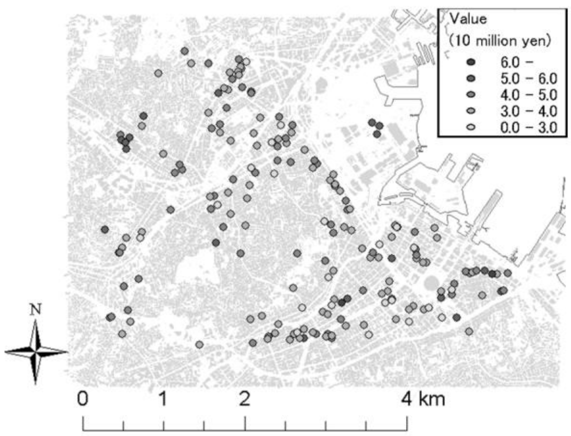

Fig. 2. Average prices of condominiums

Table 1. Descriptive statistics of condominium prices

Statistics	Value (100 million yen)
Mean	40.91

Median	39.40
Maximum	320.0
Minimum	10.90
Standard deviation	15.10
Sample size (Building / Room)	188 / 9186

2.2. Approach of evaluating visibility

It has been pointed out that influence of view could change depending on the recognized object (e.g., Yu et al. 2007). We consider three types of views: goodness of view (**Open View**), visibility of green spaces (**Green View**), and visibility of the ocean (**Ocean View**). Evaluation procedures of these views are as follows:

1. The condominium data with 2D coordinates (see sec.2.1) and the buildings data (provided by Geographical Survey Institute) are spatially combined.
2. Floor heights of condominiums are identified using their room number included in the condominium data.
3. 3D coordinates of viewpoints are set for each condominium. Longitudes/latitudes of them are identified using the building object matched in (i), and heights are identified using the floor heights obtained in (ii) (see below).
4. Digital Surface Model (2D image: figure 3; 3D image: figure 4), that is, collection of the grid cell (50 cm by 50cm) level elevation inforamtion (corresponding to the top of tree, building or ground) are obtained using the airborne LiDAR data. Then, for each viewpoint, whether each view target (tree etc.) cell is visible or invisible are calculated using ArcGIS 3D analyst. **Open View**s of each viewpoint are evaluated using this result.
5. Tree objects (a) and ocean objects (b) are extracted by the following procedure:
   - a-1 Tree objects in an aerial photos, obtained from the airborne LiDAR observation (spatial resolution: 50cm), are classified by the likelihood maximization based classification method.
   - a-2 The tree objects are spatially matched with DSM, and the DSM cells representing trees are identified.
   - a-3 Heights of the tree cells are calculated by taking the difference between DSM and Digital Terrain Map (DTM: figure 5). DTM is the mapping of the grid cell (50cm by 50cm) elevation information of the ground surface. Because heights of trees are gen-

erally more than 50cm, tree cells whose heights over 50cm (figure 7) are applied hereafter.

b Data of ocean area (created based on the dataset provided by Yokohama city) and DSM are combined, and DSM cells denoting ocean area are identified.

6. For each viewpoint, whether each tree cells and each ocean cells are visible or invisible, are calculated. **Green View** and **Ocean View** are evaluated using these results.

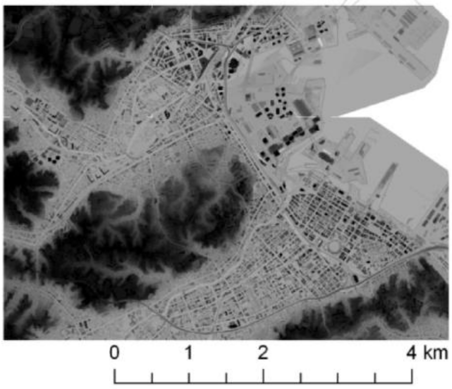

Fig. 3. DSM (Digital Surface Model)

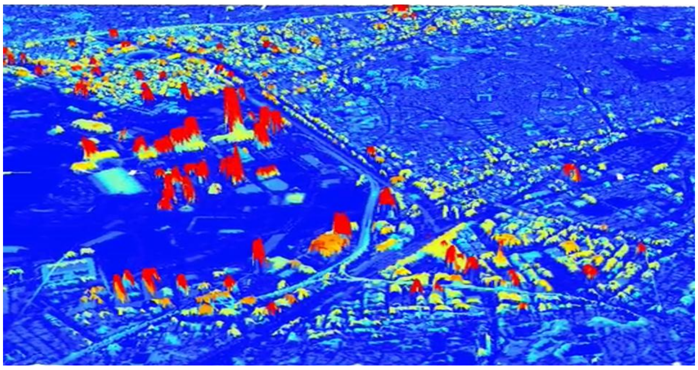

Fig. 4. DSM (3D image)

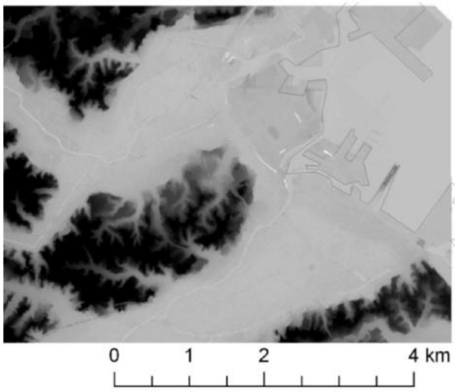

Fig. 5. DTM (Digital Terrain Model)

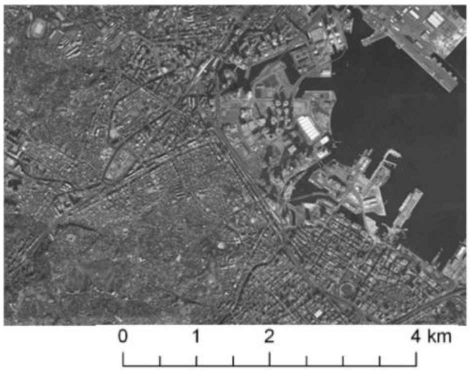

Fig. 6. Aerial photo

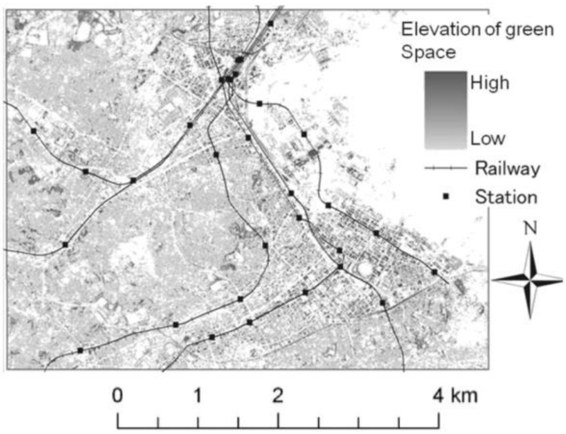

Fig. 7. Spatial distributions of the tree cells

Although it is natural to place the abovementioned viewpoints in front of the windows in each room, we have no data of window locations. Hence, 3D coordinates of the viewpoints are given as follows: the heights are set to [height of a floor (3m)] × [number of stories] + [height of human eyes (1.6m)] in accordance with Yasumoto et al. (2011), and the longitudes and latitudes are set at four midpoints of each side of condominiums approximated by a rectangular (Figure 8). Namely, views from rooms on a *f*-th floor of a *j*-th building are replaced by views form the corresponding four viewpoints given for the *f*-th froor.

Thus, the visibilities are evaluated on floor-by-floor basis not on a room-by-room basis, and accordingly, effects of the visibilities may get blurred. However, because of the difficulty to obtain window direction (east or west etc.) data, such an assumption may be needed. Hence, verifying the validity of our assumption is an important subject of the future study.

In addition, for computation, the visible range also must be determined exogenously. Following Yu et al. (2007) and Yasumoto et al. (2011), we set the range to 500m. Although this setting is somewhat subjective, the numbers of visible cells do not increase significantly even if cells distant more than 500m are counted (Yu et al. 2007; Yasumoto et al. 2011).

Open View, **Green View**, and **Ocean View** are given by the average numbers of cells that are visible from four corresponding viewpoints (figure 8). More precisely, **Open View** is defined by the average number of cells that are visible from each condominium, **Green View** is the average number visible of cells representing tree, and **Ocean View** is the average number of visible cells representing ocean.

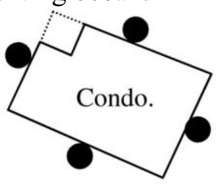

Fig. 8. Four viewpoints set for each condominium

2.3. Hedonic Model

Two models are applied in our hedonic analysis of verifying the effect of **Open View**, **Green View**, and **Ocean View**. The first model is the standard linear regression model (LM) Eq.(1):

$$y_{i,j} = \sum_k x_{i,j,k}\beta_k + \varepsilon_{i,j} \quad \varepsilon_{i,j} \sim N(0,\sigma^2)\,, \tag{1}$$

where i is the index of rooms and j is the index of buildings. $y_{i,j}$ is the natural logarithm of the condominium price (of each room), $x_{i,j,k}$ is the k-th explanatory variable, $\varepsilon_{i,j}$ is the disturbance, β_k is the k-th regression coefficient parameter, and σ^2 is the variance parameter. As is summarized in Behrer (2010), almost all of the hedonic studies regarding visibility have used LM (e.g., Peterson and Boyle 2002; Yu et al. 2007; Jim and Chen 2009; Sander and Polasky 2009; Jim and Chen 2009; Behrer 2010). However, LM cannot capture heterogeneity within a building. In fact, some studies have verified the existence of the building-wise heterogeneity in condominium prices (e.g., Gelfand et al. 2007; Yamagata et al. 2011). Ignoring such heterogeneity could induce a serious bias on the effect of the regression coefficient (Hox 1988).

To consider the building-wise heterogeneity explicitly, we apply the multilevel model (MLM: e.g., Snijders and Boske 1999) Eq.(2):

$$y_{i,j} = \sum_k x_{i,j,k}\beta_k + u_j + \varepsilon_{i,j} \quad u_j \sim N(0,\sigma_j^2) \quad \varepsilon_{i,j} \sim N(0,\sigma^2)\,, \tag{2}$$

where u_j is the building level disturbance expressing building-wise heterogeneity, and σ_j^2 is the variance of u_j.

The following are the explanatory variables: "**Const.**," which represents the intercept; "**Area**," which represents the area of units [m^2]; "**Floor**," which represents the floor of unit; dummy variables which represent room types (**1LDK**, **1R1K**, **2DK**, **2K**, **2LDK**, **3DK**, **3LDK**, **Over4**); "**Sta. time**," which represents the logarithm of the travel times to nearest stations on foot [minutes], "**Yokohama**," which represents the logarithm of the shortest-path distance from the nearest stations to the Yokohama station by train [km]; "**Green**," which represents the logarithm of the number of the grid cells denoting tree (see seq.2.2); "**Ocean**," which represents the logarithm of the straight distance to the ocean [km], dummy variables which represent land use zones ("**C1 resid**.,": category 1 (C1) residential area; "**C1 Low**,": C1 low-rise exclusive residential districts; "**C1 Med. & High**,": C 1 medium-to-high-rise residential districts; "**C2 resid**.,": category 2 (C2) residential area; "**C2 Low**,": C2 low-rise exclusive residential district; "**C2 Med. & High**,": C 2 medium-to-high-rise residential districts; "**Industry**,": industrial districts; "**Semi-Industry**,": quasi-industrial districts; "**Commerce**,": commercial districts; "**Neigh. Commerce**,": neighborhood commercial districts), and dummy variables which represent years (**1994 dummy** to **2008dummy**).

Calculation is conducted using the railway data and station data provided by the National Land Numerical Information download service (http://nlftp.mlit.go.jp/ksj-e/index.html), **Green** is calculated using the green cells, which are constructed in the previous sub-section, and the other variables are calculated using the condominium dataset provided by Marketing Research Center Co. Ltd. And, finally, our main test variables: **Open view**, **Green view** and **Ocean views** (logarithmic transformations are assumed) are calculated.

To avoid multicolinearity, explained variables whose significance below the 5 % level are dismissed (except for Open View, Green View and Ocean View) using the stepwise method.

3. Empirical Result

3.1. Evaluation result of views

Calculation results of Open View, Green View, and Ocean View are plotted on figure 9, 10 and 11. Figure 9 shows the result that a higher floor room has a better Open View as it is obviously can be imagined.

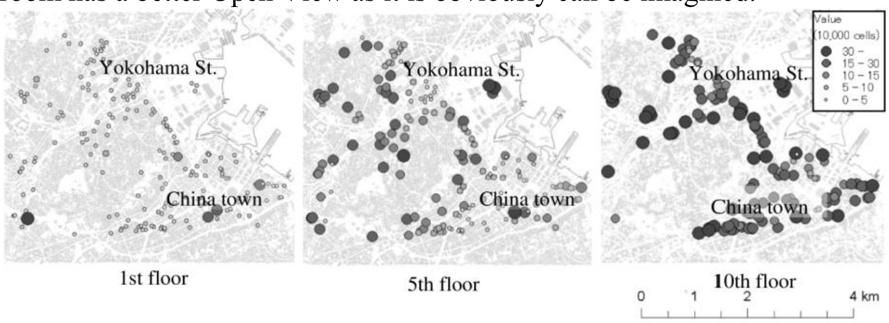

Fig. 9. Plot of Open View

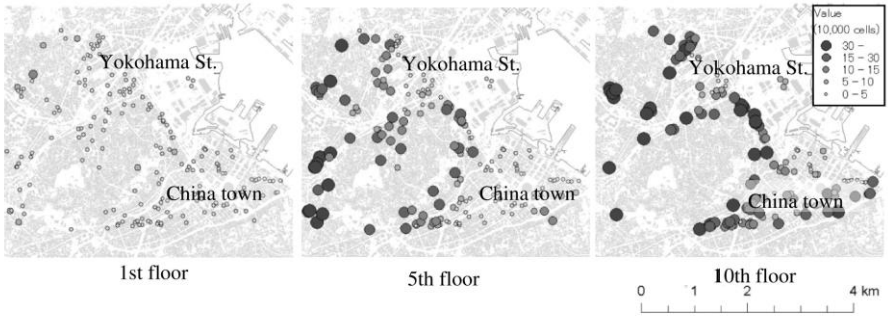

Fig. 10. Plot of Green View

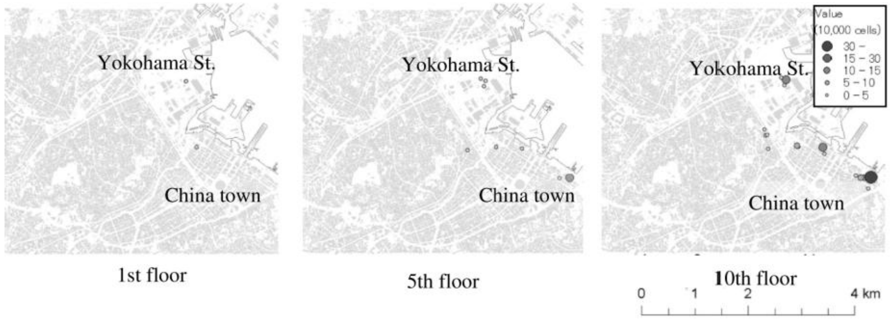

Fig. 11. Plot of Ocean View

It is also seen that Open View is relatively low at the area close to the Yokohama station and the area around China town. Similar tendencies are also found in Green View. Ocean View. It is shown that high value condominiums are located on higher floor, although most of condominiums have no Ocean View.

Estimation results of LM and MLM are summarized in table 2 and 3. VIF (variance inflation factor) in this table is a test statistics of multicollinearity, which exceeds 10 when multicollinearity is present. The table shows that multicollinearity is not a problem in each model. All of signs of the trend parameters estimated by LM and MLM are accord. However, most *t*-values estimated by MLM over *t*-values estimated by LM. This is due to the under estimation of the standard error of β_k because of ignoring the heterogeneity by buildings. In fact, AIC (Akaike Information Criteria) is improved greatly by considering the building-level heterogeneity. Hence, hereafter, we will discuss the estimation result of MLM only.

Table 2. Estimation result of LM

Variables	Estimate	t value		VIF
Const.	4.03	6.16×10^{1}	***	
Room Area	1.05	1.37×10^{2}	***	3.48
Floor	7.73×10^{-2}	2.13×10^{1}	***	3.83
1LDK	-2.57×10^{-2}	-4.37	***	1.36
1R1K	1.52×10^{-1}	1.56×10^{1}	***	3.14
2LDK	-3.96×10^{-2}	-1.18×10^{1}	***	1.26
Over 4				
C1 Low	2.36×10^{-2}	2.06	**	1.17
C2 Med.& High	1.08×10^{-1}	8.17	***	1.09
Industry	-6.51×10^{-2}	-7.29	***	1.28
Semi-Industry	3.27×10^{-2}	2.61	***	1.12
Sta. dist.	-5.32×10^{-3}	-2.30	***	1.85
Yokohama	-2.11×10^{-2}	-7.67	***	1.56
Green	4.69×10^{-2}	9.15	***	4.27
Ocean	-7.90×10^{-2}	-2.61×10^{1}	***	3.95
1994 dummy	-8.18×10^{-2}	-6.60	***	1.82
1995 dummy	-1.39×10^{-1}	-1.43×10^{1}	***	3.72
1996 dummy	-3.15×10^{-1}	-3.08×10^{1}	***	2.91
1997 dummy	-3.28×10^{-1}	-3.50×10^{1}	***	4.96
1998 dummy	-3.97×10^{-1}	-4.20×10^{1}	***	4.16
1999 dummy	-3.75×10^{-1}	-3.67×10^{1}	***	3.01
2000 dummy	-4.24×10^{-1}	-4.67×10^{1}	***	6.91
2001 dummy	-5.67×10^{-1}	-6.08×10^{1}	***	5.49
2002 dummy	-5.55×10^{-1}	-5.89×10^{1}	***	4.55
2003 dummy	-5.20×10^{-1}	-5.78×10^{1}	***	7.87
2004 dummy	-4.60×10^{-1}	-4.35×10^{1}	***	2.57
2005 dummy	-5.12×10^{-1}	-3.58×10^{1}	***	1.49
2006 dummy	-2.79×10^{-1}	-1.90×10^{1}	***	1.47
2007 dummy	-2.02×10^{-1}	-1.42×10^{1}	***	1.79
2008 dummy	-1.99×10^{-1}	-8.48	***	1.15
Green View	-5.58×10^{-3}	-2.45	**	2.84
Ocean View	8.74×10^{-3}	1.42×10^{1}	***	2.49
Open View	2.27×10^{-2}	1.23×10^{1}	***	3.37
AIC		-12891		

*, **, *** denotes significant levels (10%, 5%, and 1% respectively)

Table 3. Estimation result of MLM

Variables	Estimate	t value		VIF
Const.	3.95	3.16×10^{1}	***	
Room Area	1.11	1.78×10^{2}	***	3.81
Floor	7.65×10^{-2}	1.01×10^{1}	***	3.60
1LDK	-2.09×10^{-2}	-5.25	***	1.37
1R1K	9.23×10^{-2}	1.27×10^{1}	***	3.24
2LDK	-3.58×10^{-2}	-1.60×10^{1}	***	1.26
Over 4	-9.31×10^{-3}	-2.64	***	1.26
C1 Low				
C2 Med.& High	1.06×10^{-1}	3.43	***	1.09
Industry				
Semi-Industry				
Sta. dist.	-8.46×10^{-3}	-1.99	**	1.79
Yokohama	-2.41×10^{-2}	-4.30	***	1.56
Green	4.35×10^{-2}	4.15	***	4.08
Ocean	-9.13×10^{-2}	-1.50×10^{1}	***	3.91
1994 dummy	-1.27×10^{-1}	-5.24	***	1.81
1995 dummy	-2.02×10^{-1}	-9.95	***	3.73
1996 dummy	-3.84×10^{-1}	-1.84×10^{1}	***	2.92
1997 dummy	-4.04×10^{-1}	-2.10×10^{1}	***	4.92
1998 dummy	-4.51×10^{-1}	-2.31×10^{1}	***	4.12
1999 dummy	-4.46×10^{-1}	-2.15×10^{1}	***	3.02
2000 dummy	-4.95×10^{-1}	-2.68×10^{1}	***	6.75
2001 dummy	-6.33×10^{-1}	-3.29×10^{1}	***	5.50
2002 dummy	-6.11×10^{-1}	-3.17×10^{1}	***	4.54
2003 dummy	-5.90×10^{-1}	-3.12×10^{1}	***	7.87
2004 dummy	-5.13×10^{-1}	-2.25×10^{1}	***	2.57
2005 dummy	-5.53×10^{-1}	-1.98×10^{1}	***	1.49
2006 dummy	-3.46×10^{-1}	-1.28×10^{1}	***	1.47
2007 dummy	-2.93×10^{-1}	-1.04×10^{1}	***	1.79
2008 dummy	-1.45×10^{-1}	-3.67	***	1.15
Green View	-2.57×10^{-3}	-5.50×10^{-1}		2.81
Ocean View	5.00×10^{-3}	3.90	***	2.45
Open View	1.95×10^{-2}	5.06	***	3.15
AIC		-18807		

*, **, *** denotes significant levels (10%, 5%, and 1% respectively)

Explanatory variables (except for indexes of view) being significant at 5% level are Room Area (+), Floor (+), 1LDK (–), 1R1K (+), 2LDK (–), Over 4(–), C2 Med. & High (+), Sta. dist. (–), Yokohama (–), Green (+), Ocean (—), and year dummies. The estimates suggest that properties of rooms and accessibility affect condominium prices significantly, and that abundance of greens or proximity to the ocean influence positively to the condominium prices.

On the contrary, estimates of MLM show insignificance of Green View, whereas Open View and Ocean View are positively significant at 1% level. It is worth noting that Green View is negatively significant when LM is employed. This counterintuitive result may be brought by ignoring the building-wise heterogeneity. Thus, the result may be showing the importance of considering the multilevel structure of condominiums when hedonic analysis is conducted.

Marginal benefits of four environmental explanatory variables, that is, Green, Ocean, Open View and Ocean View are calculated. Since both explained variables and the four explanatory variables are log-transformed, marginal benefits vary depending on price and the explanatory variables. Table 4 shows marginal benefits on condominiums whose values of explanatory variables are their medians and price is 30, 50 or 100 million yen. This table suggests that, when units of explanatory variables are set as shown in this table, premiums of each variable are 1.0% (**Green**), 7.2% (**Ocean**), 0.8% (**Open View**) and 0.5% (**Ocean View**) suggesting that premiums of views are not very large. However, increase of visible cells representing ocean increases both Ocean View and Open View. In the other words, premium of improving ocean view is in fact 1.3% (0.8% + 0.5%). Thus, improving ocean views may be the first choice of receiving benefits form view. Considering the high premium of **Ocean**, we can say that the most expensive condominiums are located near the ocean with the better ocean views.

Table 4. Marginal benefits on condominiums (million yen) whose four environmental explanatory variables equal to each median

Explained variables	Prices of condominiums (million yen)		
	30	50	100
Green (unit: 1ha)	2.94×10^{-1}	4.90×10^{-1}	9.80×10^{-1}
Ocean (unit: 1km)	–2.15	–3.58	–7.16
Open View (unit: 1ha)	2.32×10^{-1}	3.38×10^{-1}	7.76×10^{-1}
Ocean View (unit: 1ha)	1.52×10^{-1}	2.53×10^{-1}	5.06×10^{-1}

4. Concluding remarks

This study evaluated the economic values of Open View, Green View, and Ocean View on condominium prices, and then, clarified the positive effect of Open View and Ocean View. We also suggest that improving Ocean View is especially important. At the same time, importance of considering multilevel structure of condominiums was confirmed by comparing LM and MLM.

Study analyzing 3D view on an urban space is still limited, and agreement of the economic value of visibility has not been obtained. So, we have challenged by analyzing more detail urban visibility using state of the art Remote Sensing and GIS technologies methods. Performing more empirical studies in various test sites is needed to verify our result as a general rule of the influence of views on condominium pricing.

Several practical applications could be considered using the proposed view indices. For example, such index might be useful urban landscape management. Namely, when a high-rise building is planned, loss of economic value based on the surrounding rooms visibility can be calculated and managed minimum by deciding the building location and height by minimizing the total loss using the indices. These indices could also be useful to evaluate and compare visibilities of city districts. Moreover, as is also discussed in Yu et al. (2007) the index might be useful to evaluate the 3D views from a building for the appropriate pricing.

However, our method of evaluating 3D views need be improved more. Firstly, we employed assumptions about the window locations and visible ranges. Validity of these assumptions must be confirmed and additional factors such as width of view, angle of elevation, and angle of depression need to be considered.

Secondly, although our study and most other studies of visibility evaluated 3D views using DSM only. However, it cannot consider a value of the land scape. Applying computer graphic (CG) tools, such as Google street view, would be more useful to evaluate more real 3D view that influence human evaluation. However, it is still difficult to express realistic living trees that change leaf volume and color seasonally. So, even more advanced virtual reality (VR) tools would be needed.

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