Influence of lot size and shape on redevelopment projects

Xiaolu Gao\textsuperscript{a,*}, Yasushi Asami\textsuperscript{b}

\textsuperscript{a}Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Jia 11, Datun Road, Chaoyang District, Beijing 100101, P. R. China

\textsuperscript{b}Center for Spatial Information Science, University of Tokyo, Japan

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Abstract

Analyses on the economic effects of living environments provide a useful tool for evaluating the planning policies of urban redevelopment. In Japanese cities, an important issue in redevelopment projects where residents contribute some land for public services such as roads and parks is whether small lot size and poor shape prevent the residents from acquiring sufficient social benefits to compensate for the sacrifice of land. This paper analyzed the influence of lot size and shape on the externalities of local environments using a hedonic approach and applied the results to examine several situations of broadening a road in a densely built residential block. The analyses showed that the benefits of the projects were significantly influenced by the size and shape of the lots. To get adequate benefits to compensate for the land and the additional costs of the projects, the involved lots should be larger than a certain limit and satisfy certain requirements on their shapes. The analyses also revealed that, because of the influence of lot size and shape, relaxing the planning controls on floor-to-area ratio (FAR) for the redeveloped areas does not necessarily create incentives for residents to be getting involved. These results suggested that appropriate considerations for lot size and shape are indispensable for the expedition of redevelopment projects.

Keywords: Planning policy; Redevelopment; Hedonic; Externality; Lot size; Lot shape

Introduction

Redevelopment is significant for urban planning more than ever before. However, there are many obstacles in redevelopment projects. One of the largest ones is probably the resistance of residents due to insufficient incentives to be getting involved or the feelings of unfairness. To address these issues, analyzing the economic effects of living environments is a useful approach.

In Japanese cities, a special issue in the implementation of urban redevelopment is the objections of residents towards the evaluation of lot size and shape. This paper applies the empirical results of hedonic regression analyses to reveal the impact of lot size and shape on the costs and benefits of redevelopment projects and attempts to provide useful implications for planning policies.

The past decades have seen a consistent increase of small properties in large Japanese cities. According to recent survey results in Tokyo metropolitan areas, 45% of land properties are less than 100 m\textsuperscript{2}. Small lot size has given rise to serious environmental problems in residential areas such as poor sunshine, loss of trees and green space, insufficient public services, and vulnerability to disasters. Therefore, improving the living environments of the densely built areas by redevelopment is a very urgent issue.

In practice, land readjustment projects are the most popular way for urban redevelopment. The basic concept of the projects is that a proportion of the existing lots are contributed for public services (such as roads and parks) and the sacrificed land is compensated by raised land values through the improvement of environments. The values of each involved lot are evaluated, upon which a land contribution rate is decided to ensure the same land values after the implementation of the projects. If a lot is too small to contribute land, a financial contribution corresponding to the land contribution should be made.
To evaluate the involved lots, the unit price of land is defined to be the product of ‘street price’ and four factors: ‘narrow-frontage factor’, ‘long-depth factor’, ‘irregular-shape penalty’, and ‘dual-front-road factor’. Street prices are the standard prices of land along main streets of cities announced by National Tax Administration once every three years (based on transaction surveys), which are identical along each street. It is used to represent the general improvement of the environments. The four factors are used to reflect the impact of lot size, shape and front roads on land values. The adjustments by the four factors are quite limited. For example, Table 1 quotes the definitions of narrow-frontage and long-depth factors. According to the definitions, if the frontage of a lot remains 4 m or larger and the ratio of its depth to frontage is less than 3.0, the values of the two factors before and after the improvement are all the same. In practice, such cases are quite popular. As a result, the rates of land contribution are almost fixed, regardless of the size and shape of the involved lots.

This evaluation method is questionable. First, there is no reason to assume that the environmental benefits of redevelopment are uniform over streets. For example, a neighborhood park might affect closer properties more and affect farther properties less. Another serious problem is that the effects of improvement may correlate to the size and shape of lots so land contribution rate should differ, but these kinds of effects have not been considered carefully.

In practice, land readjustment projects are especially difficult to be implemented in overcrowded areas. In particular, the identical rate of land contribution is concerned by the owners of small lots. Many people consider that the same amount of land of smaller lots is more valuable for dwelling so small lots should be exempted from land contribution. Sometimes, undesirable changes on the shapes of small lots resulted from redevelopment projects are not evaluated sufficiently. This also raises objections to the projects. To create more incentives for redevelopment projects, policies such as relaxing planning controls on the maximally allowed floor-to-area ratio (FAR) of lots in redeveloped areas have been adopted but they appeared to have little effect.

So far, land readjustment projects have mostly been conducted by public or semi-public sectors. When troubles arise in projects, public revenues are often induced in order to put forward the projects, but it is improper to treat the owners of small lots similar to that of the weak just because their land is small (Asami, 2000). Nowadays, land adjustment projects emphasize the involvement of residents much more than ever. Therefore, an objective evaluation for the relationships between lot size, shape and the social benefits of environmental improvement is increasingly important. Assessing redevelopment projects and planning policies based on such examinations is critical.

**Methodology**

The issues related to the impact of lot size and shape on property values have been discussed in a certain number of studies. For example, Tabuchi (1996) stated that the price of lots in many American cities decreases with lot size, while he demonstrated that larger residential lots are proportionately more expensive with samples in Osaka city, and this is explained by irreversibility of land subdivision and an oligopolistic market structure with non-decreasing marginal utility of lot size. Hatta and Akai (1996) empirically found that the unit price of land is linearly affected by the reciprocal of lot size. The fact that land values were higher for smaller lots was correlated to the existence of a basic cost for lot development. These works suggest that the effect of lot size is significant enough to be considered in project assessment.

In addition, some analysts raised evaluation models for lot size and shape. For example, Colwell and Scheu (1989) proposed an evaluation model for rectangular lots in the United States, assuming that the benefits for developing a lot are \( \pi = xF^D - \delta FD - \psi F \), where \( \pi \) is the benefit of development per lot, \( F \) and \( D \) represent, respectively, the frontage and depth of lots, \( x, \beta, \gamma, \delta, \) and \( \psi \) are parameters. The \( xF^D \) term is the value of the developed land; \( \delta FD \) and \( \psi F \) are the costs of land development. The optimum size and configuration of land lots were derived by maximizing \( \pi \). Asami (1995a) demonstrated that evaluating an ‘island lot’ (the main part is away from roads) by letting its price to be proportional to the product of its size and an irregular-shape penalty as in the land readjustment projects was problematic and Asami (1995b) modified the lot evaluation functions to resolve this problem.

A limitation of these studies is that, while they considered the influence of lot size and shape on their values, the studies did not deeply investigate the effects of redevelopment on living environments. When urban redevelopment projects involve many small lots, the external effects of the environments are significant.

Hedonic regression analyses provide a useful method for estimating the external effects of redevelopment projects. The theory of hedonic regression analyses is based on the capitalization hypothesis. That is, improvement in living environments corresponds to the rise in market prices so it...
is reasonable to predict the benefits of improvements by the observed rise in market prices. In a well-functioning market, utility maximizing households purchase houses so that their willingness to pay for a marginal increase in a particular attribute equals its implicit price, or ‘hedonic price’. Therefore, the hedonic prices of the housing attributes can be estimated by regressing on the observed prices of properties. This method is frequently used for the study of urban environments, and is shown to be effective in revealing the economic effects of environmental attributes (see, for example, Kain and Quigley (1970) on the evaluation of the blight of residential environments; Hidano et al. (1998) on the external effects of providing trees in residential blocks and the benefits of applying setback controls which may provide space for additional trees; Geoghegan (2002), Morancho (2003) and Tajima (2003) on the environmental benefits of parks and open space).

In the following sections, we first apply the results of hedonic regression analyses to identify the external effects of local environments and then analyze the impact of lot size and shape on redevelopment projects by studying the costs and benefits of the projects.

To focus on the problems of densely built blocks, a number of environmental attributes are examined. The hedonic regression model developed by Gao and Asami (2001) is used. By this model, the external effects of local environments are characterized in detail and the variables representing lot size and shape are revealed.

Afterwards, the costs and benefits of redevelopment are analyzed with an example of widening a road in a residential block. The net benefits of the project are studied in the following situations: where the improved environments and the cost of land contribution are considered; where the additional cost for road improvement is included; and where the involved house is rebuilt and the reconstruction cost is also considered. Furthermore, the impact of relaxing planning controls on FAR in redeveloped areas for improving the initiative of residents will be examined.

Hedonic model for housing and land prices

Sample and data

A sample of lots with detached housing on sites was drawn from the October 1996 to September 1997 issues of the Weekly Housing Information magazine published by Recruit Co. Ltd., Japan. This is one of the largest information companies in Japan, which provides a huge amount of housing information in urban areas (more than 10,000 pieces per month). Since the company only deals with legal properties (lots and buildings satisfying the requirements of land use regulations), some bias might be introduced. However, this may not cause serious problems to the analysis result since the number of illegal properties is small.

Only successfully transacted properties were chosen for the analyses and the final list prices of the properties were thought to be close to actual prices. Furthermore, the sample was confined to the areas around five consecutive stations on the Odakyu railway line (the only railway line crossing the sample area) in Setagaya Ward, western Tokyo. The areas are about 110 hectares, and approximately 15–20 km from central Tokyo. The sampled areas are confined as such in order to filter out the spatial heterogeneity effects of parameters (as exemplified by Goodman, 1981; Galster, 1996; Goodman and Thibodeau, 1998; Tu, 1997; Shen, 2002). This also helps reduce large variations of variables such as the distance to central urban areas, which are likely to mask the effects of weaker but more important environmental effects. Besides, the sample properties are confined to first category low-story residential zone. As a result, a sample of 190 lots with complete data is selected.

The basic information of the properties is provided by the transaction database. Through site surveys, additional data such as the neighborhood environments and the use of the lots were collected. Data on the accessibility to public facilities were obtained using GIS applications. In addition, three-dimensional CAD models of the buildings around each sample lot were established, upon which the sunshine duration and ventilation of the sample houses were evaluated.

Since the sample lots have houses on sites, variables indicating the attributes of houses, including the floor areas, structure, year of built, times of reform, the number of rooms, toilets, total number of floors, were considered. As would be shown later, the floor area, structure, year of built and times of reform (the latter three were integrated into the remaining age of houses) are significant but the number of rooms, etc. are not. This reflects the fact that the compositions of detached houses in the same urban areas do not differ very much in Japan.

Table 2 shows the summary statistics of the collected data and their definitions. For simplicity, only the variables in the Gao and Asami (2001) model are given.1

Specifications and validation

The established model adopted a linear specification as

\[
P/S = \text{constant} + \sum_{i=1}^{k} a_i \times (X_i/S) + \sum_{i=1}^{k} b_i \times X_i + \varepsilon, \quad (1)
\]

where \(P/S\) is the price of land and the house on a lot, \(S\) the lot area, \(X_i\) the independent variable representing the \(i\)th...
attribute (for \( i = 1 \) to \( k \)), \( a_i \), \( b_i \) are the parameters for attribute \( i \), and \( \varepsilon \) is the error term.

Eq. (1) was established based on preliminary stepwise regressions for price (\( P \)) and for unit price (\( P/S \)), both with \( X_i \) as independent variables. Either of them suggested interesting relationships of the local environmental attributes. Specifically, the regression for \( P \) revealed positive effects for parking lots, the abundance of trees in the neighborhood, neighboring parks, sunshine duration, and negative effects for facing a cul-de-sac. The regression for \( P/S \) demonstrated that ‘within designated landscape area’, ‘good pavement of front road’, ‘plentiful mixed land use’ and ‘good building quality in the neighborhood’ significantly affected the unit price of housing and lands.

It was found that some attributes had been included in the model for price, some in the model for unit price, and some others in both. This suggested that the effects of \( X_i \) are related to the size of lots; therefore, lot size \((S)\) should be incorporated to the regression model. In Eq. (1), the cross-product term of \( X_i \) and \( 1/S \) is included, so the extent to which the parameters of \( X_i \) are influenced by lot size can be captured: if a variable in the form of \( X_i \) is significant, its coefficient can be thought to be the effect of \( X_i \) on unit price; if a variable in the form of \( X_i/S \) is significant, its coefficient can be thought to be the effect of \( X_i \) on price; if \( X_i \) and \( X_i/S \) for the same attribute are both significant in the model, the effect of \( X_i \) on price or unit price can be interpreted by a linear function of \( S \).

The model in Eq. (1) was compared with many other specifications: simple linear function for \( P \) and \( P/S \) without cross-product terms, and a log-linear regression function for \( \ln(P/S) \). The coefficients of determination \((R^2)\) of models with \( P \) as dependent variables are higher those of other models (>0.95), but since \( P \) is not normally distributed, models for \( P/S \) and \( \ln(P/S) \) are considered more appropriate. Furthermore, the values of the Akaike Information Criterion (AIC) suggest that the model in Eq. (1) is better than that for \( \ln(P/S) \).

The cross-validation method described in Gao et al. (2002) was also used for the comparisons. That is, the price of each sample is predicted with a model estimated with the samples excluding itself, and the deviations of predicted prices from observed prices are examined. The average percentage of prediction errors of the model in Eq. (1) is 10.4%, smaller than those of non-cross-product term models and log-linear model. With this method, this established model was also compared with ‘geographically weighted regression models’ for \( P/S \) (which allow the estimated parameters to differ with locations) and a ‘spatial dependence model’ for \( P/S \) (which assumes that the prices of spatially adjacent samples are correlated). The average prediction error of the spatial dependence model is 10.4% and that of the geographical weighted regression model is 9.9%. The extent of reductions is not so large, even though they have more parameters (twice and 190 times more than those of Eq. (1)) and are less easy to interpret. These comparisons suggest that Eq. (1) is reasonable for this data set. Therefore, it was selected for the simplicity of interpretation.

### Table 2
Summary statistics of variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition (unit)</th>
<th>Min.</th>
<th>Max.</th>
<th>Average</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual_FAR</td>
<td>Ratio of building floor area to lot area</td>
<td>0.35</td>
<td>1.83</td>
<td>0.961</td>
<td>0.265</td>
</tr>
<tr>
<td>Bldg_age</td>
<td>Remaining ages of house (year)</td>
<td>0.00</td>
<td>44.00</td>
<td>25.268</td>
<td>7.641</td>
</tr>
<tr>
<td>Bldg_age/S</td>
<td></td>
<td>0.00</td>
<td>0.70</td>
<td>0.258</td>
<td>0.131</td>
</tr>
<tr>
<td>Bldq_quality</td>
<td>If building quality in the neighborhood is good, 1, otherwise 0</td>
<td>0</td>
<td>1</td>
<td>0.363</td>
<td>0.482</td>
</tr>
<tr>
<td>Frontage</td>
<td>Frontage of lot (m)</td>
<td>1.00</td>
<td>20.00</td>
<td>7.427</td>
<td>3.602</td>
</tr>
<tr>
<td>Landscape</td>
<td>If lot is within designated landscape area, 1, otherwise 0</td>
<td>0</td>
<td>1</td>
<td>0.242</td>
<td>0.430</td>
</tr>
<tr>
<td>Mixed_use</td>
<td>If the amount of mixed land use is large in the neighborhood, 1, otherwise 0</td>
<td>0</td>
<td>1</td>
<td>0.111</td>
<td>0.314</td>
</tr>
<tr>
<td>Mixed_use/S</td>
<td></td>
<td>0.00</td>
<td>0.02</td>
<td>0.001</td>
<td>0.004</td>
</tr>
<tr>
<td>P</td>
<td>Price (million Yen)</td>
<td>31.50</td>
<td>398.00</td>
<td>94.585</td>
<td>60.511</td>
</tr>
<tr>
<td>P/S</td>
<td>Unit price (million Yen/m²)</td>
<td>0.46</td>
<td>1.24</td>
<td>0.782</td>
<td>0.185</td>
</tr>
<tr>
<td>Park</td>
<td>If lot neighbors a park or public open space, 1, otherwise 0</td>
<td>0</td>
<td>1</td>
<td>0.063</td>
<td>0.244</td>
</tr>
<tr>
<td>Park/S</td>
<td></td>
<td>0.00</td>
<td>0.02</td>
<td>0.001</td>
<td>0.002</td>
</tr>
<tr>
<td>Parkinglot</td>
<td>Number of parking lot</td>
<td>0</td>
<td>3</td>
<td>1.253</td>
<td>0.741</td>
</tr>
<tr>
<td>Pavement</td>
<td>If pavement of front road is good, 1, otherwise 0</td>
<td>0</td>
<td>1</td>
<td>0.511</td>
<td>0.501</td>
</tr>
<tr>
<td>Road_width</td>
<td>Width of front road (m)</td>
<td>2.00</td>
<td>8.10</td>
<td>4.636</td>
<td>1.222</td>
</tr>
<tr>
<td>S</td>
<td>Lot area (m²)</td>
<td>34.72</td>
<td>588.05</td>
<td>124.668</td>
<td>81.244</td>
</tr>
<tr>
<td>Shinjuku</td>
<td>Time to Shinjuku station in central urban area by train (min)</td>
<td>22.00</td>
<td>30.00</td>
<td>26.626</td>
<td>3.411</td>
</tr>
<tr>
<td>Station</td>
<td>Time to the nearest railway station (min)</td>
<td>2.00</td>
<td>26.00</td>
<td>11.616</td>
<td>4.955</td>
</tr>
<tr>
<td>Sunshine</td>
<td>First floor sunshine duration of house measured in winter solstice (h)</td>
<td>0.00</td>
<td>8.00</td>
<td>3.540</td>
<td>2.150</td>
</tr>
<tr>
<td>Sunshine/S</td>
<td></td>
<td>0.00</td>
<td>0.12</td>
<td>0.033</td>
<td>0.024</td>
</tr>
<tr>
<td>Tree</td>
<td>If there are more than 15 trees (crown diameter and height ( \geq 3 ) m) in the neighborhood, 1, otherwise 0</td>
<td>0</td>
<td>1</td>
<td>0.332</td>
<td>0.472</td>
</tr>
</tbody>
</table>
By regression analyses with Eq. (1), a model with 16 independent variables was obtained. The first 11 variables were selected by a stepwise regression procedure on a significance level of \( F \) value at 0.05. The last five variables, two indicating the attributes of neighboring parks, two for mixed land use and one for the abundance of trees, had been significant in the preliminary regressions for \( P \) and \( P'/S \) and were of special interest. They were forcefully included in the model and their significance levels were satisfactory, too. Table 3 lists the estimated coefficients for this model. It explains 75.6% of the unit price of housing and lots, which is high among the unit price models for detached housing lots in the Japanese literature, perhaps due to the effect of compact sample area and the inclusion of detailed attributes.

The stability of the estimates was tested. Due to the inclusion of \( X_i \) and \( X_i/S \), multiple collinearity problems are detected (Pearson’s correlation coefficients between \( park \) and \( park/S \) and between \( mixed_use \) and \( mixed_use/S \) are 0.871 and 0.966). These are also revealed by large VIF values in Table 3 and by the condition number of the model (53.2). On the other hand, the result of collinearity diagnostics should be interpreted with caution because interaction terms would naturally lead to such results (Belsley, 1991). For this reason, the method proposed by Pelzer et al. (2004) was used to test the stability of the estimated parameters. Regressions were repetitively run with random ‘perturbations’ being added to correlated variables at each time. The means and standard deviations of the estimated parameters of the iterations were examined against the regression coefficients in Table 3. This test revealed that the estimates for the model are stable.

Table 4 lists the hedonic prices of significant attributes scaled with lot size \( S \). They show the marginal effects of each attribute on the total price of properties. The parameters of \( station \) and \( Shinjuku \) in Table 3 indicate that an extra 1-min-walk to the nearest railway station and an additional minute by train to Shinjuku station in central urban area reduce the unit price by 0.0157 and 0.0168 million Yen, respectively, so their effects on the total price are multiplied by \( S \).

The prices of properties are significantly affected by the attributes of lots and local environments. The structural attributes include the remaining ages of house (\( bldg\_age \)), actual floor area ratio of lot (\( actual\_FAR \)), lot frontage (\( frontage \)). The environmental attributes include sunshine duration (\( sunshine \)), parking space (\( parking \)), road width (\( road\_width \)), the quality of road pavement (\( pavement \)), neighboring parks (\( park \)), the abundance of trees (\( tree \)), building quality (\( bldg\_quality \)) and mixed land use (\( mixed\_use \)) in the neighborhood.

The estimated regression coefficient of \( actual\_FAR \) is 0.1276 million Yen, the hedonic price of \( actual\_FAR \) thusly equals \( 0.1276 \times S \) million Yen. Likewise, the hedonic prices of frontage and parking space are 0.0058 \( \times S \) per meter and 0.0382 \( \times S \) per parking lot, respectively. The hedonic price of sunshine duration is 0.948 million Yen per hour, suggesting that, all other conditions being the same, an additional hour of sunshine results in a 0.948 million Yen increase in the total price of a property. This point is of particular importance for planning because it can be used to evaluate the sunshine acquisition of lots affected by the developments of surrounding lots.

Most external effects of environmental attributes are proportional to lot size \( S \), but the marginal prices of \( sunshine \) and \( bldg\_age \) are not. In addition, for neighboring park (\( park \)) and mixed land use (\( mixed\_use \)), the hedonic

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Hedonic price (million Yen per unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( actual_FAR )</td>
<td>0.1276 ( \times S )</td>
</tr>
<tr>
<td>( station )</td>
<td>-0.0157 ( \times S )</td>
</tr>
<tr>
<td>( road_width )</td>
<td>0.0209 ( \times S )</td>
</tr>
<tr>
<td>( bldg_age )</td>
<td>0.5686</td>
</tr>
<tr>
<td>( sunshine )</td>
<td>-0.1726 ( \times S )</td>
</tr>
<tr>
<td>( frontage )</td>
<td>-0.0168 ( \times S )</td>
</tr>
<tr>
<td>( pavement )</td>
<td>0.0058 ( \times S )</td>
</tr>
<tr>
<td>( parkinglot )</td>
<td>0.042 ( \times S )</td>
</tr>
<tr>
<td>( mixed_use )</td>
<td>0.9476</td>
</tr>
<tr>
<td>( tree )</td>
<td>0.0335 ( S )</td>
</tr>
<tr>
<td>( park )</td>
<td>0.1956 ( 109.7 \times S )</td>
</tr>
<tr>
<td>( mixed_use )</td>
<td>0.2384 ( S )</td>
</tr>
</tbody>
</table>
prices differ with lot size and their signs may shift for lots of different sizes. Neighboring park has a positive effect when a lot is smaller than 110 m$^2$ and the effect is greater for smaller lots, which may be explained by the larger benefits of gaining sunshine and ventilation for small lots, and stronger negative effects such as noises for large lots. The effect of mixed land use is negative when lots are small and is positive when lots are large, perhaps due to increased possibilities for transferring from residential to commercial land use. These effects prove that the social benefits of environmental improvements are closely correlated to the size of lots thus careful considerations on lot size are critical in redevelopment projects.

In the model, lot size ($S$) and frontage are related to the shape of lots. The hedonic price of frontage is 0.0058 × $S$. Theoretically speaking, lot shape can only be roughly indicated by these two variables because of the existence of irregular lots such as flag-looking lots with narrow paths connecting to roads (known as ‘flag lots’). For irregular lots like flag lots, the representation by $S$ and frontage are relatively incomplete, but for regular lots, the representations are reasonable. In practice, the frontages of flag-shaped lots are usually 2.0–3.0 m, whilst for regular lots the frontage is at least about 4.0 m (3.0 m for a room plus necessary space for structures and distance to neighbors). Therefore, from the value of frontage, one can roughly distinguish regular lots from flag ones. To some sense, the hedonic price of frontage partially reflects the effect of irregular lots.

The impact of lot shape on the costs and benefits of improvement can then be analyzed with respect to lot size and frontage. Suppose, for example, some land is gathered to provide a park. According to the analysis results, the effects of the park are significantly correlated to the size of the involved lots. Smaller lots get larger benefit from the park, so it would be reasonable for small lots to make more contribution for these benefits. However, since the land contribution might be accompanied by reduced floor areas, losses of parking lots, shrunken frontages and other effects, these effects should be assessed together. Since the sample areas are limited, the estimated values need to be examined with samples of broader areas. Nonetheless, the sample areas are quite typical in urban detached housing areas in Tokyo. It is anticipated that similar result could be achieved with samples in other areas.

The analyses provide many implications for planning and practices. It is significant that with the results of the analysis, detailed changes of living environments during redevelopment projects can be captured. In the following section, the results will be used for studying the benefits and costs of redevelopment projects with some examples.

Analyses of redevelopment projects

Benefits and costs of broadening a road

A project in detached housing blocks where a road is broadened was considered. In the past, 2.7 m has always been the minimal legal width for a residential road in Japan (under Urban Building Law). The relative law was amended in 1938 where the minimal width of roads was raised to 4.0 m. However, in aged residential areas, many roads remain at 2.7 m width. Nowadays, these roads are the targets of broadening.

Consider a block with detached houses and a narrow road. Assume that the road is widened by $w$ on one side while the lots on the other side are kept intact. In practice, broadening roads on both sides is also popular but the single-side case was adopted in the current analyses for simplicity. In real projects, the lots along the overall streets are usually involved. The covered area can be seen as many attached slices each composed of a part of the road and the lots on two sides. Providing that the relationships between the slices do not change much by the redevelopment, the social benefits can be simplified to the aggregation of the benefits within the slices. One of the slices was focused. There are two lots inside, which were assumed to have the same frontage and the same depth after road-broadening.

Even though only one lot gives out land, both lots benefit from the broadened road, better road pavement, and so forth, thus the loss of land is compensated by the sum of these external effects, that is, the increased value of the two lots.

The hedonic prices in Table 4 were used to evaluate the social effects of the project. For the estimation, the following assumptions were made:

- Actual FAR of the lots prior to the project ($\text{actual}_{-}\text{FAR}$): 100%
- Time to the nearest railway station ($\text{station}$): 5 min
- Time to Shinjuku station in central urban areas ($\text{Shinjuku}$): 22 min
- Neighboring park ($\text{park}$): 0

Both lots were assumed to have one parking lot. Besides, the attributes of the neighborhood environment including landscape, building quality, mixed land use and trees were assumed to be standard so the values of the dummy variables indicating that these attributes are better or worse than standard levels are zero.

The simplest case

First, consider the simplest situation where the lot on the widened side gives its vacant part to road. Table 5 summarizes the changes of the values of the two lots under this assumption, where $w_0$ is the original road width, $w$ is

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2Flag lots are often seen in built-up areas, which have resulted from extensive subdivisions of lots in recent years.

3The analysis of other studies, for example, the price model of Gao and Asami (2005), based on vacant land samples in the whole western Tokyo areas, suggested that most attributes reported in Table 2 were significant and their estimates had the same positive or negative signs.

4Strictly speaking, the benefits are not limited to each slice. Besides, the widening of road might bring externalities to the surrounding blocks and the benefits might be constrained by non-developed blocks. These effects were omitted.
the width of the broadened part, \( d \) and \( f \) represent the depth and frontage of the lots, respectively.

Summing up the changes gave the net benefits of the project:

\[
C_1 = \sum \text{Changes of the values of the involved lots} \\
= -0.5006 \times w'f - 0.0058 \times w'f^2 + 0.0417 \times w'df \\
- 0.0209 \times w'w_0f + 0.084 \times df. \tag{2}
\]

In addition, the standard errors of the net benefits can also be computed (see Appendix A for details).

When the road is broadened from 2.7 to 4.0 m, \( w_0 \) and \( w' \) can be substituted with 2.7 and 1.3 m. Then \( C_1 \) becomes a function of \( d \) and \( f \). For illustration, Fig. 1 exhibits the net benefits of projects and the 95% confidential intervals with the depth of lots being 15 m. When the frontage is 10 m, for example, the net benefit is 12.736 million Yen and the corresponding standard error is 5.142 million Yen \((t = 2.48)\).

Letting \( C_1 \geq 0 \) gave the feasible conditions of \( d \) and \( f \) beyond which the benefits are big enough to compensate for the cost of land contribution in the project.

The required lot areas prior to and after the project with respect to frontage (lot-area-before and lot-area-after curves) are plotted in Fig. 2. Above the curves, net benefits are positive. This reveals that a minimum size is necessary to get positive net benefits. For example, if the frontage of a lot is 6.0 m, the size before the widening should be at least 44.4 m². If the frontage is 10 m, the prior size should be larger than 76.1 m². As the frontage becomes larger, the required lot size becomes larger.

---

**Table 5**  
Social benefits and costs of the two lots

<table>
<thead>
<tr>
<th>Value of attributes</th>
<th>Changes on the values of involved lots and houses (million Yen)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
</tr>
<tr>
<td>Constant</td>
<td>0.9115 \times [df -(d+w') \times f]</td>
</tr>
<tr>
<td>Actual_FAR*</td>
<td>0</td>
</tr>
<tr>
<td>Station</td>
<td>0.042</td>
</tr>
<tr>
<td>Road_width</td>
<td>0</td>
</tr>
<tr>
<td>Bldg_age/S</td>
<td>0</td>
</tr>
<tr>
<td>Landscape</td>
<td>0</td>
</tr>
<tr>
<td>Shinjuku</td>
<td>0</td>
</tr>
<tr>
<td>Frontage</td>
<td>0</td>
</tr>
<tr>
<td>Pavement</td>
<td>0</td>
</tr>
<tr>
<td>Parkinglot</td>
<td>0</td>
</tr>
<tr>
<td>Bldg_quality</td>
<td>0</td>
</tr>
<tr>
<td>Sunshine/S</td>
<td>0</td>
</tr>
<tr>
<td>Park/S</td>
<td>0</td>
</tr>
<tr>
<td>Park</td>
<td>0</td>
</tr>
<tr>
<td>Mixed_use/S</td>
<td>0</td>
</tr>
<tr>
<td>Mixed_use</td>
<td>0</td>
</tr>
<tr>
<td>Tree</td>
<td>0</td>
</tr>
<tr>
<td>Sum of changes</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

*Since building floor areas \((= \text{actual_FAR} \times S)\) do not change, this term brings no change to the total values.

---

**Fig. 1. Net benefits of projects.**

**Fig. 2. Effective area of net benefits.**

The contours of net benefits in Fig. 2 are uprightly parallel. Therefore, for same-sized lots, those with narrower frontages get larger benefits. For instance, see two...
lots $L_1 (f_1, S_1)$ and $L_2 (f_2, S_2)$ in Fig. 2 ($f_1 < f_2, S_1 = S_2$). The net benefits of $L_1$ are larger than those of $L_2$.

With the cost of road improvement considered
In real projects, the cost of road improvement is also considered. Assume that the cost is directly proportional to the surface area of road. The net benefits become

$$C_2 = C_1 - \beta(w_0 + w')f,$$  \hspace{1cm} (3)

where $\beta$ is the unit cost of road. The experienced value in road improvement project in western Tokyo, 0.04 million Yen per m$^2$, was used for $\beta$.

Again, letting $C_2 = 0$ gave the balancing conditions. The lot-area-before curve is plotted in Fig. 3. The flow of the curve is similar to that of Fig. 2, with the feasible areas above the curve. Due to enlarged costs, the curve is higher and rises up more rapidly than in Fig. 2, suggesting that lots with larger frontages should bear a larger part of the road cost. The minimal lot sizes in the above two cases differ just a little if the frontage is small, but they differ more if the frontage is large.

With the house reconstructed
Assume that the lot on the broadened side does not have enough vacancy for road, so the house is reconstructed. In this case, the additional cost for rebuilding the house and more environmental changes than in the former cases are considered.

First, assume that the remaining age of this house is prolonged from 5 to 30 years (the average life span of wood-structure detached house in Japan). Second, suppose that the exterior wall of the new house along the road setbacks from its previous position, and, consequently, the sunshine duration of the new house (or sometimes the house to its north side) extends for 1 h. In addition, notice that the floor areas of the newly built house might change. Use $FAR_b$ and $FAR_a$ to represent the actual floor area ratios of the lots before and after the redevelopment. These additional changes are summarized in Table 6.

The construction cost function was obtained by running a regression with the data of 39,401 detached houses provided by the Public Financing Corporation of Housing (Fig. 4). As a result, the construction cost is obtained:

$$\text{Construction cost} = 4.642 + 0.115 \times S_{\text{floor}} \text{ (million yen)},$$  \hspace{1cm} (4)

where $S_{\text{floor}}$ is the floor areas of the houses, equaling $FAR_b \times df$. The constant term can be explained by the costs of kitchen facilities, toilet, air-conditioning systems, etc., which are relatively constant for all houses. Eq. (4) fits well with the construction cost data. The $R^2$ is 0.984.

The above benefits and costs were then added to Eq. (3) and the net benefits were given by

$$C_3 = C_2 + 0.9476 + 0.5686 \times 25 + 0.1276 \times FAR_a \times (d + w') \times f$$

$$- (4.642 + 0.115 \times FAR_a \times df).$$  \hspace{1cm} (5)

Generally, when a road is broadened a higher FAR is permitted. According to Japanese Building Standard Law, the maximally allowed FAR of a residential lot is 0.4 times of the width of the front road (if road width is no more than 12 m). For example, the highest FAR of lots fronting a 3.0 m road can be 120% and that fronting a 4.0 m road can be 160%. In addition, the actual FAR cannot exceed the upper limits of zoning, which for low-rise detached housing areas are usually no more than 150%. Here, assume that $FAR_b$ is 100% and $FAR_a$ is 150%.
Similar to the former cases, the balancing curve of lot size before the project was derived by letting $C_3 = 0$ (Fig. 5). In order to get positive net benefits in the redevelopment project, the size and the corresponding frontage of lots should be higher than the curves. For instance, if the frontage is 12 m, a minimum size of 152.6 m$^2$ is required. Vice versa, a 152.6 m$^2$ lot requires a frontage of less than 12 m.

From the viewpoint of actual use, some constraints on the size and shape of lots are necessary. These constraints are especially important for small lots. They should include

\[ f \geq f_{\text{min}}, \quad d \geq d_{\text{min}}, \quad \text{and} \quad S \geq S_{\text{min}}, \]

where $f_{\text{min}}$, $d_{\text{min}}$, and $S_{\text{min}}$ are, respectively, the minimal frontage, depth, and size making sense in practice. The effective areas of lot size satisfying these conditions are shaded in Fig. 5.

In the figure, $f_1$, $f_2$, and $f_3$ are used to indicate the frontages at which the three constraints and the $C_3 = 0$ curve meet. The values of $f_1$, $f_2$, and $f_3$ can be computed as below:

If $f_2 > f_3$, $f_1$ and $f_2$ are the vertexes of the effective areas, and

\[
\begin{align*}
  f_1 &= \frac{S_{\text{min}}}{d_{\text{min}}} \\
  f_2 &= 66.313 \times (-1.123) \\
  &= +\sqrt{0.317 + (1.123 - 0.0295d_{\text{min}})^2} +0.0295d_{\text{min}}).
\end{align*}
\]

If $f_2 \leq f_3$, $f_3$ is the vertex of the effective areas, and

\[
  f_3 = 66.313 \times (-1.123 + 0.0298\sqrt{1774.7 + S_{\text{min}}}).
\]

Similar to the former cases, a minimum lot size is necessary and the size limit becomes larger as the frontage increases. Moreover, when the frontage is larger than the maximum of $f_2$ and $f_3$, the effective area is restricted by the $C_3 = 0$ curve; otherwise, it is subject to the constraints of $f_{\text{min}}$, $d_{\text{min}}$, and $S_{\text{min}}$. This suggests that, if the frontage is very small, considerations on the feasible use are more important than the economic balances.

For regular lots, the depth can be roughly estimated from the ratio of lot size and frontage. The feasible area for the marginal depth-frontage conditions to get positive net benefits is plotted in Fig. 6. It reveals that, given a certain lot size, there is a marginal configuration ($f^*$, $d^*$) and the positive net benefits are larger if the ratio of depth to frontage is bigger. The largest value for $d/f$ on the $C_3 = 0$ curve can be derived by maximizing the partial derivative of $C_3$ on $f$. Being larger than this ratio is actually a sufficient condition to ensure positive net benefits.

The analysis results in the above three cases strongly suggest that the net benefits of redevelopment are not always positive. For lots smaller than a certain limit the benefits are negative. When the lots involved in the road-widening project are wide (the frontages are large), the limit of lot size is even larger. The net benefits differ with the shape of lots, too. Even if the involved lots have the same size, those with better shapes get greater benefits. On the contrary, poor shapes (such as wide and shallow) not only pare the benefits but also yield difficulties for practical use. Therefore, adopting uniform land contribution rates without analyzing the size and shape of each lot, as in the land readjustment projects, is not reasonable.

**Impact of relaxing FAR controls**

According to the current building regulations, the maximal FAR of lots is in proportion to the width of the front roads thus the widening of road would lead to a higher FAR. Relaxing the planning controls as such is thought of an incentive for stimulating the involvement of residents in redevelopment projects.

In the case of the road-widening project, the effect of relaxing FAR controls was examined by comparing the net benefits of the project in a relaxation case with a non-relaxing case. One may notice that the hedonic regression model had only identified the effect of actual FAR of lots, which is not necessarily the maximal FAR permitted by planning, since property owners can arbitrarily decide how
many floor areas to build under market conditions. To make a simple investigation, two cases were compared, one with the actual FAR being raised after the project and one with it remaining the same. As of the former case, the relaxation cases were compared in respect to frontage were obtained with Eq. (5). Then the marginal conditions of lot size with respect to frontage were obtained with Eq. (5). Then the relaxation and non-relaxation cases were compared in Fig. 7.

The curves of the relaxation case are lower than the non-relaxation case, implying that it becomes easier to get economic balance if the controls on FAR are relaxed. However, attentions should be paid in that the effects of relaxation are very limited for small lots. In addition, the relaxation does not affect the interception of the balancing curves on the frontage-axis. This suggests that relaxing FAR controls cannot raise the net benefits of the land lots if their frontage is less than this threshold. Actually, if the frontage is smaller than the intersection of the balancing curves with the bounding line of lot size, the relaxation makes no meaningful effect.

These examinations prove that, at least in densely built residential areas, relaxing FAR controls does not effectively raise the net benefits of redevelopment project as expectation. Furthermore, in overcrowded residential areas, it may inversely lead to higher building densities and amplify the difficulties of redevelopment (Asami, 2000). Density incentives also have the adverse consequences of infrastructure pressures, loss of environmental characters, accelerated economic obsolescence, etc. (Lum et al., 2004). These considerations should be incorporated to the current planning regulations.

Conclusions

This paper applied the results of hedonic regression analyses on the externalities of local environments to analyze the influence of lot size and shape on urban redevelopment projects. Although the analyses were based on a limited sample, the analyses provide quite a lot of implications for planning and practice.

The main results of the analyses are that a minimum lot size is necessary for providing enough social benefits to compensate for the sacrificed land and other costs in redevelopment projects. The net benefits of redevelopment are not always positive and for lots smaller than the above limit the benefits are negative. When the frontage of the lots involved in the road-widening project is large, the limit of lot size is even larger. Meanwhile, the net benefits also differ with the shape of lots. The lots with poor shape get less or no benefits. Further analysis revealed that relaxing FAR controls is useful for achieving economic balance but the policy is less effective for small lots and has no effect on lots with very small frontage. These results suggest that it is critical to reconsider the effects of lot size and shape in the planning policies of redevelopment projects for getting more residents involved.

Acknowledgments

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Appendix A. The standard errors of the net benefits of projects.

With the standard errors of individual estimates (s.e.($a_i$)) and their correlations (ρ($a_i$, $a_j$)), the standard error of net benefit can be computed with the following formula:

$$
\text{s.e. of } \sum_i a_i x_i = \left[ \sum_i (\text{s.e.}(a_i))^2 + \sum_{i,j} (2\text{cov}(a_i, a_j)) \times x_i \times x_j \right]^{0.5},
$$

where $a_i$ is the regression coefficient for the $i$th factor, $x_i$ is the $i$th factor (such as $[df - (d + w') \times f]$), and $\text{cov}(a_i, a_j)$ means the covariance of $a_i$ and $a_j$, which equals $\rho(a_i, a_j) \times \text{s.e.}(a_i) \times \text{s.e.}(a_j)$.

<table>
<thead>
<tr>
<th>Corresponding variable</th>
<th>$x_i$</th>
<th>$a_i$</th>
<th>s.e.($a_i$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-w/'f</td>
<td>0.9115</td>
<td>0.0994</td>
</tr>
<tr>
<td>Station</td>
<td>-w/'f</td>
<td>-0.0157* 5</td>
<td>0.0016 * 5</td>
</tr>
<tr>
<td>Road_width</td>
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<td>0.0073</td>
</tr>
<tr>
<td>Shinjuku</td>
<td>-w'f</td>
<td>-0.0168 * 22</td>
<td>0.0026 * 22</td>
</tr>
<tr>
<td>Pavement</td>
<td>df</td>
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<td>0.015 * 2</td>
</tr>
<tr>
<td>Frontage</td>
<td>-w'f</td>
<td>0.0058</td>
<td>0.0024</td>
</tr>
<tr>
<td>Parkinglot</td>
<td>-w'f</td>
<td>0.0382</td>
<td>0.0108</td>
</tr>
</tbody>
</table>
In the case of $C_1$, which has seven terms defined in Table 5, $x_i, a_i, \text{s.e.}(a_i)$, and $\rho(a_i, a_j)$ are given in Tables A.1 and A.2.

**References**


