

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 non-constructible 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 theory 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 non-constructible 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

33 **1. Introduction**

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

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

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

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

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

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

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

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

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

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

115 **2. Literature review**

116 **2.1 Right to development**

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

120 This study analyzed and compiled literature on the right to development. Domestic and
 121 non-domestic literatures on PDR calculation are shown in Table 1 and 2, respectively.

122 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	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
Land 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

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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 destination 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 PROGRAM GUIDELINES	Whatcom County (2018)	Whatcom County, Washington, USA	The study explained the guidelines for the Agricultural, Forestry and Ecological PDR Program in Whatcom County.

126 Source: Compiled by this study

127 **2.2 Right to development**

128 The right to development refers to the right of landowner to change the mode of use of
129 the land for more intensive use or to engage in construction or development. It is a right
130 created by property law as derived from ownership (Costonis, 1973).The connotation of this
131 right is part of a bundle of rights in land ownership (Lu, 1980).Those who have obtained the
132 right to development have the right to engage in development and construction. Landowners
133 who have lost the right to development can only maintain the original use of their land, or
134 reserve vacant land without the right to engage in development (National Taipei University,
135 2007).

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

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

143 The first PDR program was developed in Suffolk County, New York in 1974. In the
144 1980s, PDR was adopted by various local governments in northeastern USA. Most PDR
145 programs were set up to protect land for agricultural use, maintain open spaces, or be used on
146 larger-scale land. The operational concept of these programs was that landowners have various
147 rights, including development, rental, licensing, mortgaging, and mining rights, as well as the
148 right to restrict the development of the land.

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

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

167 **2.3 Real option**

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

175 Real option theories originated in 1977. Stewart Myers proposed a groundbreaking idea
176 that the Black–Scholes option valuation model developed in 1973 can be used for capital
177 budgeting, which was later verified by Folta and O’Brien (2004) and Borison (2005). Myers
178 (1977) initially defined real options as the opportunity to purchase physical assets on possibly
179 favorable terms (Čirjevskis & Tatevosjans, 2015). Merton (1998) noted that the future is
180 uncertain (otherwise options are not required because we now know what to do in the
181 future). Having flexibility in deciding what to do after uncertainties are resolved is extremely
182 valuable. Option valuation theories provide a method to measure this value. This study refers to
183 Li et al. (2014), in which the ROV model was used in various real estate development
184 decisions from planning to operation and from operation to abandonment (Hui et al.,
185 2010). The studies have used ROV to predict land prices (Grovenstein et al., 2011; Shen &
186 Pretorius, 2013) and land rents (Hsieh & Lin, 2016). Others have applied ROV to evaluate
187 types of real estate development, such as entertainment facilities (Leung & Hui, 2002), social
188 housing renovations (Ho et al., 2009), office building construction (Fu & Jennen, 2009), and
189 farms (Stokes, 2012).

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

200 3. Research scope and methods

201 This study proposed a model based on the ROV method for appraisal of the compensation
202 for alteration of privately-owned constructible land. In this model, landowners¹ have complete
203 ownership and decision-making power of the land before receiving
204 compensation. Subsequently, the study employed real option theories for private landowners to
205 determine the real options of the proposed model at the decision-making stage. In addition, the
206 study examined a case of altered land and its valuation.

207 3.1 Net present value of compensation for alteration of privately-owned constructible 208 land at the decision-making stage

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

$$212 \text{NPV} = \sum_{t=0}^n \frac{(CI_t - CO_t)}{(1+q)^t} \quad (1)$$

213 Here, t represents time (measured in years) and n represents the pricing date difference
214 between the price of privately-owned constructible land before and after the alteration. As

¹The 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.

215 shown in Eq. (1), three crucial parameters exist for estimating the NPV of the land before and
216 after the alteration, namely CI_t , CO_t , and q . In Eq. (1), NPV represents the compensation for
217 alteration of the land. Therefore, the source of CI_t is the cash inflow (expressed as the price of
218 constructible land before the alteration) of privately-owned constructible land in year t (during
219 the application for compensation). Regarding CO_t , its source is the cash outflow (expressed as
220 the price of the non-constructible land) of privately-owned constructible land in year t
221 (during the compensation application); and q is the discount rate.

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

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

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

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

245 **3.2 Expanded net present value of the compensation for alteration of privately-owned** 246 **constructible land at the decision-making stage**

247 Options are generally divided into European or American options. The only difference
248 between them is that European options can only be exercised when they expire, whereas
249 American options can be exercised at any time before the expiration date (Hui et al.,
250 2010). Due to their additional flexibility, American options may be more valuable. To avoid
251 arbitrage, the price must be at least the same as the potential earnings. The right to sell allows
252 the asset to be sold at a specified strike price, and the right to buy allows the asset to be
253 bought at the strike price (Balajewicz & Toivanen, 2017).

254 The real options applicable to real estate development can be summarized as options to
255 defer, abandon, expand, contract, switch, grow, and compound (Trigeorgis, 2005; Guma,
256 2008). In international literature on land development and public construction, the most
257 common types are options to defer, expand, and abandon (Chen et al., 2004).

258 With the characteristics and management flexibility of the proposed model, a private
259 individual (referred to as the landowner according to the Measures for Compensating Loss
260 Incurred during The Implementation of Spatial Planning) generally have two real options in
261 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

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

$$OP(S_t, T) = \text{Max}[(S_t - C_t), 0] \quad (3-2)$$

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

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

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

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

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.

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

307 $ENPV = \text{passive NPV} + OP$ (ROV, flexibility and strategic values).

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

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

317
$$ENPV = \sum_{t=0}^n \frac{(CI_t - CO_t)}{(1+i_c)^t} + S_0 e^{-\delta T} N(d_1) - C_0 e^{-r_f T} N(d_2) \quad (5-1)$$

318
$$d_1 = \frac{\left[\ln(S_0/C_0) + (r_f - \delta + \sigma_s^2/2) \right]}{\sigma_s \sqrt{T}} \quad (5-2)$$

319
$$d_2 = \frac{\left[\ln(S_0/C_0) - (r_f - \delta + \sigma_s^2/2) \right]}{\sigma_s \sqrt{T}} = d_1 - \sigma \sqrt{T} \quad (5-3)$$

320 4. Case study

321 4.1 Basic data

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

327 The land was located on Shenghe Road, Taiping District, Taichung City, which was a
 328 Type C construction land. It was a non-disaster-type environmentally sensitive area measuring
 329 153.38 m². On April 30, 2021, the administrative district announced its spatial plan, and the
 330 unit land price at the time of the announcement was estimated by this study to be NT\$15,000
 331 per m² (i.e., the price of the constructible land before the alteration was NT\$15,000 per
 332 m²). The landowners can apply for compensation for the alteration on July 1, 2026. The unit
 333 land price at the time of the application for compensation was estimated by this study to be
 334 NT\$5000 per m² (i.e., the price is NT\$5000 per m² after the constructible land was altered). The
 335 land designated as **non-constructible** is 153.38 m², and the scope of land ownership rights
 336 included was "all" (1/1). According to the valuation of this study, if the time point (April 30,
 337 2021) of the announcement of the spatial plan was used as the benchmark to the time point of
 338 application for compensation (July 1, 2026), the reasonable land price increase rate for the
 339 surrounding Type C constructible land is 10%. Table 3 presents the main indices used in the
 340 study.

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342

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 non-constructible (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

343

344 4.2 Model parameters

345 4.2.1 Parameters related to net present value

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

351

$$\begin{aligned}
 352 \quad CI_t &= \text{Unit land price at time of spatial plan announcement adjusted to unit land price at the} \\
 353 \quad &\quad \text{time of compensation application} \times \text{land area designated as non-constructible} \times \text{scope} \\
 354 \quad &\quad \text{of land ownership rights} \\
 355 \quad &= (\text{NT}\$15,000/\text{m}^2 \times (1 + 10\%)) \times 153.38 \text{ m}^2 \times (1/1) \\
 356 \quad &= \text{NT}\$2,530,770
 \end{aligned}$$

$$\begin{aligned}
 357 \quad CO_t &= \text{Unit land price at time of compensation application} \times \text{land area designated as non-} \\
 358 \quad &\quad \text{constructible} \times \text{scope of land ownership rights} \\
 359 \quad &= (\text{NT}\$5,000/\text{m}^2) \times 153.38 \text{ m}^2 \times (1/1) \\
 360 \quad &= \text{NT}\$766,900
 \end{aligned}$$

361 $q = 2.26\%$ (Calculated in accordance with Article 43 of the Regulations on Real Estate
362 Appraisal, which is estimated as 2.26% by this study).

363 4.2.2 Real option-related parameters

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

374 The third parameter was the investment cost C_0 . In this case, it referred to the price of
375 privately-owned constructible land made non-constructible at the time of the application for
376 compensation. It was also the discounted value at the decision-making stage, which can be

377 estimated based on q and irreversible investment. According to the aforementioned
 378 parameters, C_0 can be calculated as NT\$766,900.

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

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

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

393 5. Results and discussion

394 Input the aforementioned parameters of the compensation for alteration relative to the
 395 NPV into Eq. (1), and the NPV of the compensation for privately-owned constructible land in
 396 this case was calculated as NT\$1.58 million, which was positive. Subsequently, OP-
 397 related parameters were substituted into Eqs. (5-2) and (5-3) to obtain d_1 and d_2 , producing 1.68
 398 and 0.71, respectively. In addition, $N(d_1)$ and $N(d_2)$ were obtained from the standard normal
 399 distribution function table as 0.9292 and 0.8212, respectively. Next, $N(d_1)$ and $N(d_2)$ and other
 400 OP-related parameters were substituted into Eq. (5-1) to obtain the OP value, which was
 401 NT\$1.73 million. Finally, NPV and OP were added together to obtain the ENPV of the
 402 compensation, which was NT\$3.31 million. In Table 4, an overview of the OP-related
 403 parameters and their values is provided.

404

405

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

Variable	Symbol	Description	Value
OP-related parameters	T	The maturity time	1 year
	S_0	The current value	2.53 million NTD
	C_0	The investment cost	0.77 million NTD
	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	$\frac{[\ln(S_0/C_0) + (r_f - \delta + \sigma^2/2)]}{\sigma\sqrt{T}}$	1.68
	d_2	$\frac{[\ln(S_0/C_0) - (r_f - \delta + \sigma^2/2)]}{\sigma\sqrt{T}}$	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, $S_0 e^{-\delta T} N(d_1) - C_0 e^{-r_f T} N(d_2)$	1.73 million NTD	

Variable	Symbol	Description	Value
	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

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

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

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

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

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

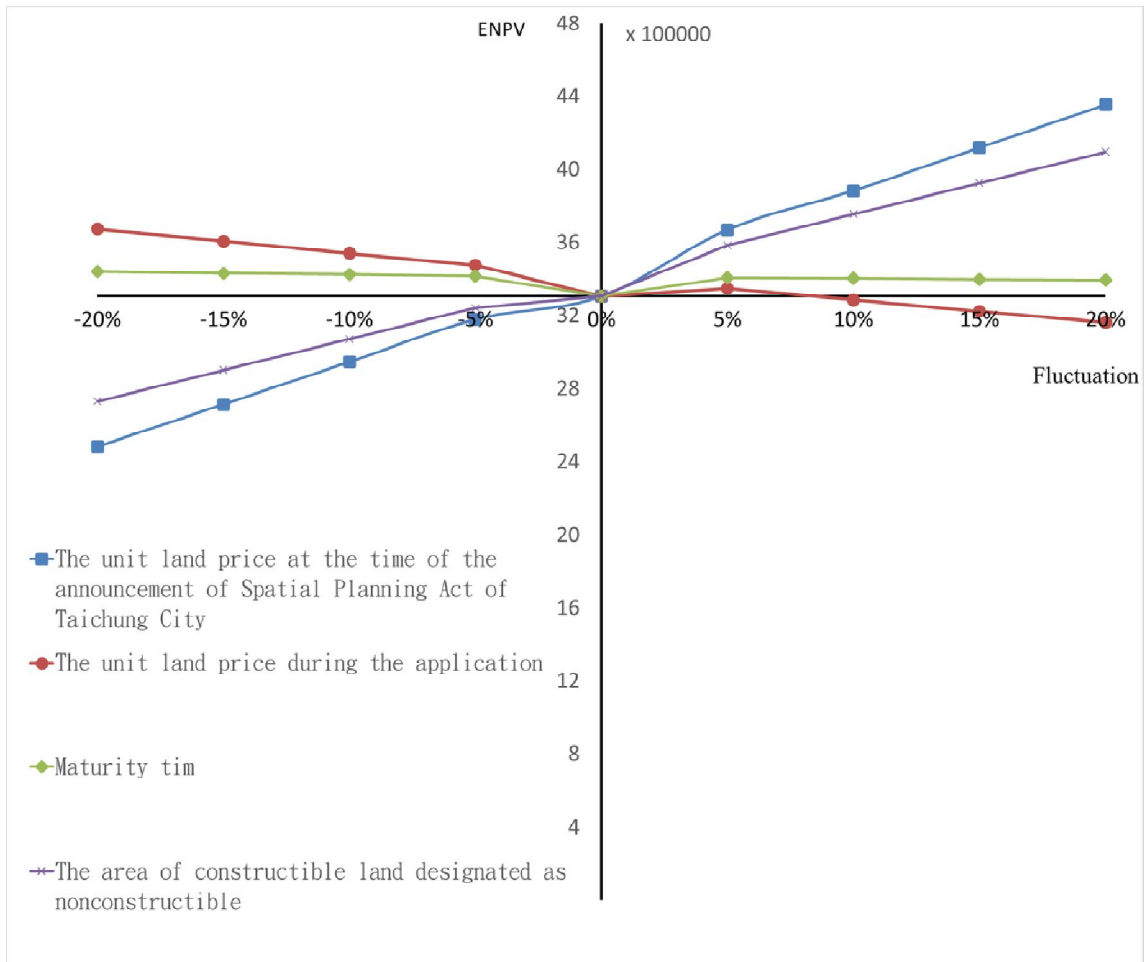


Figure 1. Sensitivity analysis results

436
437

438

439 6. Conclusion

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

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

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

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

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

465 For the proposed valuation model, only the deferral option is considered. Nonetheless, the
466 OP generated by the 1-year deferral option is positive. With the proposed calculation model
467 of compensation for alteration of privately-owned constructible land, there will be greater
468 management flexibility and corresponding real options during the compensation application
469 period. Therefore, the proposed model can be used to comprehensively appraise the
470 compensation for alteration of privately-owned constructible land during the decision-making
471 stage. This study can also be used to understand whether the calculation method of
472 compensation for alteration is reasonable in Taiwan. Future research may determine other real
473 options for compensation for alteration during the application period; and construct related
474 valuation models.

475

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