An Impact Analysis of Land Use Control and Incentives on Roadside Environment

Kenji DOI*, Dr. of Engineering
Mr. Naohisa Okamoto**

1. Introduction

Since the latter half of the 1960's, environmental problems resulting from the increase in road traffic demand began to draw attention in Japan. At present, various emissions such as noise, NO_x, CO and CO_2 by the transport sector are drastically increasing ahead of those from the industrial and household sectors. In order to cope with the problems, which affect local as well as the global environment, a wide range of efforts has been made in addition to improvement of the motor vehicle and traffic regulations and controls to preserve the harmony between roads and their environment as follows:

- improvement of road structure such as the installation of noise barriers and buffer zones,
- development of a systematic road network including bypasses and ring roads and
- roadside improvement which aims at modifying land use utilization to bring it in harmony with the roadside environment.

However, the quality of roadside environment along many trunk roads has become rather worse in terms of welfare damage and so on. One of the major causes of this problem is the difficulty in controlling land use, specifically the inadequate utilization of areas adjacent to the trunk road due to the construction of dwellings along these areas.

This study aims at analyzing the mechanism of roadside land use considering land market and planning regulation and consequently examining the potential ability of land use control and incentives in improving environmental damage. This study first develops a system of simultaneous equations comprising zoning decision by planning authorities and land price formation, whereby the effects of zoning regulation on the land market are examined. Zoning decision model and land price model are specified as functions of locational attributes, i.e.,

*Associate Professor, Department of Information and Environmental Engineering, Tokyo Institute of Technology
**Research Associate, Department of Civil Engineering , Tokyo Institute of Technology

accessibility to trunk road, traffic condition and environmental quality and so on. Secondly, a modeling technique for describing roadside land use is developed as a locational competition model. Finally, an impact analysis on land use and the environment in roadside areas is conducted by using the model and the feasibility of relieving environmental damage is examined.

2. Land Use in Roadside Areas and Its Influence on Environmental Value

a) Land Use in Areas Adjacent to the Trunk Roads

Figure 1 shows the land use patterns of roadside areas in the eastern part of the Tokyo Metropolitan Region in 1989. Due to the progress of suburban development in these areas a rapid increase in road traffic and accompanied environmental deterioration have been observed (see Picture 1). More than 2 thousand land use data are selected from the areas adjacent to trunk roads by random sampling. . In the figure, land use is classified into five categories, namely, dwellings, neighborhood commercial facilities, commercial facilities, industrial facilities and vacant sites, wherein the roadside is divided into 3 areas according to the distance from trunk roads. It is obvious that even in the area of a 0-25m distance from the trunk road, the share of dwellings is highest and then, this is followed by commercial facilities. The share of dwellings is as much as 37 % in the 0-25m area and 54% in the total area i.e., 0-75m area. Current nonsuitable utilization of roadside area is assumed to be mainly caused by insufficient planning

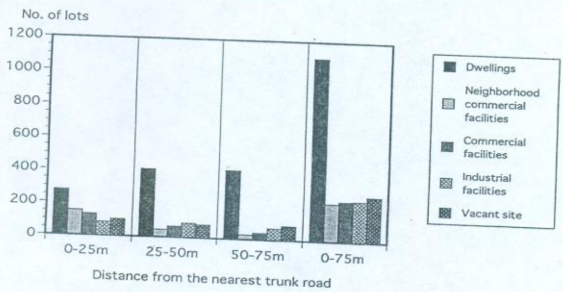
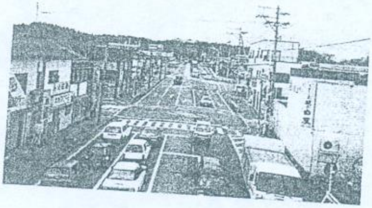


Figure 1. Land Use Pattern in Areas along Trunk Roads



Picture 1. Land Use along Trunk Roads

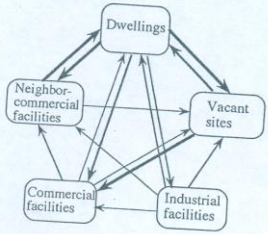


Figure 2. Direction of Land Use Change

direction or lack of enforcement by local planning authorities.

Figure 2 shows the major direction of land use change during the period of 1984-1989. This figure shows that a change from dwellings to neighborhood commercial facilities and that from vacant site to commercial facilities are the most significant. However, the change from neighborhood commercial facilities to dwelling, which is less suitable for roadside is also noticeable.

b) Influence on Environmental Value

Even at the same location, environmental value differs depending on locators or utilization of land. In this paper, the hedonic price approach is adopted for valuing roadside environmental quality. This approach is based on capitalization hypothesis and is proved to have high effectiveness in measuring intensive and localized impact such as roadside pollution. The following hedonic price function is often applied to value air quality, noise emission and so on.

$$P_{ki} = P_k(Q_i, X_i) \qquad (1)$$

where P_{ki} is land price at site **i** which is utilized in land use category **k**, Q_i is environmental quality and X_i represents attributes at site **i** except environmental quality. Although the original hedonic function is developed by Rosen(1974) and Freeman(1978) as a housing-price function, this study applies it to commercial, industrial and the other land price functions. Table 1 shows the estimated results of the equation by using the sampled data.

Table 1. Estimated Result of Hedonic Land Price Equations

	Dwellings	Neighborhood commercial facilities	Commercial facilities	Industrial facilities	Vacant sites
Noise emission level (dB(A))	-0.157* (-5.76)	-0.0474* (-3.49)	0.0223 (0.18)	0.0594 (0.78)	-0.0831 (-1.01)
Distance from the trunk road (10m)	0.00963* (-3.15)	-0.0658* (-2.23)	-0.143* (-4.85)	-0.0559* (-2.83)	-0.0729* (-3.27)
Supply of sewerage system (dummy)	0.0742 (1.81)	0.0915* (2.30)	0.239* (2.75)	0.0514 (1.69)	0.0680 (1.93)
Day-time population density (person / ha)	0.618* (2.12)	0.546* (4.40)	0.478* (3.55)	0.592 (0.78)	0.536* (3.01)
Constant	0.484* (2.51)	-0.412* (-3.64)	11.4* (3.48)	-6.40* (-3.11)	-7.77 (-1.75)
R square	0.646	0.622	0.741	0.794	0.727
No. of observations	132	45	59	47	41

Note: hedonic price func. P_{ki} (10 thousand yen/m^2) $= \alpha_k Q_i + \Sigma \beta_{km} X_{mi}$
Significance at the 5% level is indicated by *

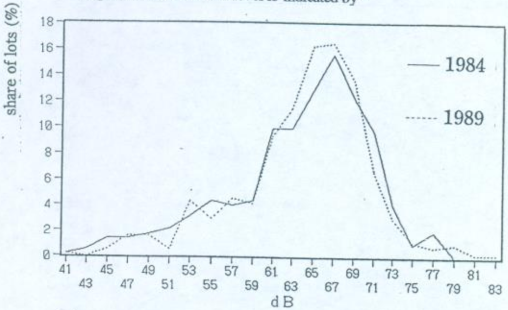


Figure 3. Noise Emission Level in Roadside Areas

In the model specification, noise emission level is introduced as an indicator of roadside environmental quality. Figure 3 shows the distribution of noise emission level in 1984 and 1989 for sampled sites. The estimated parameters of noise emission level have an expected sign and significance for dwelling and neighborhood commercial facilities. The effect of an increase in noise emission level is estimated to be about 1570 yen/m²/dB(A) for dwellings and 430 yen/m²/dB(A) for neighborhood commercial facilities. It is also shown in the Table 1 that both commercial and industrial facilities are not affected significantly by noise emission.

Figure 4 shows two kinds of definition of measure of environmental impact, i.e., a) environmental damage cost(DC) and b) opportunity cost(OC). The first one is defined as a difference in land value between acceptable level **e*** and current level **e** of environmental quality. The second one is defined as a difference between land value under residential use and the land value under non-residential use which is not affected too much by road traffic and its environmental impact. This represents an opportunity cost i.e., a loss of value which would have been secured if roadside land was occupied by non-residential facilities instead of residential facilities. By using the estimated values of noise parameters, it is concluded that the opportunity cost in the study areas is 1000 - 1500 yen/m²/dB(A)

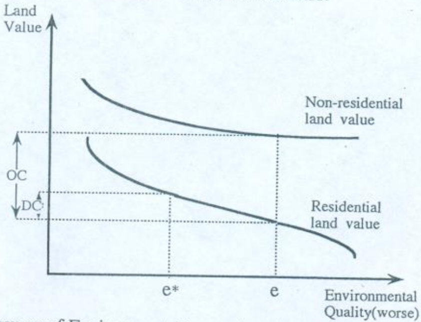


Figure 4. Measures of Environmental Impact based on the Change in Land Values

c)Inefficient Utilization of Roadside Areas and the Institutional Countermeasures

A majority of the road sections suffering emission level which exceed the environmental standard can be found in the roadside areas of residential district. Therefore, in addition to the improvement of structures, the promotion of amendments to land utilization suitable for the areas along trunk roads has been implemented. In 1980, the "Law for the Improvement of Areas Along Trunk Roads" -commonly referred as "Roadside Law" - which includes measures such as designation of roads for environment improvement, the drawing up of roadside improvement plans and regulations based on the Building Standard Law was enacted. However, since the drawing up of the plans usually takes several years, no more than five routes with a total length of 83.5km have been targeted for improvement until 1993.

3. Modeling the Roadside Land Use under Zoning Regulation

a) Land Use Decision under Single Zoning Regulation

Under perfect competition, land is allocated to the highest bidder, and to the extent that local planning authorities mimic the market, more land is allocated to a use the higher its relative value. However, in roadside areas which often bear severe environmental damage, planning authorities are expected to play a positive role in guiding land use in harmony with road traffic.

In this paper, the effects of planning regulations on land use decision are considered in the modified framework of locational competition theory. At first, a two-stage estimation procedure is used that allows us to determine the responsiveness of land use zoning to land values. Secondly, because land values provide an information on the suitability of utilization of a site, land use decision is modeled as a probabilistic choice model of an alternative utilization type.

Zoning Decision (single)

A single zoning decision in which authorities either designate a district as a planning zone or not can be formulated as follows:

$$I_i^* = \begin{cases} 1 & \text{if} \quad I_i \geq 0 \\ 0 & \text{if} \quad I_i < 0 \end{cases} \tag{2}$$

$$I_i = \gamma Z_i + v_i \tag{3}$$

where I_i is an index which represents the suitability of site **i** to the zoning and is assumed to be a function of locational attributes Z_i. V_i is an error term which is assumed to be normally distributed with variance σ_v. γ is a coefficient parameter.

Land Price Formation

Since zoning decision imposes a restriction on utilization of land, land values with a zoning regulation differ from those without as below:

$$y_{wi} = \beta_w x_i + u_{wi} \qquad \text{(w: with a zoning regulation)}$$
$$y_{oi} = \beta_o x_i + u_{oi} \qquad \text{(o: without)} \qquad (4)$$

where x_i is a vector of locational attributes at site i and u_i is an error term which is assumed to be normally distributed with variance σu. β is a coefficient parameter.

By incorporating eq.(2) into eq.(4), land price which can be observed in the market is provided by the following equation:

$$y_i^* = \begin{cases} y_{wi} & \text{if} \quad I_i^* = 1 \\ y_{oi} & \text{if} \quad I_i^* = 0 \end{cases} \qquad (5)$$

The above equation indicates that land price y_i^* is observed as y_{wi} at a site with the zoning regulation and as y_{oi} without it. Wallace(1988) and McMillen and McDonald(1989, 91) have argued that this kind of land price equations(4) will exhibit selectivity bias if local authorities use land values to guide zoning decisions. Selectivity bias pointed by Wallace et al. will be present in land price formation if land value y_i is also determined depending on locational attributes. Therefore, correlation between u and v cannot be assumed to be equal to zero and consequently, land price y_i^* is observed as expected values, as shown below:

$$E[\, y_{wi} \mid I_i^*=1 \,] = \beta_w x_i + E[\, u_{wi} \mid v_i \geq -\gamma z_i]$$
$$E[\, y_{oi} \mid I_i^*=0 \,] = \beta_0 x_i + E\,[\, u_{oi} \mid v_i < -\gamma z_i] \qquad (6)$$

The second term contains the expected value of the error which follows the truncated normal distribution due to the correlation between zoning decision error v_i and land price formation error u_i.

Land Use Decision

Actual land use does not always comply with the zoning regulation especially when it is not strictly enforced, and thus , it mimics the market. It is possible that the utilization against the zoning regulation is realized if expected land price in such utilization is higher than that of the utilization in accordance with the zoning regulation. In such case, land use decision can be explained in the following stochastic competition model:

$$P_i = \frac{1}{1+\exp(E[y_{oi}|I_i^*=1] - E[y_{wi}|I_i^*=1])} \tag{7}$$

where P_i is probability that the utilization according to the regulation is realized. In deriving the above equation, error terms u_{wi} and u_{oi} concerning land values are assumed to follow the Gumbel distribution instead of the normal distribution for simplicity .

b) Land Use Decision under Multi-Zoning Regulation

The mechanism of zoning decision, land price formation and land use decision can be easily extended to the case of multi-zoning regulation as follows.

- Zoning Decision (Multiple):

$$I_i^* = s \quad \text{if} \quad I_{si} \geq \max_r\{ I_{ri},\ r=1,..,M,\ r\neq s\}, \quad \text{where} \quad I_{ri} = \gamma_r z_i + v_{ri} \tag{8}$$

where I_{ri} represents the suitability of a zoning category **r** at site **i**, which is explained by the attributes of the site.

Based on eq.(8), the probability that site **i** is designated to a zoning category s is represented as follows:

$$\mathrm{Prob}(I_i^*=s) = \mathrm{Prob}(I_{si} \geqq \max_r\{ I_{ri}, r\neq s \})$$

$$= \mathrm{Prob}(v_{si} \geqq \max_r\{ I_{ri}, r\neq s \} - \gamma_s Z_{si})$$

Supposing that the error term v_s follows the Gumbel distribution, the following zoning decision model in the form of Logit model can be derived, as shown below:

$$\mathrm{Prob}(I_i^*=s) = \frac{\exp(\gamma_s z_i)}{\sum_r \exp(\gamma_r z_i)}$$

- Land Price Formation

$$y_{si} = \beta_s x_i + u_{si} \qquad \text{if} \quad I_i^* = s \tag{9}$$

where y_{si} is land value of site **i** with a zoning category **s**.

Similar to eq.(6), expected land price with each category of zoning is shown as follows:

$$E(y_{si} \mid I_i^*=s) = \beta_s X_{si} + E(u_{si} \mid v_{si} \geqq \max_r\{ I_{ri}, r \neq s \} - \gamma_s Z_{si}) \quad (10)$$

$$E(y_{si} \mid I_i^* \neq s) = \beta_s X_{si} + E(u_{si} \mid v_{si} < \max_r\{ I_{ri}, r \neq s \} - \gamma_s Z_{si}) \quad (11)$$

By replacing $\max_r\{ I_{ri}, r \neq s \} - v_s$ by ε_s, the above equations are transformed as follows:

$$\begin{aligned} E(y_{si} \mid I^*=s) &= \beta_s X_{si} + E(u_{si} \mid \varepsilon_{si} \leq \gamma_s Z_{si}) \\ &= \beta_s X_{si} - \rho_s \sigma_s W_{si}, \end{aligned} \qquad W_{si} = \frac{\phi[J_s(\gamma_s Z_{si})]}{1-F_s(\gamma_s Z_{si})} \quad (12)$$

$$\begin{aligned} E(y_{si} \mid I^* \neq s) &= \beta_s X_{si} + E(u_{si} \mid \varepsilon_{si} > \gamma_s Z_{si}) \\ &= \beta_s X_{si} + \rho_s \sigma_s W_{si} \end{aligned} \quad (13)$$

where ρ_s is the correlation coefficient between u_s and ε_s and σ_s is the variance of u_s. $F_s(\cdot)$ and $\phi(\cdot)$ represent the cummulative function of Gumbel distribution and the density function of standard normal distribution individually. $J_s(\cdot)$ is the transformation function from Gumbel disrtibtion to standard normal distribution.

The degree of selectivity bias in land price formation is shown by the value of $\rho_s \sigma_s$. If it is obtained as a negative value, it suggests that the zoning in category **s** tends to follow the market and thus increases the land price under the utilization in accordance with the zoning **s**. On the contrary, a positive value sign of $\rho_s \sigma_s$ suggests that the zoning decreases the land price.

- Land Use Decision

$$P_{ki} = \frac{\exp(\sum_r \alpha_{rk} y_{ri})}{\sum_{k'} \exp(\sum_r \alpha_{rk'} y_{ri})} \quad (14)$$

where P_{ki} is the probability that the roadside area **i** is occupied by land use **k**, y_{ri} is the land price under the zoning in category **r** and α_{rk} is a coefficient parameter. In the above model, the expected land price is regarded as a determinant of land use and attractiveness of the area for a utilization as defined by the weighed combination of expected land prices $\Sigma\, \alpha_{rk} \cdot y_{ri}$.

Figure 3 shows the framework of modeling the zoning decision, land price formation and land use decision.

4. Estimation Results

For model estimation, a two-stage procedure is applied. In the first stage, simultaneous equations of zoning decision and land values are estimated by using maximum-likelihood techniques and then, land use dicision model is estimated based on the estimated parameters in the equation of land price formation. In Table 2, zoning regulation related to residential and commercial use in Japan is described.

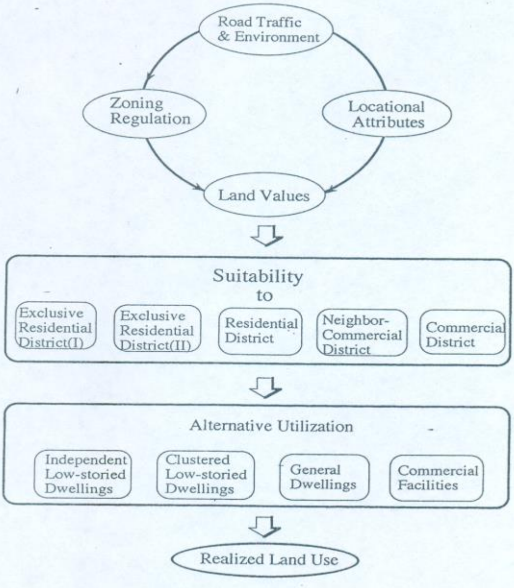


Figure 5. Framework of the Models

Table 2. Zoning Category

Exclusive Residential District(I):	
	Designated for the protection of a desirable living environment for independent low-storied dwellings.
Exclusive Residential District(II):	
	Designated for the protection of a desirable living environment for intermediate -and high-storied dwellings.
Residential District:	
	Designated for utilization by dwellings
Neighborhood Commercial District:	
	Designated to increase the convenience of the commercial facilities engaged in the supply of daily necessities of the inhabitants in nearby residential facilities.
Commercial District:	
	Designated for the ulitization by commercial facilities

Table 3 shows the estimated value of parameters in the zoning decision model. In the table, parameters are estimated with the condition that those values for Residential District are zero. These results suggest that day-time population density has the highest contribution to the zoning decison, followed by the distance from the station, which is regarded as the center of the district. Furthermore, it is shown that the higher population density of the area is and the nearer the area is located to the station, the less Exclusive Residential District is designated and

Table 3. Estimated Result of Zoning Decision

—	Exclusive residential District		Residential District	Neighborhood Commercial District	Commercial District
	Type I	Type II			
Distance from the nearest station (km)	1.192* (2.77)	0.501 (1.69)	—	-0.153* (-1.26)	-3.994* (-4.45)
Distance from the trunk road (100m)	-0.0575 (-1.13)	0.0210 (0.583)	—	-0.0252 (-1.53)	-0.0128 (-1.31)
Day-time population density (person / ha)	-0.348* (-8.45)	-0.0419* (-1.56)	—	0.0237* (5.42)	0.154* (7.57)
constant	-1.412* (-2.77)	-0.553 (-1.24)	—	-0.246 (-0.463)	2.158* (3.87)
No. of observations	42	40	36	32	45
Likelihood ratio	0.202				
Hit ratio	0.629				

Notes: Volume ratio-- Ratio of the total floor area of buildings to the site area
Significance at the 5% level is indicated by *

Table 4. Distribution of land price

	Mean	Standard deviation	
Exclusive Residential District (I)	210,476	121,147	(42)
Exclusive Residential District(II)	435,575	182,189	(40)
Residential District	397,889	207,397	(36)
Neighborhood Commercial District	1,145,864	662,811	(32)
Commercial District	3,447,714	2,772,024	(35)

unit of land price: yen/m^2 , ( ): No. of observation

the more Commercial District is designated. Distance from the trunk road does not have a significant influence on zoning decision. Goodness of fit of the model shows 0.629 in hit ratioand 0.202 in likelihood ratio. Table 4 shows a distribution of land prices, which is used to estimate the land price formation model by zoning category. Land price in areas with the designation of Commercial District is highest, which is 10 times higher than that with the designation of Exclusive Residential District(I).

Table 5 shows the estimated results of land price models. Similar to the results in Table 1, the environmental factor, i.e., noise emission level is significant at the 5% level and estimated as a negative value in roadside areas included in Exclusive Residential District and Residential District. Selectivity bias $\rho\ \sigma$ is significant in all zoning districts, and thus, it can be concluded that zoning regulation affects the land market. Except in the Residential District, bias parameters are estimated as negative values which indicate that zonings such as Exclusive Residential District, Neighborhood Commercial Distrrict and Commercial District tend to follow the market. A positive value of $\rho\ \sigma$ concerning Residential District suggests that too many areas along trunk roads are designated as Residential District and land values would have been higher if the areas were assigned to other types of utilization.

Table 6 presents the estimated land use decision model for roadside areas. In this table, for

Table 5. Estimated Results of land price equations

	Exclusive Residential District		Residential District	Neighborhood Commercial District	Commercial District
	Type I	Type II			
Noise emission level (dB(A))	-0.173* (-5.21)	-0.148* (-2.83)	-0.942* (-3.15)	-0.224 (-1.79)	0.0196 (0.86)
Distance from the trunk road (10m)	-0.0184 (-1.11)	0.0270* (2.23)	0.0069 (0.05)	-0.0526* (-2.60)	-0.103* (-1.62)
Distance from the nearest station (km)	-0.0116 (-0.086)	-0.240* (-3.42)	-0.0834 (-0.616)	-0.0308* (-2.51)	-0.309* (-2.31)
Sewerage system (dummy)	0.144 (1.50)	0.161 (1.42)	0.638 (0.381)	0.163 (0.879)	0.408 (1.75)
Day-time population density (person / ha)	0.573* (7.23)	0.389* (3.16)	0.653* (5.25)	0.621* (4.24)	0.507* (3.24)
Designated volume ratio* (%)	0.0245 (1.74)	0.0214 (1.15)	0.0238 (2.52)	0.0331* (2.37)	0.0338* (3.70)
constant	11.2* (4.09)	11.2* (3.47)	11.3* (2.54)	11.5* (3.13)	12.1* (1.95)
bias W	-0.281* (-3.27)	-0.923* (-5.61)	0.0626* (2.38)	-0.652* (-3.48)	-1.14* (-3.53)
R square	0.799	0.612	0.601	0.764	0.719
No. of observations	42	40	36	32	35

example, the locational attractiveness for independent low-storied dwellings is explained as a weighed combination of suitability to Exclusive Residential District (I) and that of Exclusive Residential District (II). Also, the following outcomes were obtained:

- utilization of land by clustered low-storied dwellings depends solely on the suitability to Exclusive Residential District (II),
- utilization of land by high-storied dwellings depends on the suitability to Exclusive Residential District (II) and Residential District and
- utilization of land by commercial facilities depends on the suitability to Residential District, Neighborhood Commercial District and Commercial District.

In the table, parameters which are not significant at the 20 % level are omitted. The fitness of the model seems to be very high with values of 0.521 in the likelihood ratio and 0.792 in the hit ratio.

Table 6. Estimated Results of Land Use Decision Model for Roadside Areas

	Independent low - storied dwellings	Clustered low- storied dwellings	High - storied dwellings	Commercial and business facilities
Suitability to Dxclusive Residential District (I)	0.371* (4.77)	0.360* (4.12)		
Suitability to Exclusive Residential District (II)	0.0815* (2.11)		0.0768 (1.89)	
Suitability to Residential District			0.271* (5.08)	0.219 * (3.74)
Suitability to Neighbor-Commercial District				0.0246* (3.34)
Suitability to Commercial District				0.0327* (4.03)
Constant		-0.951 (-1.36)	-1.38 (-1.53)	
No. of observations	169			
Likelihood Ratio	0.521			
Hir ratio	0.792			

5. The Impact of Land Use Control and Incentives on Roadside Environment

In the above section, it was confirmed that the zoning of Residential District in roadside areas gives an unfavorable effect on land price formation and land use decision and consequently, dwellings located in these areas bear the most serious environmental damage. Legal zoning system provides regulation and incentives on land use mainly by controlling the volume ratio, which determines the profitability of land and therefore, in this section, it is examined whether the control of volume ratio has a possibility in improving roadside land use and the environment.

The following scenario, namely, an increase in volume ratio from 200% to 400% in areas designated to Residential District are chosen. As shown in Table 7 which represents current condition of volume ratio, the lowest maximum volume ratio in Residential District is 200% and the highest is 400%. Figure 6 shows the predicted change of land use in terms of probability of utilization by each type of facility. This figure shows that given an increase in volume ratio, the probability of utilization by scattered dwellings decreases and that by commercial facilities increases. An increase of volume ratio as much as around 30% makes it possible to change dominant land use from dwellings to commercial facilities in roadside areas.

Figure 7 shows an increase in roadside environmental value due to the improvement of land use. In the study area of which around 60% of land is occupied by dwellings, it is predicted that the increase in volume ratio from 200% to 400 % can reduce environmental damage cost by as much as around 7200 yen/m^{2}.

Table 7. Restrictions on Utilization of land

	Exclusive residential district(I)	Exclusive residential district(II)	Residential district	Neighbor-Commercial district	Commercial district	Industrial disctric
Designated Volume Ratio (%)	50 60 80 100 150 200	100 150 200 300	200 300 400	200 300 400	400 500 600 700 800 900 1000	200 300 400
Building-to-land Ratio (%)	30,40 50,60	30,40 50,60	60	80	80	60

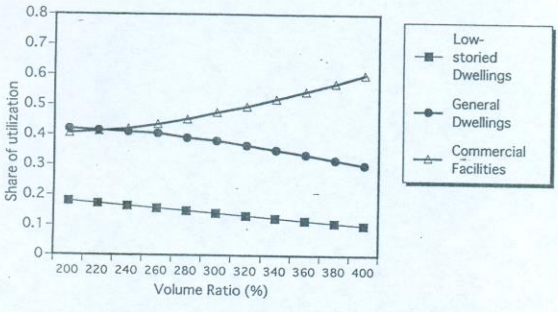


Figure 6. Change in Roadside Utilization due to the Increase of Designated Volume Ratio

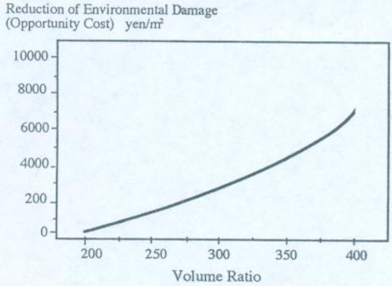


Figure 7. Change in Roadside Environmental Value

6. Conclusion

To relieve environmental damage in roadside areas has been one of the key issues in environmental policies in Japan. This study attempted to estimate the effect of zoning regulation on land use and the environmental value in roadside areas, based on a system comprising zoning decision model, land price formation model and land use decision model. It was confirmed that current zoning regulation provide an unfavourable bias on land price formation and utilization of roadside areas and consequently, dwellings located in these areas bear the serious environmental damage. Furthermore, environmental opportunity cost caused by inefficient land use is estimated at 1000 -1500 yen/m^2/dB(A).

Although these results provide the evidence that establishment of a more appropriate land use control including a prohibition of utilization, which is specific to roadside areas and more strict than the current zoning system, is necessary for roadside areas, but, it seems difficult in Japan to introduce it due to the difficulty in securing a public consensus. Instead of a stricter land use control, the modification of the volume ratio has been tried. Therefore, a scenario analysis was conducted on the effect of modification of designated volume ratio which plays a key role in the current zoning system. Subsequently, it was shown that an increase in volume ratio in roadside areas can contribute to change the utilization of land from residential facilities to non-residential facilities, and therefore, considerably mitigating environmental damage.

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