Benefits of undergrounding utility lines in consideraion of three-dimensional urban landscape

Shota ISHIGOOKA[1], Tatsuhito KONO[2], and Hajime SEYA[3]

[1] Non-Member of JSCE, Graduate Student, Dept. of Information Sciencies, University of Tohoku
(6-06, Aza-aoba 6, Aramaki, Aoba-ku, Sendai-shi, Miyagi 980-8579, Japan)
E-mail:shota.ishigooka.q2@dc.tohoku.ac.jp
[2] Member of JSCE, Professor, Dept. of Information Sciencies, University of Tohoku
(6-06, Aza-aoba 6, Aramaki, Aoba-ku, Sendai-shi, Miyagi 980-8579, Japan)
E-mail:kono@plan.civil.tohoku.ac.jp
[3] Member of JSCE, Associate Professor, Dept. of Civil Engineering, University of Kobe
(1-1, Rokkodai-cho, Nada-ku, Kobe 657-8501, Japan)
E-mail:hseya@people.kobe-u.ac.jp

We appraise the benefits of undergrounding utility lines and clarify the effects of road width and building height. Our results show that the willingness to pay (WTP) for undergrounding utility lines is lower as the road becomes wider and the buildings along the road become higher. However, when the road is wide, the WTP does not change much regardless of the height of the buildings. In addition, the average value of the benefit-cost ratios of previous undergrounding projects is approximately 2.27 to 2.65. However, 3-17% of these projects have benefit-cost ratios of less than 1. This indicates that we should perform cost-benefit analyses for the future undergrounding projects.

Key Words : *Undergrounding utility lines, Hedonic approach, Width of a road, Height of buildings*

1. Introduction

Recently, discussion on undergrounding utility lines has grown in Japan. For instance, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) launched a committee in January 2017 to discuss the potential direction for undergrounding utility lines. However, Japan is left behind by not only developed countries but also developing countries. For example, the rate in the 23 special wards of Tokyo is 7%, while almost 100% undergrounding rate is attained in large cities in Europe[1)]. Typical discussion indicates that a main cause of such low rates in Japan is the cost of undergrounding lines. Because of such high costs, it may not be realistic to underground all utility lines in Japan. Instead, we need to discuss where we should underground lines and where we should not.

However, appropriate evaluations have not been conducted in past undergrounding projects. In addition, studies that measured the benefits of undergrounding utility lines in residential areas are rare (Mcnair (2010)[2)], Adachi, Inoue (2011)[3)]). A study group on the effects of undergrounding (MLIT (2007)) [4)]explored the benefit measurement method of undergrounding utility lines. But their method of setting the unit value is not based on sufficient reasoning due to a lack of reliable data.

The current study adopts the hedonic approach, which is a conventional benefit evaluation method of neighborhood amenities based on revealed preference, to estimate the benefit of undergrounding utility lines. The current paper is the first to evaluate the benefit, using the comprehensive data of undergrounded lines all over Japan.

Furthermore, the current study focuses on the improving landscape which is one of the benefits of undergrounding utility lines. Improving landscape could depend on the condition of the width of a road and the height of buildings. So, this condition can affect benefits of undergrounding utility lines. No previous papers have considered the effects of the width of a road and the height of buildings.

2. Analysis method

The current study adopts the hedonic approach. The current study uses the data of road rating (valuation of inheritance tax) as a dependent variable. This data is collected on the same method by the national tax agency and has a large number of locations. We can adjust the scale to derive the market value by dividing the value by 0.8. We use land price data in residences of municipalities which have undergrounded utility lines. Furthermore, in order to eliminate the effects of outliers, we only use the land price date within the 45% range from the median by prefectures.

We use this data of 2015 year. So, explanatory variables are prepared for the same year if possible, and for the nearest available year if not.

We can calculate benefits of undergrounded utility lines and explore the effects of the effects of the width of a road and the height of buildings, by hedonic approach based on capitalization hypothesis.

3. Empirical analysis

3.1. Empirical model

The functional form of empirical hedonic models cannot be pre-determined. We adopt the following three typical functional forms, that is, linear (eq. (1)), full log (eq. (2)), and semi Box-Cox (eq. (3)). These three forms have a common function Φ, which expresses the effects of undergrounding utility lines.

$$P_i = \alpha_0 + \sum_{k=1}^{K} \alpha_k z_{ik} + \Phi + \varepsilon_i \tag{1}$$

$$\ln(P_i) = \alpha_0 + \sum_{k=1}^{K} \alpha_k \ln(z_{ik}) + \Phi + \varepsilon_i \tag{2}$$

$$\frac{P_i^{\lambda} - 1}{\lambda} = \alpha_0 + \sum_{k=1}^{K} \alpha_k z_{ik} + \Phi + \varepsilon_i \tag{3}$$

$$\Phi = \delta_{iu}\left(\beta_u + \sum_{w=1}^{K} \beta_w \delta_{iw} + \beta_h \delta_{ih} + \sum_{m=1}^{K} \beta_m \delta_{im} + \sum_{p=1}^{K} \beta_p \delta_{ip}\right) \tag{4}$$

where P_i is land price per m^2, α_0 is the intercept, Z_{ik} is the kth (k = 1,2,…,K) attribute, ε_i is error term, α_k is the regression coefficient for the kth attribute, δ_{iu} is the dummy variable representing whether the utility lines on the road are undergrounded or not, δ_{iw} is the dummy variable for the width of a road. δ_{ih} is the dummy variable for the height of buildings. δ_{im} is the dummy variable of the multiplier effects of the width of a road and the height of buildings. δ_{ip} is prefecture dummy variable. β_u, β_p, β_w, β_m, and β_p are regression coefficients for the dummy variables.*i* means location i. The detail of Z_{ik} is shown in appendix.

The land price is appraised for each road, and we make a dummy variable of whether the utility line along the road is undergrounded or not (Yes:1, No:0). To capture neighborhood benefits, we define the neighborhood as the roads which at least partly lie within 50 m of the roads with undergrounded lines.

In terms of the dummy variable of the height of buildings, the current study uses a regulation value of the floor area ratio. The height of utility lines can be a threshold across which the willing to pay (WTP, hereafter) for undergrounding utility lines differs. This is because the increase in the expanse of the sky which we would be able to see if the utility lines were undergrounded depend on whether the height of buildings is higher than utility lines or lower. The buildings which are higher than utility lines can be built along the road where the floor area ratio is higher than 2 in consideration of building coverage ratio. So, we use the dummy variable of the height of building representing whether the floor area ratio is higher than 2 or lower.

The current study performed two types of analyses. First, we explore the effects of the width of a road and the height of buildings on WTP in the Tokyo metropolitan area in Japan(Analysis 1). Second, we appraise B/C in consideration of the effects of the width of a road in fifteen prefectures(Analysis 2).

For the Box-Cox type (eq. (3)), in all estimations, the values of λ which maximize the likelihood are estimated to be zero. That implies that the LHS of eq. (3) is ln(P). We show the result of this functional form because this form has the highest R-squared.

3.2. Analysis 1

After estimating the coefficient estimates for undergrounding utility lines, the current study calculates WTP per household in four categories, in order to explore the effects of the width of a road and the height of buildings on the WTP. We show the regression coefficients for analysis 1 in Table 1.

Table 1 Regression coefficients for analysis 1

Variables	Coefficient	P value
Intercept	11.92	0 ***
1) UGUL		
Basis	0.2320	2.58.E-57 ***
Middle and Wide	-0.1130	3.05.E-07 ***
High	-0.0515	2.53.E-03 **
Middle and Wide and High	0.0627	1.70.E-02 *
2) Neighbrood	0.0590	8.83.E-77 ***
Sample size	294,504	
R-squared	0.932	
P value of F-Statistic	< 2.20.E-16	

Note: “Basis” implies the parameter for the roads with a narrow width and low height of buildings

Table 2 Descriptive statistics for culclating WTP

	Width of a road			
	Narrow		Wide	
	Height of building			
	i) Low	ii) High	iii) Low	iv) High
1) Regression coefficient	0.232	0.181	0.119	0.130
2) Median value of floor area (m²/household)	59	55	64	58
3) Median value of land price	118	124	125	131
4) Benefits (1000JPY/m²)	27	22	15	17
5) WTP (1000JPY)	1,614	1,225	958	997

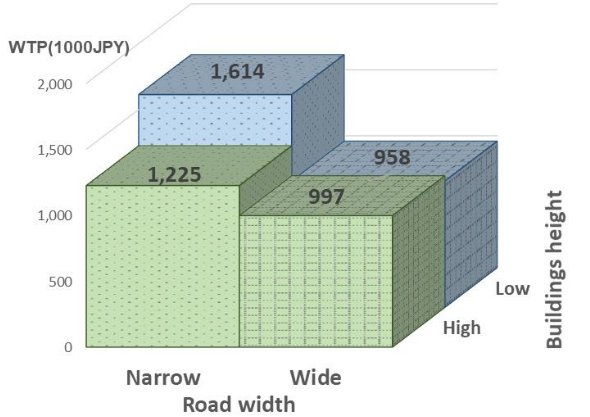

Fig.1 WTP in four categories

WTP is calculated by eq. (5). So, depending on the land price and lots area, WTP changes. Therefore, when we discuss WTP, we use the median value of the date of land price and lot area along the road classified in each category.

$$WTP = \Delta P \times h \tag{5}$$

$$\Delta P = \alpha_x \times P^* \tag{6}$$

where h is the lot area per household, α_k is the regression coefficient for the kth attribute, P^* is the land price after undergrounding lines.

As a result, we get the property of the result. The main characteristics of the result are summarized as Property 1.

Property 1.

(1) The WTP is higher as the width of a road becomes narrower.

(2) The WTP is higher as the height of buildings becomes lower.

(3) In the case of the wide width of a road, WTP does not change whether the height of buildings is high or low.

We conjecture that these properties depend on the increase in the expanse of the sky which we would be able to see, if the utility lines were undergrounded. The image of the increase in the expanse of the sky.

Regarding Property 1 (1), in the case of a narrow road, the increase in the expanse of the sky is wider than before the utility lines are undergrounded. On the other hand, in the case of a wide road, the increase in the expanse of the sky does not change whether the utility lines are undergrounded or not.

In respect to Property 1 (2), in the case of low buildings along the undergrounded road, the increase in the expanse of the sky is wider than the case of high buildings. In addition, the view from residences' room window is much improved by undergrounding utility lines in the case that the room is below the utility lines. But, the view will not change if the room is above the utility lines.

Regarding Property 1 (3), in the case of a wide road, the increase in the expanse of the sky does not change whether buildings are high or low. The increase in the expanse of the sky is wide in the first place. Therefore, the WTP does not change whether buildings are high or low.

3.3. Analysis 2

The current study appraises cost-benefit ratio in each road with undergrounded utility lines in consideration of the effects of the width of a road. We have the date of the length of the road, so we can appraise benefits of each road which have been undergrounded before 2015 year by multiplying the increase in land price by the length of the road. In order to calculate benefits of undergrounded utility lines, the current study defines how far benefits affect. We show the regression coefficients for analysis 2 in Table 3.

As a result, the average value of B/C is calculated to be 2.27 to 2.65, depending on the functional forms. This means that the previous undergrounding

Table 3 Regression coefficients for analysis 2

Variables	Semi Log		
	Coefficient	P value	
Intercept	11.01	0	***
1) UGUL			
Basis	0.1964	4.68E-79	***
Middle	-0.0603	4.25E-09	***
Wide	-0.1144	2.01E-09	***
2) Neighbrood	0.0892	8.04E-276	***
Sample size	868,007		
R-squared	0.937		
P value of F-Statistic <	2.20E-16		

Note: "Basis" implies the parameter for the roads with a narrow width

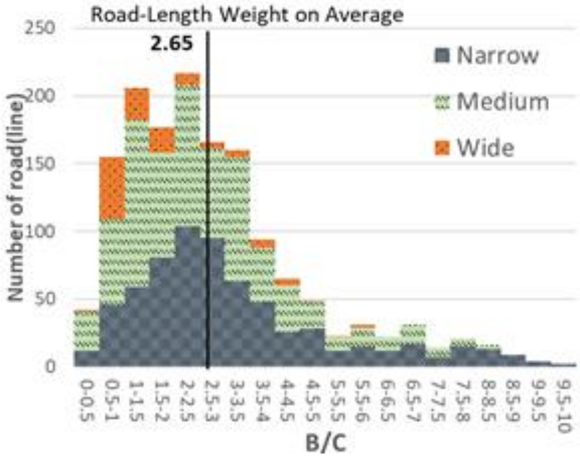

Fig.2 Histgram of Benefit-cost ratio

projects are efficient overall. However, as shown figure 2, the B/C takes a wide range of values. Some roads have high B/C, but 3-17% of roads have less than 1, depending on the functional forms. It implies that the utility lines are undergrounded on the road which should not be undergrounded. The reason may be that there is currently no available guideline showing how the benefit of undergrounding utility lines should be evaluated.

In the case of the wide width of road, there is a high possibility that the undergrounding project has a smaller B/C, than the average value.

4. Concluding remarks

The current study performed two types of analyses. As a result, the WTP is lower as the width of a road becomes wider and the height of buildings becomes higher. However, in the case that the width of a road is wide, the WTP do not change whether the height of buildings is high or low.

The average value of B/C of the projects of undergrounding utility lines is 2.27 to 2.65, depending on the functional forms. So, the previous undergrounding projects are efficient as a whole. However, when we look at the B/C ratio of each project, although some roads have high B/C, 3-17% of undergrounding projects have less than 1, depending on the functional forms. This suggests that we should undergo cost-benefit analyses for the future undergrounding projects.

ACKNOWLEDGMENT

This research was supported by grants from the Ministry of Education, Culture, Sports, Science and Technology (Grant-in-Aid for Scientific Research (B) 17H02517), which are gratefully acknowledged.

APPENDIX

We show the explanatory variables shown bellow.

1. Distance to the main station in the prefecture
2. Distance to the nearest station
3. Distance to the nearest bus station
4. Distance to the nearest primary sclool
5. Distance to the nearest middle school
6. Distance to the nearest hospital
7. Distance to the nearest clinic
8. Distance to the nearest post office
9. Maximum floor area ratio
10. Maximam building coverage ratio
11. Each of the following seven residential districts are considered as a dummy variable
    (i)Category 1 low-rise exclusive residential districts
    (ii)Category 2 low-rise exclusive residential districts
    (iii)Category 1 medium-to-high-rise exclusive residential districts
    (iv)Category 2 medium-to-high-rise exclusive residential districts
    (v)Category 1 residential districts
    (vi)Category 2 residential districts
    (vii)Quasi-residential districts
12. Landscape planning area dummy
13. Landscape emphasis planning area dummy
14. Newtown dummy
15. Newtown developped before 1976 dummy
16. Municipality dummy
17. Width of a road dummy(wide, middle, narrow)

REFERENCES

1) Ministry of Land, Infrastructure, Transport and Tourism (MLIT): Current situation of undergrounding utility cables in Japan (Title is translated into English by the authors) 2017. (https://www.mlit.go.jp/road/ir/ir-council/chicyuka/pdf03/09.pdf) (2020/2/20 access) (in Japanese).
2) McNair, B. and Abelson, P. : Estimating the value of undergrounding electricity and telecommunications networks, The Australian Economic Review, 43 (4), pp.376–388, 2010.
3) Adachi, Y. and Inoue, T. : Economic Benefit of Landscape without Electricity Pole (title is translated in to English by the authors), Jutaku-Shimpo-Sha, INC (in Japanese).,2011.
4) Ministry of Land, Infrastructure, Transport and Tourism (MLIT): The society for researches about the effect measurement technique of undergrounding utility lines: The manual cost benefit analysis about undergrounding utility lines, (Title is translated into English by the authors) (in Japanese), 2007.
5) Pines, D. and Weiss, Y.: Land improvement projects and land values, Journal of Urban Economics, 3 (1), pp.1–13,1976

(Received February 26, 2020)