Original Research Article

Valuation of compensation for land use restriction

Abstract

The Spatial Planning Act of Taiwan was implemented on May 1, 2016. To protect the legal rights of landholders, the Ministry of the Interior stipulated Measures for Compensating Loss Incurred during The Implementation of Spatial Planning in accordance with Article 32, Paragraph 3 of the Spatial Planning Act. Compensation is available for relocation or for alteration, where alteration refers to compensation for losses incurred when constructible land is made nonconstructible by a special municipality or county (city) and the land cannot be built on. It therefore includes compensation for the value of the right to develop the land.

Real estate is immobile and inflexible, which reduces uncertainty in its use. Studies have generally used net present value to analyze investment in and development of land. The conventional passive net present value method is employed to appraise land value, usually assuming that the investment plan must be developed immediately and is reversible. This is contrary to the characteristics of real estate investment and development, where ignoring the opportunities and flexibility generated by asset value uncertainty can readily lead to misappraisal of the value of an investment plan. The inclusion of future uncertainty in the valuation is the main difference between the option valuation model and the conventional valuation model.

Because correctly calculating the compensation for alteration is crucial to whether landowners successfully obtain appropriate compensation when applying for compensation, this study proposed a real option valuation model to appraise compensation for the alteration of privately-owned constructible land. In the model, landowners possessed complete ownership of and decision-making power regarding the land before compensation. Subsequently, the study adopted real options theories to assist private landowners in determining real options at the decision-making stage. The study also took the case of constructible land in Taichung City that was made nonconstructible in accordance with the spatial planning of Taichung City as an example to apply the model.

Keywords: compensation for alteration; net present value; real option valuation model; sensitivity analysis; geometric Brownian motion

1. Introduction

The importance of real estate appraisal increases with economic development, necessitating the need for real estate appraisers. Taiwan passed the Real Estate Appraiser Act in 2000. The act stipulates that professional appraisers be managed by the Department of Land Administration (of the Ministry of the Interior) and local land administration bureaus.

Because Taiwan's geographical conditions and geological environments are sensitive and fragile, and the challenges posed by climate change, strengthening Taiwan's land resilience is an urgent matter that must be addressed. Therefore, the Ministry of the Interior has continued to complete its spatial planning and promote the rational use of land while ensuring ecological and economic development to achieve a "sustainable Taiwan" (Construction and Planning Agency, Ministry of the Interior, 2016).

The Spatial Planning Act, formulated by the Executive Yuan, was in effect on May 1, 2016. According to Article 45 of the Act, the central competent authority was to announce the implementation of the national spatial plan within two years starting from the date that the Act came into effect. The Ministry of the Interior was to promulgate and implement a national spatial plan in accordance with previous regulations and submit it to the Executive Yuan for approval. The plan was promulgated and implemented on April 30, 2018. The Spatial Planning Act was revised by the president on April 21, 2020, and the development periods for special municipality and county (city) spatial plans and functional zone maps were extended to April 30, 2021, and 2025, respectively.

To protect the rights of landholders, the Ministry of the Interior established the Measures for Compensating Loss Incurred during The Implementation of Spatial Planning on the basis of Article 32, Paragraph 3 of the Spatial Planning Act; the measures were announced on September 14, 2020. The document follows the scope of compensation specified in the Spatial Planning Act and divides it into two categories, namely, compensation for relocation or alteration. Compensation for alteration refers to compensation for losses sustained when existing constructible land is "altered" to be nonconstructible according to the spatial planning of the special municipality or county (city). It also refers to compensation for the value of the right to develop the land (reflected in the difference in unit land price before and after the implementation of the spatial plan), and land is not expropriated. Therefore, the calculation method is identical to that for expropriation (refer to Articles 30 to 36 of the Land Expropriation Act). Statutory compensation for expropriation can be divided into land value, land item improvement, land improvement, business operating loss, relocation, other rights, and lessee liability compensation. Among them, land value compensation is calculated differently, and the appraisal method for land value is also different from the current appraisal method for land expropriation-based land value compensation.

Spatial planning is novel in Taiwan, and the country does not have previous examples to refer to for appraising the compensation for alteration. Appraising the compensation for alteration also involve various professional skills. In addition, due to compensation for alteration involves special land types, the appraisal of compensation for alteration entails assessment and compensation for the loss incurred because of loss of development rights. The appraisal differs from the current method for land expropriation-based land value compensation. Compensation for alteration generally involves land located in remote mountain areas where the land transaction volume is low and land transaction prices in neighboring areas (through real-price registration information) are difficult to obtain.

Real estate is immobile and inflexible, which reduce uncertainty in its use. In the past, the net present value (NPV) method was generally used for land investment and development analysis. Dixit and Pindyck (1994) noted that the conventional passive NPV method is used to

appraise land value and usually assumes that the investment plan is developed immediately and reversible. These are contrary to the characteristics of real estate investment and development; that is, ignoring the opportunities and flexibility generated by the uncertainty of asset value can readily lead to misappraisal of the value of investment plans. Specifically, the inclusion of future uncertainty in the appraisal is the main difference between option valuation models and conventional valuation models. McDonald and Siegel (1986) discussed the effects of future cash flow and investment cost uncertainty on option value and timing in investment projects, assuming that both earnings and cost conform to the stochastic process of geometric Brownian motion (Peng et al., 2011).

Titman et al. (1985) applied real options theories to land development and noted that real options affect the land development decisions of landowners. Real options theories state that the uncertainty of the future situation is the source of real option value. As the uncertainty increases, the opportunity for land development is delayed and the value of undeveloped land increases (Liu, 2006).

Titman et al. (1985) extended the option valuation theories to land development decision making and used a single-period binomial option pricing model to establish an urban undeveloped land price model. Because vacant land has development options in said model, increase in future earnings uncertainty, as mentioned, will increase the land value and cause delays in development. The concept was later widely discussed and used in real estate investment decision making. For example, Williams (1991) derived and developed an abandon option model; and Childs et al. (1996) and Williams (1997) created a redevelopment option model (Peng et al., 2011).

Because correct calculation of the compensation for alteration is crucial to whether landowners obtain appropriate compensation, this study calculated the compensation for alteration listed in Article 11 of the Measures for Compensating Loss Incurred during The Implementation of Spatial Planning and proposed suggestions for amendments to the calculation formula. Subsequently, the study suggested a real option valuation (ROV) model for the appraisal of compensation for the alteration of private constructible land. In the model, landowners have complete ownership of and decision-making power over constructible land before receiving compensation for alteration. By using real options theories, private landowners can determine the real options of the model at the decision-making stage. Additionally, the study took the case of constructible land in Taichung City that was made nonconstructible in accordance with the Taichung City spatial plan as an example and presented the valuation results.

2. Literature review

2.1 Right to development

The concept of the right to development originated in the United Kingdom (UK), whereas that of transferable development rights (TDR) originated in the USA. The purchase of development rights (PDR) evolved into the TDR due to financial budget issues.

This study analyzed and compiled literature on the right to development. Domestic and nondomestic literature on PDR calculation are shown in Table 1 and 2, respectively.

Table 1. Summary of Taiwanese literature on PDR calculation

Research topic	Author (Year)	Empirical region or law	Methodology	Results
An Analysis of	Chen (1998)	Germany	Literature review and	The study used legal analyses, case analyses, and characteristics analyses of

Research topic	Author (Year)	Empirical region or law	Methodology	Results
Compensation for the Restricted Use of Farmland in Water Resource Protection Areas in Germany			meta-analysis	farmland use restriction and loss compensation in Germany's water resource protection areas as a reference for Taiwan. Taking Baden-Württemberg and North Rhine-Westphalia as examples, loss caused by restrictions on the use of pesticides and fertilizers (which caused decreases in crop yields of farmland) in restricted water resource protection areas was explained and estimated.
A Study on the Implementation of Agricultural Conservation Easement—Based on Administrative Deed	Ling (2005)	Sanxing Township, Yilan County	Literature review and case study	Through analyses of related literature and cases of agricultural easements in the USA, the study identified the practical application of agricultural easements and explained the direction of domestic applications of agricultural land maintenance and management. A simulation of the implementation in Sanxing Township, Yilan County was used to understand the problems that frequently occur when purchasing domestic agricultural easement, such as small-scale agricultural land, large number of property owners, and complex attributes. The study explored and explained how agricultural easements in Taiwan should be constructed to address the domestic environmental policy background, and proposed voluntary participation in the negotiation of agricultural easements as the setting mechanism (top-down planning and bottom-up application), and adjusted the agricultural easements operating method in Taiwan.
The research to evaluate the non-market value in Agricultural Easement - A study of I-LAN	Hu (2006)	Yilan County	Literature and empirical analysis	The study discussed the possible macroeconomic benefits of agricultural easement planning and explored its nonmarket value. Subsequently, agricultural easement value was evaluated through nonmarket value evaluation techniques, and Yilan County was selected for empirical study.
Application of the U.S. Agricultural Easement to the Conservation of Agricultural Land	Ling and Chen (2007)	Agricultural land policies of Taiwan	Literature review	With the connotation of restriction on the use of agricultural easement, it led to the conservation of agricultural land control idea, and introduced the planning and practice of this system in the USA as a reference for domestic agricultural land policy.

Research topic	Author (Year)	Empirical region or law	Methodology	Results
Resources in Taiwan				
Study on Feasibility of Transform Value of Rights Model of Land Expropriations by Analyzing Land Value Factors	Lin (2009)	Public real estate bidding in Taichung City	Literature review, analytic hierarchy process, and fuzzy theory	Factors influencing land price were summarized through a literature review. Questionnaires were used to obtain the factors affecting bid price changes and weight ranking, and to discuss the method of replacing money payment with value of rights transformation. It also considered combining with the concept of equivalent exchange in the PDR method and proposed a value of rights ratio transformation model as a strategic approach to the problem of acquiring land for public facilities.
The Study on Charitable Trust - With Analysis of the Conservation Easement	Tung (2012)	Trust law	Literature review and system comparison	By discussing the conservation easement of charitable trusts in the UK and USA, the study compared the differences between conservation easements and real estate easements in Taiwan, and analyzed applying the conservation easement system to the preservation of cultural assets or environmental and ecological conservation through revision of the legal system.
The Institutional Design of Transferable Development Rights for Farmlands in Taiwan	Liu (2012)	TDR for farmlands in Taiwan	Literature review	By analyzing the theoretical basis of the TDR, economy, and actual cases in the USA, the study extended the TDR scope to farmland conservation policies according to the current agricultural situation in Taiwan, and discussed the applicable farmland TDR system and design process from different detailed plans.
Introducing Conservation Easements into Taiwan's Private Land Conservation －Studies of Statutory Covenants of National Trust And Conservation Easements of United States	Kao (2013)	Qionglin Township of Hsinchu County, Natural Valley Environmental Education Base in Hengshan Township, Civil Code, Trust law	Literature review	After reviewing the statutory covenants of the British National Trust and the U.S. conservation easement system, the study proposed legislative suggestions for the conservation easement system in Taiwan.

Source: Compiled by this study

Table 2. Summary of nondomestic literature on PDR calculations

Research topic	Author or institution (Year)	Empirical region	Research results
Evaluating Farmland Preservation through Suffolk County, New York's Purchase of Development Rights Program Comment	Mark R. Rielly Follow (2000)	Suffolk County, New York, USA	The PDR provides a legal and permanent method of land protection. However, the evaluation of farmland conservation efforts in Suffolk County demonstrated that the effectiveness of the PDR program was limited, and it was most successful when performed as part of a larger farmland conservation effort. Although the PDR of farmland can permanently preserve the land, this method is severely restricted by the cost of obtaining these rights. As the program of the Suffolk County recommends, even with all the authorized funds, other preservation methods are still necessary. Therefore, wealthier communities may find PDR program unfeasible. However, it may be worthwhile to purchase permanent protection measures to protect the identity of the community from the threat of sprawl development.
Agricultural Conservation Easements and Appraisals	New York Agricultural Land Trust	New York	The study explained estimation of the value of conservation easements.
Stafford County Purchase of Development Rights (PDR) Program Frequently Asked Questions	Stafford County's PDR Committee (2017)	Stafford County, Virginia, USA	The study explained PDR and related calculation methods.
Purchase of Development Rights Ordinance	Prince William County (2019)	Prince William County, Virginia, USA	The study explained the PDR ordinance in the area.
Whatcom County Agricultural, Forestry, and Ecological Purchase of Development Rights	Whatcom County (2018)	Whatcom County, Washington, USA	The study explained the guidelines for the Agricultural, Forestry and Ecological PDR Program in Whatcom County.

Research topic	Author or institution (Year)	Empirical region	Research results
PROGRAM GUIDELINES			

Source: Compiled by this study

2.2 Right to development

The right to development refers to the right of landowner to change the mode of use of the land for more intensive use or to engage in construction or development. It is a right created by property law as derived from ownership (Costonis, 1973). The connotation of this right is part of a bundle of rights in land ownership (Lu, 1980). Those who have obtained the right to development have the right to engage in development and construction. Landowners who have lost the right to development can only maintain the original use of their land, or reserve vacant land without the right to engage in development (National Taipei University, 2007).

The right to development is a right that is created by society and governed by law; and has economic value. According to the planning viewpoint, the right to development should be restricted by land use control, and development should be pursued without affecting the private ownership of land or land use planning. It limits the spread of social externalities and protects private and public ownership (Wu, 2000).

As mentioned, the right to development originated in the UK, but the concept of TDR was developed in the USA. PDR gradually turned into TDR due to financial budget issues.

The first PDR program was developed in Suffolk County, New York in 1974. In the 1980s, PDR was adopted by various local governments in northeastern USA. Most PDR programs were set up to protect land for agricultural use, maintain open spaces, or be used on larger-scale land. The operational concept of these programs was that landowners have various rights, including development, rental, licensing, mortgaging, and mining rights, as well as the right to restrict the development of the land.

The right to development is generally purchased by government agencies or other organizations (e.g., land trusts) for appropriate purposes. The terms of agreement are legally binding, and the conservation easement is set on the deed of the real property. Participants retain the ownership and other rights of the real property, and can settle, cultivate, inherit, purchase, or transfer the property, and provide undeveloped land as a conservation easement in accordance with the contract. Most easement restrictions limit real estate to only agricultural use, whereas conservation easements generally may be used as farmhouses, employee dormitories, or self-occupied buildings.

In most PDR programs, property development rights are valued by real estate appraisers or local easement appraisal systems. The value of the development right is the price difference between the value of the land under control and the maximum and most appropriate use of the land. The organization or institution that manages the PDR program pays the valuation amount to the real estate owner. For instance, if a farmer owns 100 acres of land, the land is worth US$10,000 per acre on the market if it is available for residential use. An independent real estate appraiser estimates that the land value at only US$5,000 per acre if the land remains undeveloped and continues to be used for agricultural purposes. Thus, the current value of the development right is US$500,000 and the PDR program must pay farmers this price (Department of Urban Development, Taipei City Government, 2010).

2.3 Real option

A real option is the right to act (e.g., deferring, expanding, contracting, or abandoning) within a predetermined period (the effective period of the option), but it is not an obligation (K, 2014). Similar to other financial derivatives, the value of real options depends on five basic variables plus one essential variable. These are as follows: (1) value of the underlying risk asset; (2) strike price; (3) expiration date of the option; (4) standard deviation of the value of the relevant risk asset; (5) risk-free interest rate during the effective period of the option; and (6) dividends payable by the underlying asset (Copeland, 2002).

Real options theories originated in 1977. Stewart Myers proposed a groundbreaking idea that the Black–Scholes option valuation model developed in 1973 can be used for capital budgeting, which was later verified by Folta and O'Brien (2004) and Borison (2005). Myers (1977) initially defined real options as the opportunity to purchase physical assets on possibly favorable terms (Čirjevskis & Tatevosjans, 2015). Merton (1998) noted that the future is uncertain (otherwise options are not required because we now know what to do in the future). Having flexibility in deciding what to do after uncertainties are resolved is extremely valuable. Option valuation theories provide a method to measure this value. This study refers to Li et al. (2014), in which the ROV model was used in various real estate development decisions from planning to operation and from operation to abandonment (Hui et al., 2010). Studies have used ROV to predict land prices (Grovenstein et al., 2011; Shen & Pretorius, 2013) and land rents (Hsieh & Lin, 2016). Others have applied ROV to evaluate types of real estate development, such as entertainment facilities (Leung & Hui, 2002), social housing renovations (Ho et al., 2009), office building construction (Fu & Jennen, 2009), and farms (Stokes, 2012).

In summary, as an effective valuation model, ROV has been widely used in decision making for different types of real estate development. Spatial planning is newly promoted in Taiwan, and no previous examples are available as references for compensation for alteration. Therefore, this study refers to nondomestic literature on conservation easements and their valuations, and applies ROV at the decision-making stage to estimate compensation for privately-owned legal constructible land. With options embedded at the decision-making stage identified, this study takes the case of constructible land in Taichung City that was made nonconstructible in accordance with the city's spatial plan as an example. At the decision-making stage, the calculation model of the compensation for alteration for the privately-owned constructible land fills a gap in the literature.

3. Research scope and methods

This study proposed a model based on the ROV method for appraisal of the compensation for alteration of privately-owned constructible land. In this model, landowners[1] have complete ownership and decision-making power of the land before receiving compensation. Subsequently, the study employed real options theories for private landowners to determine the real options of the proposed model at the decision-making stage. In addition, the study examined a case of altered land and its valuation.

3.1 Net present value of compensation for alteration of privately-owned constructible land at the decision-making stage

[1] The subject of compensation for alteration is the applicant (i.e., landowner) who applies to the central competent authority of the special municipality or county (city) as the landowner listed in the cadastral transcript at the time. Therefore, the owner refers to the landowner listed in the cadastral transcript at the time when applying for the compensation for alteration.

Conventionally, discounted cash flow analyses are used to value projects, companies, or assets, in which the time value of money is calculated at a discount rate. The sum of all discounted cash flows each year is the NPV, which can be calculated as follows:

$$\text{NPV} = \sum_{t=0}^{n} \frac{(\text{CI}_t - \text{CO}_t)}{(1+q)^t} \quad (1)$$

Here, t represents time (measured in years) and n represents the pricing date difference between the price of privately-owned constructible land before and after the alteration. As shown in Eq. (1), three crucial parameters exist for estimating the NPV of the land before and after the alteration, namely CI_t, CO_t, and q. In Eq. (1), NPV represents the compensation for alteration of the land. Therefore, the source of CI_t is the cash inflow (expressed as the price of constructible land before the alteration) of privately-owned constructible land in year t (during the application for compensation). Regarding CO_t, its source is the cash outflow (expressed as the price of the nonconstructible land) of privately-owned constructible land in year t (during the compensation application); and q is the discount rate.

The cash inflow of the land in year t (during the compensation application) can be calculated by the land area and the unit land price (unit land market price) of the constructible land before the spatial plan announcement of the special municipality or county (city) and pricing date adjustment. The market price of a unit of land it can be estimated by the supply, demand, and transaction status of the surrounding constructible land market; the pricing date adjustment can be calculated by the change in a price index such as the land price index.

The cash outflow of privately-owned constructible land in year t (during the compensation application) can be calculated by the land area and the unit land price (unit land market price) when applying for compensation. The market price of land can be estimated by the supply, demand, and transaction status of the surrounding nonconstructible land market.

Regarding q, referring to Article 43 of the Regulations of Real Estate Appraisal, the discount rate should be based on whichever of the follow methods are the most comprehensive and appropriate: risk premium, market extraction, weighted average capital cost, debt coverage ratio, and effective gross income multiplier methods. In addition to the aforementioned methods, q can be calculated by several quantitative methods, including capital asset pricing model, multi-factor asset pricing model, and arbitrage pricing theory, or qualitatively designated by management according to the company's requirements or according to the threshold of a specific project (Mun, 2005).

Regarding financial feasibility evaluation, both financial feasibility and balance mechanism must be considered. For financial feasibility, the following four conditions must be met: NPV > 0, internal rate of return > weighted average capital cost, discounted payback period < concession period, and self-liquidating ratio > 1 (Organization of Urban Re-s, 2015; Huang, 2019).

3.2 Expanded net present value of the compensation for alteration of privately-owned constructible land at the decision-making stage

Options are generally divided into European or American options. The only difference between them is that European options can only be exercised when they expire, whereas American options can be exercised at any time before the expiration date (Hui et al., 2010). Due to their additional flexibility, American options may be more valuable. To avoid arbitrage, the price must be at least the same as the potential earnings. The right to sell allows the asset to be sold at a specified strike price, and the right to buy allows the asset to be bought at the strike price (Balajewicz & Toivanen, 2017).

The real options applicable to real estate development can be summarized as options to defer, abandon, expand, contract, switch, grow, and compound (Trigeorgis, 2005; Guma, 2008), In international literature on land development and public construction, the most common types are options to defer, expand, and abandon (Chen et al., 2004).

With the characteristics and management flexibility of the proposed model, a private individual (referred to as the landowner according to the Measures for Compensating Loss Incurred during The Implementation of Spatial Planning) generally have two real options in the decision-making stage, which are the deferral option and the abandonment option. Regarding abandonment, because it is irreversible, this is the least desirable option and will not be used under normal circumstances. In general, only the deferral option is considered (Li et al., 2014). The deferral option for privately-owned constructible land is an American option because after an individual obtains ownership of legally constructible land, they may apply in writing to the special municipality or county (city) for compensation for alteration from the day after the 1-year expiration the functional zone map was announced.

A variety of models and methods can be used to evaluate the option premium (OP), among which the Black–Scholes model is the most widely used due to its simplicity and accuracy. As mentioned, the deferral option is the primary real option for private landowners applying for compensation for alteration at the decision-making stage, and it shall be removed at any time from the day one year after the announcement of functional zone maps by the special municipality or county (city) competent authority. Because of the short period, the deferral option for private individuals to apply for compensation for alteration is simplified to European style. Therefore, the Black–Scholes model is suitable for the calculation. In addition, the basic model is modified by considering value leakage, which has various causes during the deferral period.

With reference to Hui et al. (2011), three assumptions are made before constructing the Black–Scholes model. (1) The compensation for privately-owned constructible land follows geometric Brownian motion, and its rate of return is normally distributed. (2) Throughout, the risk-free interest rate and land price fluctuations are known and remain constant. And, (3) the option is priced in a frictionless market. If the value leakage is δ, according to the stochastic differential equation, the value S_t at time t of the land before the alteration price S will change in the following form:

$$dS_t = (r_f - \delta)S_t dt + \sigma_s S_t dB_t \quad (2)$$

Here, r_f is the risk-free interest rate; σ_s is the average volatility of social housing rent; and B_t is one-dimensional Brownian motion. On the basis of the risk-neutral hypothesis and Itô's lemma (Chen, 2007), the stochastic differential equation and its boundary conditions for the value of privately-owned social housing options can be written as

$$\frac{\partial OP}{\partial t} = r_f OP - \left(r_f - \delta\right)S_t \frac{\partial OP}{\partial t} - \frac{1}{2}\sigma_s^2 {S_t}^2 \frac{\partial^2 OP}{\partial {S_t}^2} \quad (3\text{-}1)$$

$$OP(S_t, T) = Max[(S_t - C_t), o] \quad (3\text{-}2)$$

Here, C_t is the price at which the privately-owned constructible land is made nonconstructible in year t. Solve the stochastic differential equations of Eqs. (3-1) and (3-2) as follows:

$$OP_t = S_t e^{-\delta(T-t)} N(d_1) - C_t e^{-r_f(T-t)} N(d_2) \quad (4\text{-}1)$$

$$d_1 = \frac{\left[ln\left(S_t/C_t\right)+\left(r_f-\delta+\sigma_s{}^2/2\right)\right]}{\sigma_s\sqrt{T-t}} \quad (4-2)$$

$$d_2 = \frac{\left[ln\left(S_t/C_t\right)-\left(r_f-\delta+\sigma_s{}^2/2\right)\right]}{\sigma_s\sqrt{T-t}} = d_1 - \sigma_s\sqrt{T-t} \quad (4-3)$$

Here, T is the expiration date of the deferral option for compensation for alteration of privately-owned constructible land; and $N(d_1)$ and $N(d_2)$ are the cumulative probability of variables smaller than d_1 and d_2 under standard normal distribution, respectively.

The conventional NPV method has been criticized for its inadequacy in dealing with uncertainty, irreversibility, and management flexibility, and such inadequacy can be improved through ROV. However, as a widely used decision-making method, NPV contains numerous advantages (Chen, 2007). With reference to Trigeorgis (2005), this study proposed a new expanded net present value (ENPV) standard to obtain the added value of management and operational flexibility and other strategic exchanges.

ENPV = passive NPV + OP (ROV, flexibility and strategic values).

In such a model, there may be legitimate reasons for accepting negative NPV under expected cash flow (if the expected cash flow is offset by a larger OP generated by the additional flexibility and strategic value) or to delay an investment with positive NPV until the ENPV is maximized under uncertainty (Trigeorgis, 2005). This study adopted, optimized, and illustrated the model to appraise the compensation for alteration of privately-owned constructible land.

The study calculated the value of the compensation at the decision-making stage. When Eqs. (4-1) to (4-3) are combined with Eq (1), t becomes 0, and the ROV model at the decision-making stage can be written as

$$ENPV = \sum_{t=0}^{n} \frac{(CI_t - CO_t)}{(1+i_c)^t} + S_0 e^{-\delta T} N(d_1) - C_0 e^{-r_f T} N(d_2) \quad (5-1)$$

$$d_1 = \frac{\left[ln\left(S_0/C_0\right)+\left(r_f-\delta+\sigma_s{}^2/2\right)\right]}{\sigma_s\sqrt{T}} \quad (5-2)$$

$$d_2 = \frac{\left[ln\left(S_0/C_0\right)-\left(r_f-\delta+\sigma_s{}^2/2\right)\right]}{\sigma_s\sqrt{T}} = d_1 - \sigma\sqrt{T} \quad (5-3)$$

4. Case study

4.1 Basic data

To illustrate the application of the real option in the model, this study used a case in which constructible land in Taichung City was made nonconstructible by the city's spatial plan. The main index related to constructible land was taken from the Taichung City Spatial Planning Technical Report published on the website of the Construction and Planning Agency of the Ministry of the Interior.

The land was located on Shenghe Road, Taiping District, Taichung City, which was a Type C construction land. It was a non-disaster-type environmentally sensitive area

measuring 153.38 m^2. On April 30, 2021, the administrative district announced its spatial plan, and the unit land price at the time of the announcement was estimated by this study to be NT$15,000 per m^2 (i.e., the price of the constructible land before the alteration was NT$15,000 per m^2). The landowners can apply for compensation for the alteration on July 1, 2026. The unit land price at the time of the application for compensation was estimated by this study to be NT$5000 per m^2 (i.e., the price is NT$5000 per m^2 after the constructible land was altered). The land designated as nonconstructible is 153.38 m^2, and the scope of land ownership rights included was "all" (1/1). According to the valuation of this study, if the time point (April 30, 2021) of the announcement of the spatial plan was used as the benchmark to the time point of application for compensation (July 1, 2026), the reasonable land price increase rate for the surrounding Type C constructible land is 10%. Table 3 presents the main indices used in the study.

Table 3. Main indices of privately-owned constructible land

Name	Value	Name	Value
Land area before alteration (10^4 m^2)	0.015338	Area of land designated as nonconstructible (10^4 m^2)	0.015338
Unit land price at the time of the spatial plan announcement (NT$/$m^2$)	15,000	Unit land price when applying for compensation (NT$/ m^2)	5,000
Pricing date adjustment rate (%)	10	Scope of land ownership rights	1/1

4.2 Model parameters

4.2.1 Parameters related to net present value

According to the proposed valuation model, certain parameters should be predetermined to calculate the NPV of the compensation, including CI_t, CO_t, and q. In accordance with the calculation formula in Article 11 of the Measures for Compensating Loss Incurred during The Implementation of Spatial Planning and after adjusting prices and dates, this study obtained the calculation results for relevant parameters, as follows:

CI_t = Unit land price at time of spatial plan announcement adjusted to unit land price at the time of compensation application × land area designated as nonconstructible × scope of land ownership rights

= (NT$15,000/$m^2$ × (1 + 10%)) × 153.38 m^2 × (1/1)

= NT$2,530,770

CO_t = Unit land price at time of compensation application × land area designated as nonconstructible × scope of land ownership rights

= (NT$5,000/$m^2$) × 153.38 m^2 × (1/1)

= NT$766,900

q = 2.26% (Calculated in accordance with Article 43 of the Regulations on Real Estate Appraisal, which is estimated as 2.26% by this study).

4.2.2 Real option–related parameters

To calculate the OP in Eqs. (5-1) to (5-3), six parameter values were required. The first parameter was maturity time T. After ownership of constructible land was obtained, the deferral option of an application for compensation for alteration (American option) could be exercised at any time from 1 year after the competent authority publishes the functional zone maps. With reference to the surrounding land price changes, T was estimated to be 1 year. To be precise, when appraising the compensation, the 1-year deferral option was considered. The second parameter was the current value of S_0, which was the discounted value at the decision-making stage. It could estimate the unit land price of the land at the time of the announcement based on q (3.26%) and the pricing date adjustment rate (estimated as 10%). According to the aforementioned parameters, S_0 was calculated as NT$2,530,770.

The third parameter was the investment cost C_0. In this case, it referred to the price of privately-owned constructible land made nonconstructible at the time of the application for compensation. It was also the discounted value at the decision-making stage, which can be estimated based on q and irreversible investment. According to the aforementioned parameters, C_0 can be calculated as NT$766,900.

The fourth parameter was value leakage δ. According to data availability, only δ caused by the increase in cost is considered. The C_0 of this case was calculated based on the price change at the time of the compensation application. Moreover, this study used the period during compensation application as the basis for price calculation, and the unit land price of the land at the time of the announcement was adjusted to the price. The price fluctuation of the nonconstructible land did not need to be considered when applying for compensation. Therefore, the δ of the compensation for alteration is calculated as 0%.

The fifth parameter was the risk-free interest rate r_f, which was generally based on the rate of return on government debt (Chen, 2007). On November 8, 2019, the Central Bank of the Republic of China sold a 30-year treasury bond with an annual interest rate of 0.95%. This was used for the calculation of r_f. Therefore, in this study, the r_f of the renewed land and buildings related to the discount to offset the common cost was 0.95%.

The sixth parameter was the average volatility of the price of privately-owned constuctible land σ_s. This study calculated σ_s as 2.00% (10%/5 years).

5. Results and discussion

Input the aforementioned parameters of the compensation for alteration relative to the NPV into Eq. (1), and the NPV of the compensation for privately-owned constructible land in this case was calculated as NT$1.58 million, which was positive. Subsequently, OP-related parameters were substituted into Eqs. (5-2) and (5-3) to obtain d_1 and d_2, producing 1.68 and 0.71, respectively. In addition, $N(d_1)$ and $N(d_2)$ were obtained from the standard normal distribution function table as 0.9292 and 0.8212, respectively. Next, $N(d_1)$ and $N(d_2)$ and other OP-related parameters were substituted into Eq. (5-1) to obtain the OP value, which was NT$1.73 million. Finally, NPV and OP were added together to obtain the ENPV of the compensation, which was NT$3.31 million. In Table 6, an overview of the OP-related parameters and their values is provided.

Table 4. Overview of OP-related parameters and their values

Variable	Symbol	Description	Value
OP-relative parameters	T	The maturity time	1 year
	S_0	The current value	2.53 million NTD
	C_0	The investment cost	0.77million NTD

Variable	Symbol	Description	Value
	δ	The value leakage of the discounted price of the land and buildings	0.00%
	r_f	The risk-free interest rate	0.95%
	σ_s	The average volatility of SH rent	2.00%
	d_1	$\frac{\left[ln\left(S_0/C_0\right)+\left(r_f-\delta+\sigma^2/2\right)\right]}{\sigma\sqrt{T}}$	1.68
	d_2	$\frac{\left[ln\left(S_0/C_0\right)-\left(r_f-\delta+\sigma^2/2\right)\right]}{\sigma\sqrt{T}}$	0.71
	$N(d_1)$	Cumulative probability of less than d_1 variable under standard normal distribution	0.9292
	$N(d_2)$	Cumulative probability of less than d_2 variable under standard normal distribution	0.8212
	OP	Option premium, $S_0e^{-\delta T}N(d_1)-C_0e^{-rT}N(d_2)$	1.73 million NTD
	ENPV	Expanded net present value of the land and buildings after the renewal of the common cost is offset by the discount	3.31 million NTD

Therefore, this case was acceptable financially if the OP generated from the 1-year deferral option was considered. In general, compared with immediate application on the day after the special municipality or county (city) competent authority announces functional zone maps after the expiration date of 1 year, private landowners should wait an additional year after the expiration date before applying for compensation for alteration.

However, the private landowner in this case may be dissatisfied with the ENPV of the compensation for alteration and be eager to learn of methods to enhance ENPV. When this occurs, sensitivity analyses can be performed to determine possible influencing factors.

Regarding the case in this study, this study identified three factors potentially influencing ENPV. For earnings, these were calculated based on the price before the alteration of the land by the spatial plan. The unit land price at the time of the announcement was the most influential, hence, it was a potential factor. Regarding cost, it was calculated based on the price change of the land, which would have fluctuated over time. However, cost in this case was generated only during the compensation application. Moreover, this study used the time when compensation was applied for as the basis for price calculation, and the unit land price of the land at the time of the announcement was adjusted to the price at that time. Therefore, the price fluctuation of the land during the application did not need to be considered, and the unit land price during the application was a potential factor.

Another potential factor was the area of constructible land designated as nonconstructible, which will affect both cost and earnings. Among the OP-related parameters, both S_0 and C_0 were affected by NPV-related parameters, whereas δ, r_f, and S were not under private control in this case. Therefore, T (in the OP-related parameters) was also a potential factor. This was because after obtaining ownership of the constructible land, the private landowner in this case can defer the compensation for alteration from 1 year after the competent authority publishes the functional zone maps.

The calculations indicated the effect of these three potential influencing factors on the ENPV of the compensation. The sensitivity analysis is shown in Figure 1. Apparently, the unit land price at the time of the plan announcement is the most crucial factor affecting its ENPV. The second most crucial factor was the area of constructible land made nonconstructible. Regarding T, its effect was minor and could be ignored.

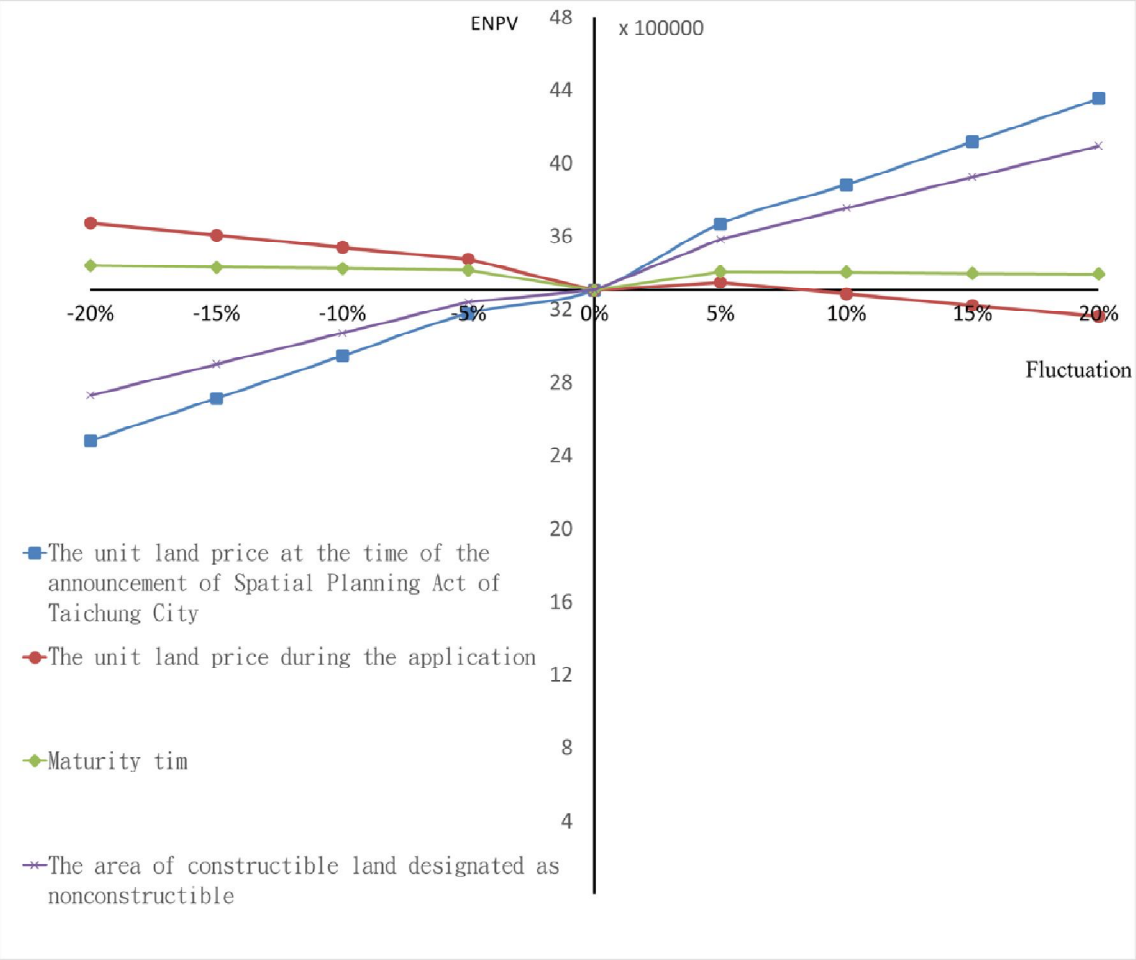

Figure 1. Sensitivity analysis results

6. Conclusion

To protect the rights of landholders, the Ministry of the Interior has established the Measures for Compensating Loss Incurred during The Implementation of Spatial Planning under the authorization of Article 32, Paragraph 3 of the Spatial Planning Act, which provides for compensation for relocation and alteration. Compensation for alteration refers to compensation for losses suffered when constructible land is made nonconstructible in the spatial planning of the special municipality or county (city). It is to compensate for the value of the development rights of the land (reflected in the difference in unit land prices before and after the spatial planning), and the land is not expropriated.

Land type must be assessed for compensation for alteration. The compensation amount is appraised and compensated for the loss of land development rights. The appraisal method is different from the current method of market price of land expropriation and compensation.

Thus, land must be assessed for compensation for alteration. However, the appraisal method differs from the current method of market price for land expropriation and compensation. This study proposed a new calculation model of compensation for alteration of privately-owned constructible land. According to the management flexibility of the model at the decision-making stage, the study considered only the deferral option. Subsequently, the

study established an ROV model in which the expanded (or strategic) NPV was represented by ENPV, was is equal to the sum of the NPV and the OP.

The study also took the case of constructible land in Taichung City made nonconstructible in accordance with the city's spatial plan as an example to illustrate the valuation model. However, because the OP generated from the 1-year deferral option was positive, the compensation for alteration in this case shall be applied 1 year after the expiration date of the functional zone maps announced by the competent authority. Through sensitivity analyses, the study identified that the unit land price at the time of the spatial plan announcement was the factor with the greatest effect on the ENPV.

For the proposed valuation model, only the deferral option is considered. Nonetheless, the OP generated by the 1-year deferral option is positive. With the proposed calculation model of compensation for alteration of privately-owned constructible land, there will be greater management flexibility and corresponding real options during the compensation application period. Therefore, the proposed model can be used to comprehensively appraise the compensation for alteration of privately-owned constructible land during the decision-making stage. Future research may determine other real options for compensation for alteration during the application period; and construct related valuation models.

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