Real Options Analysis: Empirical Testing of Real Options in Residential Real Estate Development

Laura YAO Huimin & Frederik Pretorius

The University of Hong Kong

Abstract

From a real options analysis perspective, the modern theoretical view is that development land represents a perpetual call option to the landowner on the conversion and subsequent development of the land. In the research literature, modeling this process typically follow institution-free assumptions, allow for unconstrained land use mix, density, exercise timing, and other assumptions that otherwise influence "optimal" development decisions. However, in real property markets analysis of land development options are significantly more constrained by institutions than typical stylized land development options encountered in academic literature and research. Hong Kong practices the leasehold system of land management, through which land use and improvements are controlled through leasehold contract conditions in conjunction with urban planning regulations. Developers speculatively purchase long-term land leases with the intention to apply successfully to convert land use and changes in development density, in practice similar to systems that operate under freehold systems, with one important exception: land development options are not perpetual American calls but instead are very long-dated American calls. This paper reports on the experimental application of the perpetual American call option model in the Hong Kong market for very long-dated land development options, and tests if the model explains the behavior of developers through the analysis and testing of option values in ten cases that involved the purchase of development land, holding the land over long periods, and converting and developing the land. Despite it being a perpetual model and not a term-specific long-dated call as the leasehold land management system would specify, in eight out of ten cases the perpetual call model yields "optimal" results that match actual developer behavior. This finding could complicate significantly the standard expectation that American call options with no dividend should not be exercised early. This constitutes the research question for the second phase of this research (not reported on here), which aims to compare these results with results obtained from a study of the same sample but with options valued with a long-dated American call option model with consideration of potential early exercise.

Keywords: capital budgeting methodology, land use conversion; real options analysis; empirical testing

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1. Introduction

Contingent claims analysis logic and the "Real Options Revolution" has changed significantly corporate capital budgeting theory and practice, and has become widely used in some industries including resource extraction, ship- and aircraft building, energy, and some infrastructure developments – often extreme capital intensive asset-finance led applications where the value of flexibility is very prominent. One widely accepted real options analysis (ROA) theory in land economics and real estate has it that under freehold, owning rights to development land represents holding a (perpetual) Call Option to build at an optimal Time, Scale and Land Use Mix, with the building structure on the land as its underlying asset and construction cost as option exercise price. Reality however typically allows significantly less flexibility in practical real estate development applications. However, Real Options Analysis (ROA) has not developed into generally accepted applications in real estate industry practice, despite huge advances in and accessibility of option pricing methods. One explanation for this phenomenon may be that the Institutional Complexity involved in applying ROA methodology in actual real estate markets practically constrains its application. Another explanation is that developers intuitively behave according to the ROA model anyway, it is just not formally applied in practice.

The overall aim of our paper is to test experimentally for evidence that flexibility embodied within the institutional and regulatory framework that governs land and real estate development in Hong Kong influences land developers actual strategic behavior following ROA principles. The institutional and regulatory framework that governs land management in Hong Kong is based on Leasehold, rather than freehold. Land use, land use changes and improvements are all managed through Long-term Land Leases, controlled through leasehold contract conditions in conjunction with urban planning regulations. As is typical and as part of urban development processes in normal land markets, most Hong Kong developers purchase speculatively land (i.e. leases) with the intention successfully to apply to convert land use and obtain changed (increased) development density. Prior to such conversion, these leases may still have substantial time to termination, often exceeding 30, even 40 years, and new leases are typically for 30-50 years. Land use changes and densities that may optimize profits are not guaranteed anywhere, and these are further influenced by urban planning and zoning regulations (or unstated regulatory preferences). Development rights are typically also bundled with constraints, such as building covenants – development time constraints.

Against this background, we set about to search for empirical evidence that flexibility embodied within the institutional and regulatory framework that governs land and real estate development in Hong Kong influences land developers actual strategic behavior following ROA principles. As we are to experiment with methodology in the first instance, we merely state our EXPECTATIONS. Thus, we expect to find:

1. there is a non-trivial positive difference between the land conversion premium calculated by option pricing theory, and the land conversion premium calculated by regulatory authorities based on present value principles;
2. developers are expected to delay the development of land to the point predicted by the real options model as "optimal".

To test our expectations, we selected 10 high-rise residential development projects located in the Tuen Mun and Tsuen Wan Districts of the New Territories of Hong Kong, and were completed during the period from 1990 to 1997. These projects all involved conversion of agricultural/village land to urban-residential, and required lease consolidation, lease modifications, and payment of lease premiums. We reverse engineered the development process to estimate the ROA effects we were interested in:

- To value the converted land at the time of conversion, we assumed the Land Premium paid represented ROA "intrinsic value" (PV) of the land. We then value the land using the option model, and at the same time assess to what extent the developer delayed ("timed") development optimally.
- For convenience, for our first analyses we use the Perpetual American Call Option Pricing Model for individual case analysis, based on the assumption that option values for long-dated calls and perpetual calls converge quite early with reasonable assumptions. The advantage in using this model is that it also yields as part of its output insight into "optimal development timing" as we want to assess in our second expectation. Our approach differs from that of Man (2011), who tests if developers' winning bids at land auctions reflect option premia associated with potential extensions of time that form part of land development time constraints (embedded in the "building covenants"), which he models as sequential compound option.

Our findings support expectations. Results from 8 out of 10 selected cases suggest that the development land was more valuable than the land premiums paid by developers at the time of conversion, on average around +2.5% of current value of the underlying asset. Results from 7 cases out of 10 selected cases suggests (cautiously guarded!) that developers do manage to "delay optimally" development to take advantage of market circumstances. The results suggest that confirmation of these results using term-specific options is called for. The next stage of the research is thus to confirm or otherwise these findings with a duplicate study of the same data, using a range of term-specific flexibility options to value the land, and assess to what extent developers timed and delayed development to optimize benefits.

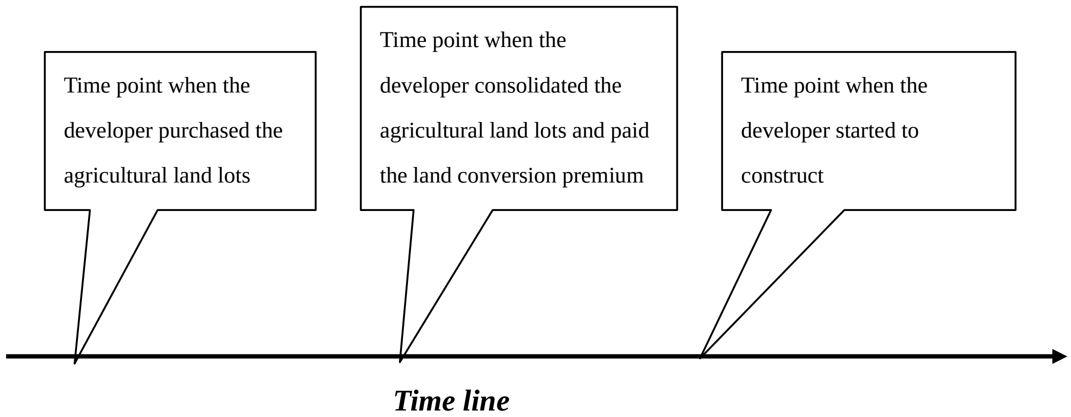
2. Background and Literature

The institutional and regulatory framework that governs land management in Hong Kong is based on leasehold, rather than freehold. Land use, land use changes and improvements are all managed through long-term land leases, controlled through leasehold contract conditions in conjunction with urban planning regulations. As stated above, we concentrate on one typical land development opportunity in Hong Kong, namely development opportunities at the urban-rural fringe. Typically land leases of this type have terms that are long enough to blur the financial distinction between freehold and leasehold; for example, in our sample lease terms to potential strike dates for conversion range between twenty and thirty years before renegotiation to acquire changes in land use and issue of a new consolidated lease becomes time-essential for development purposes. This explains the first stage of our research which simply aims to test how such long-dated land conversion choices perform ex-post if viewed and tested as perpetual options.

As is typical and as part of urban development processes in normal land markets, developers speculatively purchase land with the intention to apply successfully to convert land use and changes in development density. A key factor in the financial success of such projects is to time the land use conversion process and subsequent development to capitalize on favourable market conditions. The specific institutional environment and regulatory requirements that govern urban development, and thus the land use rights that result from land use modifications (if any), affects directly the "framing" of any real options held by landowners in this context. It is also typical of Hong Kong land management practice. This process is everywhere commercially extremely risky because land use changes are not guaranteed anywhere. In principle, a slightly expanded view of the process governing applications for land use changes in Hong Kong can be presented as consisting of two steps, again comparable to what happens in most well-regulated jurisdictions. First there is the formal application for a change in land use rights and negotiations with the authorities that may (or may not) lead to a decision in principle to allow land use conversion and at what density, depending on urban planning and zoning regulations. In order to capitalize on market conditions the timing of the application and granting of land use changes is critical, as has been explained. Land use changes in Hong Kong occur in exchange for a fee known as a “land premium” (comparable to a betterment tax in many jurisdictions), and payment of it is associated with the formal changed land use rights pertaining to the land. We are interested in the value of the land after land use change has been granted, the developer has paid the premium, and has elected to commence.

For practical purposes, the grant and payment of the premium may be viewed as coincident. Typically the granting of changed land use rights also is bundled with a regulatory requirement to develop the land within a specified time period. The amount of the associated premium also depends on the state of the market when conversion is negotiated, and developers thus also attempt to pay the premium at a lower point in the cycle than when the completed development is to be marketed – a time period constrained by what is allowed when the development rights are granted. This time period - from granting of the rights to completion of the development – is typically long enough to allow the developer to delay the starting date of the development to some extent, but not by much, as will be observed from the data. Thus, once the changed land use rights are granted and the premium has been paid, there is practically very little flexibility that remains to developers. They have to complete the development within a prescribed period, and may have limited flexibility to delay the start of development. Failure to complete the development in the prescribed time carries a financial penalty, although extensions of time are allowed following a set of penalties based on a sliding scale benchmarked against land value. In extreme cases of developer breach, the land may be resumed by the authorities (“expropriated”, in freehold terminology). After the entrepreneurial land purchase decision, the main concerns of the developer are thus to time optimally the decision to convert, and then limited flexibility to delay development to capitalize optimally on market trends. We see, however, that in reality the most important strategic flexibility that developers have beyond the original decision to purchase land with a view to conversion, is the decision to time the land conversion and development in response to perceived market conditions. Overall, a simplified timeline of the decision points embedded in the description above is illustrated in Diagram 1, and more details of the institutional arrangements governing land management are presented in Appendix 1.

<u>Diagram 1</u>: Typical Land Development Decision Points



This very brief outline of the land conversion process associated with rural-urban land use conversion, and the timing of development contrasts somewhat with the assumptions underlying the modern theoretical view of land use conversion at the urban fringe. The options-based view of urban land development is intended to generalise aspects of urban development and the behavior of land markets using options models, and while it typically assumes institution- and constraint free activities, the strength of the approach is that it has identified the range of real options analysis models required to operationalise and evaluate the set of specific land development case studies after adjusting for actual institutional constraints. As explained above, the general institutional environment that governs land development ventures at the urban-rural fringe in Hong Kong typically allows two kinds of flexibility in land development, after purchase of development land. The first is flexibility in the timing of the decision to convert to urban land use; and the second is limited flexibility to delay commencement of the development against an overall regulator-imposed time constraint. We thus consider below important literature on options embedded in these two stages.

The nature of the economic circumstances surrounding the decision to convert land at the urban fringe to an alternative (usually higher) use is probably the most exciting of all real estate development activities, as it may be viewed as a demonstration of the dynamics of the urban economy and its spatial manifestation. Capozza and Helsley(1990) and Capozza and Li (1994), Capozza and Sick(1994), Geltner, Riddiough and Stojanovic (1996), and Gunnelin (2001) all developed relevant insights into land use conversion decisions under uncertainty, irreversibility and various interpretations of accepted spatial models of urban economies. With varying assumption about risk aversity, all three models show it pays to delay land conversion decisions with uncertainty. Capozza and Helsley (1990) develop a model of an urban area with growth and uncertainty, and risk neutral investors. Household income, rents, and prices for land follow stochastic processes. They show that uncertainty (i) delays the conversion of land from agricultural to urban use, (ii) imparts an option value to agricultural land, (iii) causes land at the boundary to sell for more than its opportunity cost in other uses, and (iv) reduces equilibrium city size. It is implied that risk aversion is not the primary cause of postponed development with uncertain future rents, but that development is delayed because land conversion is irreversible. Conversion is delayed because the opportunity cost of conversion includes the option value of delaying conversion. With delay and as the level of urban land rent drifts upward, the probability that rents will fall below agricultural rents decreases, and even a risk neutral investor will adopt such a strategy in an uncertain environment.

Capozza and Sick (1994) then explore risk-aversity in a simplified bid-rent and mono-centric model of urban land. Their model of urban and agricultural land prices integrates spatial and asset pricing theories and characterizes the spatial and temporal risk structure of the land market. Urban land is priced following Capital Asset Pricing Model (CAPM) principles and agricultural land is priced as a real option to convert into urban land. Capozza and Li (1994) model the decision to replace durable capital in an optimal stopping framework when capital intensity is variable, and apply the model to land-use decisions and show that the ability to vary capital intensity interacts with the timing, taxes, and project values. The ability to vary capital intensity raises hurdle rents and delays development decisions. They show that simultaneous optimization over time and capital intensity raises hurdle rents and delays development decisions.

Under the assumption of irreversibility and uncertainty, Titman (1985), Williams (1991), Quigg(1993) and Capozza and Li (2002) all analyzed the optimal timing of urban land development using contingent-claims valuation methodology. Titman (1985) made a seminal contribution to the research in applying real options methodology in real estate analysis and his work continues to be entirely relevant. By using binomial option pricing method, he showed that the value of vacant land should reflect not only its value based on its best immediate use, but also its option value if development is delayed and the land is converted into its best alternative use in the future. It may thus pay to hold land vacant for its option value, even in the presence of currently thriving real estate markets. If there is a lot of uncertainty about future real estate prices, then the option to select the type of building in the future is very valuable. Williams (1991) confirms Titman's (1985) results, and determines the optimal points at which to abandon and to develop property, as well as the optimal density of development and the value of developed and undeveloped property. He also expands the investigation focus by analyzing the effects of an option to abandon on the value of undeveloped property. Titman's (1985) conclusion was also confirmed by Quigg(1993), the first research that attempts to examine the empirical predictions of a real option-pricing model using a large sample of actual land market transactions. Using data on 2700 land transactions in Seattle, she found a mean option (time) premium of 6% of the theoretical land value, and generally that the option valuation model has explanatory power over and above the intrinsic value model for predicting land market transaction prices.

Capozza and Li (2002) further model optimal land development decisions when net rents are growing geometrically and uncertainly, and capital intensity is variable. They derive simple rules for the optimal timing of land development projects based on the commonly used internal rate of return and net present value criteria. They show that, even under certainty, projects are optimally delayed beyond the point where net present value becomes nonnegative, if expected cash flows are growing. The implication is that uncertainty is a sufficient but not a necessary condition for optimal delay. Growth expectation in the future by developers can also trigger delay in development. Projects can be further delayed if capital intensity is variable.

3. Methodology, Data and Results

Our research is generally in the spirit of Quigg (1993). As explained, we set about to search for empirical evidence that flexibility embodied within the institutional and regulatory framework that governs land and real estate development in Hong Kong influences land developers actual strategic behavior following ROA principles. We aim to test if developers' timing of the decision to pay the premium and commence with the development is optimal, following the logic developed in the literature. Two things are thus of interest: whether the developer has timed land conversion and payment of the premium optimally (indicating the decision to commence); and secondly, at the time of that action, does the premium that was paid reflect what the ROA model would predict. As argued above, we experiment with methodology in the first instance and so only state our expectations. Thus, we expect to find:

1. there is a non-trivial positive difference between the land conversion premium calculated by option pricing theory, and the land conversion premium calculated by regulatory authorities based on present value principles;
2. developers are expected to delay the development of land to the point predicted by the real options model as "optimal".

For data to conduct the test we selected 10 high-rise residential development projects located in the Tuen Mun and Tsuen Wan Districts of the New Territories of Hong Kong, and were completed during the period from 1990 to 1997 (see details of the 10 cases in Appendix 3). These projects all involved conversion of agricultural/village land to urban-residential, and required lease consolidation, lease modifications, and payment of lease premiums. We reverse engineered the development process to estimate the ROA effects we were interested in:

- To value the converted land at the time of conversion, we assumed the Land Premium paid represented ROA "intrinsic value" (PV) of the land. We then value the land using the option model, and at the same time assess to what extent the developer delayed ("timed") development optimally.
- For this (first) stage of the research, we use the Perpetual American Call Option Pricing Model for individual case analysis, based on the assumption that option values for long-dated calls and perpetual calls converge quite early with reasonable assumptions.

The model chosen for evaluating cases is the perpetual American call option pricing model, as formulated by Samuelson and McKean (SM) in 1965, and as used by Quigg (1993). We present its essence in Appendix 2 together with how we estimate the values for input variables, (see Geltner, et. al. (2007), for more details). We calculate the theoretical critical value of the underlying asset at which it is optimal to build, and compare it to the actual value of the underlying asset when the developer started to build. The difference between the land conversion premium calculated by the option pricing method and the land conversion premium calculated by the residual value method assuming immediate development divided by current value of the underlying asset, represents the option value (for the purpose of Expectation 1).

Details of the projects and the real option analysis results are presented in Appendix 3. Summary statistics for calculation of option premium of the 10 cases and for testing of optimal timing of option exercise of the 10 cases are presented in Table 1.

<u>Table 1: Summary Statistics and Option Premium</u>

Project	Option Premium(% of current value of the underlying asset)	The ratio of current value of the underlying asset to critical value of the underlying asset (V/V^*)
Case 1--Parkland Villas Block	3.58%	0.7561
Case 2--Bauhinia Garden	1.13%	0.9494
Case 3--Botania Villa	6.94%	0.5996
Case 4--Sea Crest Villa Phase 4	0.24%	0.9997
Case 5--Sea Crest Villa Phase 3	4.74%	0.8805
Case 6--Sea Crest Villa Phase 2	3.32%	0.9487
Case 7-- The Cafeteria	0.75%	0.8615
Case 8--Verdant Villa	4.23%	0.7593
Case 9--Villa Tiara	0	1.30
Case 10—Palm Cove	0	1.54
Mean Option Premium	2.49%	

8 cases out of 10 were found to contain positive time premiums and thus support Expectation 1. It is noteworthy that case 9 and case 10were found to contain zero option premiums when the developers formally applied for land use conversion, as in these cases the call options were too deep in the money to have any time premiums at the evaluation time point. The average option premium for the 10 cases was found to be 2.49 % of the current value of the underlying asset (see Appendix 3). Therefore, the results of the 10 case studies may be generalized and viewed as support for Expectation 1.

As for Expectation 2, the current value of the underlying asset of the 8 cases with positive option premiums is less than the critical value of the underlying asset for optimal option exercise, but to differing extents. According to the first hitting time approach for optimal option exercise, those cases with less than unity ratios (V/V^*) embedded in the 8 cases with positive time premiums, mean that the 8 option holders can afford to wait before exercising their options and thus “own” some flexibility before timing optimal exercise. The practice of the developers in the 8 cases with positive option premiums and that started to develop the land at a later time, provides support for Expectation 2—the developers are *expected* to delay the development of land to the optimal points predicted by the real options model. The other

2 cases, cases 9 and 10 (with zero option premiums), delayed the development of land beyond the optimal points predicted by the real options model, and thus do not support Expectation 2. In fact, they should have developed the land at a much earlier time than the time they actually started to develop. It may therefore be concluded that the empirical evidence also largely supports Expectation 2. Overall, there appears to be sufficient evidence to assume confirmation of both Expectation 1 and 2.

Neither case 9 nor case 10 was found to support Expectation 1 or Expectation 2. These two cases were shown to contain no time premium and options involved in these two cases were not optimally exercised as expected. Rather, developers in these two cases seemed to have delayed the development of land beyond the optimal points predicted by the real options model. We suggest four explanations for this observation. First, they seemed to demand a much higher return than the threshold return by DCF principles and also the threshold return implied by ROA principles, in order to trigger development. Second, they seemed not to fear preemption by competitors, which is opposite to the predictions of option game theory in the presence of competition, a further development in real options research (see Grenadier, 2000). In option game theory, developers should exercise options at a time much earlier than the time predicted by the real options model to avoid preemption. Third, the volatility of real estate asset returns, combined and interacting with growth prospects in the real estate market, may both lead to further delay in development. This may partly have provided empirical evidence for Capozza and Li's (2002) view, namely that uncertainty is identified as a sufficient but not a necessary condition for optimal delay. Growth expectation in the future by developers can also trigger delay in development. Fourth, we have suggested a financial explanation for this observed seemingly anomalous behavior, based on the financial flexibility of the developers. Although it may have been time to optimally exercise the options, it is entirely feasible during periods with abundant opportunities that these developers were possibly unable to exercise their options timely and promptly, due to being constrained by their debt capacity or capacity to execute projects. Thus the optimal timing opportunity elapsed with no exercise, leading to postponement of development beyond the points predicted by real options model.

A further implication of the findings indicates that the Hong Kong government systematically seems to have undervalued the land involved in these lease modification cases. Since land premiums present quite a significant portion of fiscal revenue, and is particularly sensitive especially during cyclical downturns in the real estate sector (as was experienced during the Asian Financial Crisis and subsequent SARS scare, 1998-2003), the financial implications of the land premium estimated here also shows that using the real option approach to value development land could change significantly public revenue from land conversion transactions and requires public policy attention.

6. Conclusion

We conclude by first reviewing the key findings of our study, and thereafter we consider its implications and suggest possible further research directions.

This study demonstrated that real options had practical value (rather than descriptive value as shown by Quigg,1993), and found an average positive option premium for real options in the Hong Kong real estate development context. This study also finds further empirical confirmation of optimal exercise of real options in a highly regulated real estate market, which demonstrates that most developers wittingly employed the "delay" strategy to maximize profits. The results suggest that confirmation of these results using term-specific options is called for. The next stage of the research is thus to confirm or otherwise these findings with a duplicate study of the same data, using a range of term-specific flexibility options to value the land, and assess to what extent developers timed and delayed development to optimize benefits.

We note at least three potential implications of the study, pending confirmation of results reported here with a comparative study using long-dated American call option pricing rateher than SM. In our view, the most important implication concerns Public Policy. By applying the principles of ROA, we inferred that the Hong Kong government possibly may have systematically undervalued development land in the lease modification cases, and that a significant part of public land generated fiscal resources may have been transferred to private developers. Notwithstanding any political implications, it at least merits consideration of modifying public land valuation methodology to include explicitly the influence that real options may have on public finances in a city where revenues from land management activities form such a prominent part of fiscal resources. The second implication concerns the private sector. We found that two developers in our case studies may not have had the financial flexibility to exercise their options optimally, and instead let their options lapse without optimal exercise. Future theoretical work could fruitfully investigate the interactions between financial flexibility and optimal exercise of real options. The third facet is the practical contribution and direct application of the real option pricing model in a particular land market taking into consideration the details of regulatory constraints that both frame the option and influence its exercise. It was shown that to facilitate option pricing in practice and help bring ROA closer to practitioners, the set of key variables involved in option pricing in a particular regulatory environment needs to be classified and identified before the real options can be identified, described and valued.

Appendix 1: Institutional Context of Land Development in Hong Kong

Hong Kong practices the leasehold system of land management, through which land use and improvements is controlled through leasehold contract conditions in conjunction with urban planning regulation. This system controlled and presently still controls uses of leased land through leasehold conditions, while new or renewed leases regulate land uses by zoning regulations functioning through statutory town planning, and with appropriate conditions incorporated in new leases. Since many leases were granted decades ago, old land leases require lease modifications to formalize proposed changes in land use in order to realize the actual present economic value of the land, or to reflect current market land use demands. From a real options analysis perspective, these land use conversions and analysis of real options associated therewith are significantly more complex than typical stylized land development real options encountered in academic literature and research. There is thus considerable interest in obtaining empirical evidence of the performance of real options valuation in land development applications where options associated with land development rights are substantially constrained due to regulatory influences (Yao & Pretorius, 2004).

Typically lease modifications in Hong Kong are allowed following entrepreneurial land purchase by developers and then negotiation between the government and the developer to change land use, subject to land use planning and other regulatory constraints, and in exchange for a fee known as a "land premium" (comparable to a *betterment tax* in many jurisdictions). This process is commercially extremely risky and resembles a series of real options, for example, which allow strategic actions at various stages. From land use conversion until eventual land development, the main concerns of the developer remain to minimize the amount of land conversion fee if he chooses to convert the land to a higher use, and optimally time the development of the land to capitalize on rising market trends for realizing maximum profit. As explained later, this study concentrates on the period between when raw land is acquired and when actual construction of the development starts, and as becomes clear, the regulatory framework that governs land development significantly narrows typical real options as perceived in academic land development literature (Yao & Pretorius, 2004).

At the land "purchase" stage, "buy raw land" means actually buying the lease over land use from a present owner of the lease. But the land use permitted does not change with this event. The real estate development company will buy this raw land only if it considers the land to be profitably developable, so it makes a decision based on what it thinks may happen in the future, which requires research and investigation into the land's potential profitability in developed form. This includes assessing the possibility that the state will allow the conversion of the present land use to another land use that is profitable, and discussions with government.

Such a change in land use requires surrender of the existing lease, and both parties then enter into a new lease on the same land, with revised land use conditions and at a “premium”. But there is typically no firm commitment by the government that it will allow a change of land use—only verbal or other non-binding assurances (sometimes quite strong) that it most likely will do so. So, buying the raw land is risky, because there is no guarantee that the government will allow a change in land use and enter into a new lease with the real estate development company. At the land conversion stage, the developer thus may have acquired the raw land through private negotiation with initial land lease owners, held the piece of land, may have waited for infrastructure to be brought into this area, and then pursues formal and legal conversion from a lower use to a higher use.

Once a real estate development company bought a lease over raw land, it is in a position to start investing further in its proposed development of the land. When it has completed its investigation, it presents its proposals to the government for consideration, thereafter there is negotiation between the parties. During the negotiation process, the government may impose conditions they think fit, or conditions advised by government departments. As a result, current urban planning considerations can be applied through the lease modification process. Densities, gross development area and land uses that govern the development on the land are effectively decided by the Hong Kong government.

Although there are stringent regulatory constraints in the process of lease modification, the developers still have access to one kind of flexibility, i.e., time flexibility. Once there is agreement by the government and the real estate development firm, the two sides involved will sign a formal agreement: the government agrees to enter a new lease with the real estate firm under the new agreed land use agreements, at a fee—the “land premium”—payable to the government because the new land use will usually be higher than the previous land use. As we know, real estate markets are highly cyclical, consequently when the market is high, the premium will be high, and vise versa. But the real estate firm typically does not have to pay this land conversion fee immediately when agreement has been reached with the government—actually, this fee is payable only when the real estate firm formally enters into the new lease. It will only enter into the new lease and formally pay the fee when it chooses to do so. So when to pay this land conversion fee and thus when formal conversion of land use takes place is an important timing decision. There is an advantage for the real estate firm to defer the payment of the land conversion fee until it is expected to be most favorable for itself.

After paying the premium, the developer still holds another important option—the timing of the start of the actual construction. Although there are typically time restrictions in the building covenant (BC) attached to the land use conversion contract stipulating that the development on the land must be completed in a defined period (typically three or four years) depending on the scale of the development, there still remains some flexibility for the developer to delay the actual construction through approved extension to the BC period at a monetary penalty (see Land Administration Office Instructions, Section D-21). Also, with formal procedural and administrative measures, the developer can still take action to delay the actual construction process if there is much uncertainty about the future market trend, for example, to delay the engineering process of foundation works. So, from the whole process from formal land use conversion to eventual land development, in practice, the developer has the potential within the system to delay the conversion and development of land significantly, if not indefinitely, although not without costs. Therefore, the land development decision within the Hong Kong land administration system may be viewed as a decision that may be deferred practically for an indefinite period at a cost, which allows it to be viewed and modeled technically as a perpetual American call option that requires periodic renewals at option costs.

Appendix 2: Perpetual Option Pricing Model

The value of perpetual American call option:

$$
\text{Land Value} = \begin{cases} \left(V^* - K\right)\left(\dfrac{V}{V^*}\right)^{\eta} & \text{when } V < V^* \\ V - K & \text{when } V > V^* \end{cases}
$$

Option Variables (Real Options One, Two and Three)

Real Option One: Perpetual American Call Option

Variable		Notes
Present Value of Asset – Gross Development Value	**V**	"Market Value" of Asset – Gross Development Value. For practical purposes this is the only one stochastic variable used for analysis, i.e., the stochastic future payoff V (see K below). For estimation of the current value of the underlying asset, transaction prices of comparable residential properties surrounding the subject property at the time the premium was paid will be used.
Exercise Price – Cost of Construction	***K***	The approximate order of construction cost will be estimated using data from *Levett and Bailey Chartered Quantity Surveyors* at the time the premium was paid. Construction cost K is not treated as stochastic and is estimated separately for each case based on industry data. To commence it is assumed that construction is immediate, but we aim to reconsider this assumption once the scale of values yielded by the model is known.
Critical Value of underlying asset that triggers immediate development.	***V****	Critical Value of underlying asset that triggers immediate development, defined as $V^* = K\,\eta/(\eta-1)$, where V^* represents the hurdle value of the building below which the land should be left undeveloped, and $\eta/(\eta-1)$ is defined as the hurdle benefit/cost ratio.
Risk-free Rate of Return.	r_f	Where cases precede the creation of the Hong Kong Monetary Authority, the risk free rate is estimated from US government securities, and thereafter from the Exchange Fund Notes and Bills program.
Riskiness of Asset	σ	Volatility of returns of residential real estate assets is estimated from HKU Real Estate Investment Series (HKUREIS), specifically the Repeat-sales Monthly Index for the Residential Sector (non-age-adjusted) of Hong Kong, a customized index developed at the University of Hong Kong (HKUREIS).
Option elasticity.	η	Option elasticity is specified as: $\eta = (\delta - r + \sigma^2/2 + ((r-\delta-\sigma^2/2)^2 + 2r\sigma^2)^{1/2})/\sigma^2$
Yield of Developed Property.	δ	Payout ratio of the built property – i.e. rental yield, estimated for the district from *Private domestic—average rentals by class* and *Private domestic--average prices by class* in the journal of *Hong Kong Property Review*, published by the Ratings and Valuation Department of the Hong Kong Government.

Appendix 3: Development Cases: Constraints and Critical Time Points and Real Option Analysis

	Parkland Villas	Bauhinia Garden	Botania Villa	Sea Crest Villa Phase 4	Sea Crest Villa Phase 3	Sea Crest Villa Phase 2	The Cafeteria	Verdant Villa	Villa Tiara	Palm Cove
Completion on or before:	30 Sept., 1998.	30 June, 1995	30 June 2000	30 June 1995	30 Sept. 1995	30 Sept. 1995	31 March 2000	31 Dec. 1998	30 June 1998	31 Jan. 2000
Total gross floor area (“density”) Minimum:	**35, 560 m2**,	**9,148 m2**,	**26,190 m2**	**17,640 m2**,	22,932 m2	11,844 m2	2,208 m2	5,148 m2	20,790 m2	12,714 m2
Maximum:	**59,265 m2**.	**15,246 m2**	**43,650 m2**	**29,400 m2**	38,220 m2	19,740 m2	3,680 m2	8,580 m2	34,650 m2	21,190 m2
Land Use	Residential.	Residential.	Residential.	Residential.	Residential.	Residential	Residential	Residential	Residential	Residential
Land Purchase	June, 1987 (8 small lots)	1933 (19 small lots)	1991, 1992, 1995 (14 small lots)	March 1989	1980, 1987, 1989	Febr. 1987	July 1996	August 1985	1990, 1992 (44 old lots)	Sept. 1993 (37 old lots)
Payment of premium	Sept. 1994	June 1992	May 1996	May 1991	October 1991	Sept. 1991	Jan. 1997	Feb. 1996	May 1994	Febr. 1996
Commencement of Construction	Dec. 1994	Sept. 1992	Sept. 1996	Nov. 1991	May 1992	Feb. 1992	July 1998	Aug. 1997	Oct. 1994	Aug. 1996
Real Option Variables										
Volatility (σ)	27.90%	29.74%	26.83%	30.66%	30.36%	30.43%	26.42%	27.00%	28.15%	
Dividend Yield (δ)	4.77%	5.99%	4.65%	7.61%	6.54%	6.96%	3.62%	5.60%	5.21%	5.43%
Risk-free Rate of Return(r)	5.38%	4.07%	5.56%	5.73%	4.20%	5.26%	5.36%	4.98%	5.03%	4.98%
Strike Price (K)	562,678,425	122,955,118	545,375,426	210,204,913	286,868,916	140,577,212	46,583,127	125,894,352	248,791,313	180,112,655
Gross Development Value(V)	1,060,380,572	244,348,989	813,535,461	418,632,488	512,879,593	273,723,651	117,959,370	202,649,880	749,123,582	600,297,846
Option elasticity(η)	1.67	1.91	1.67	2.01	1.97	1.95	1.52	1.89	1.76	1.86
Critical value: underlying (V^*)	1,402,456,167	257,361,846	1,356,,711,791	418,739,081	582,468,612	288,530,294	136,930,490	266,875,201	574,447,330	389,657,972
V/V^*	0.7561	0.9494	0.5996	0.9997	0.8805	0.9487	0.8615	0.7593	1.30	1.54
Land Value after Change	526,473,389	121,695,261	344,975,360	208,427,589	230,049,785	133,507,731	72,069,832	83,720,307	500,332,268	420,185,191
Land Value before Change	132,280,400	11,156,840	103,633,520	50,000,000	49,602,471	22,180,210	57,000,000	23,334,090	52,112,064	220,184,791
Land Premium Using OPT	394,192,989	110,538,421	241,341,841	123,689,658	142,105,684	89,076,233	15,069,832	60,386,218	454,590,000	230,810,000
Land Premium Using DCF	356,250,000	107,770,000	184,870,000	122,670,000	117,800,000	80,000,000	14,180,000	51,820,000	454,590,000	230,810,000
Difference	37,942,989	2,768,421	56,471,841	1,019,658,	24,305,684	9,076,233	889,832	8,566,218	0	0
Option premium	3.58%	1.13%	6.94%	0.24%	4.74%	3.32%	0.75%	4.23%	0	0

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