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Land Development as a Portfolio of Options

A framework for valuing and managing land development projects

Author	: Nico Mulder
Student number	: 314484
Thesis supervisor	: Dr. Sebastian Gryglewicz
Co-supervisor	: Tiantian Huang
Company	: Fakton B.V.
Company supervisor	: Peter Vlek
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PREFACE AND ACKNOWLEDGEMENTS

‘A new paradigm for valuing development projects in the world of real estate. When viewed through the options lens, projects are nothing more than tomatoes!’. Expectations were set high when these words from my thesis supervisor Peter Vlek from Fakton marked the start of the research process for this Master Thesis. Now that the results are finalized I can look back at a period where I learned a great deal about the real estate development process and am glad that I took on this challenge. Real options analysis has been around for a while, but there still remains a large barrier for practitioners in real estate to pick up on this new valuation tool and start looking through an options lens in valuing, managing and contracting development projects. I hope that this Master Thesis contributes to lowering that barrier.

Hereby I would like to thank a couple of people who’ve helped making this Thesis and finalization of my studies possible. Foremost I would like to thank Peter Vlek, my supervisor at Fakton, who not only supplied vital knowledge of the practice of land and real estate development but also provided the necessary modeling expertise. Next I want to thank my colleagues at Fakton who always stood ready to give the necessary critiques, encouragements and revisions and therefore helped mold this Thesis into its correct shape. Last but certainly not least I want to thank my girlfriend Linda van Kouwen for her never ending support, love and patience at times where I was submerged into the writing process.

Nico Mulder, November 4th 2010

EXECUTIVE SUMMARY

In this thesis a model has been developed that is able to value land- and real estate development projects with multiple embedded real options that are subject to both market risk in the form of fluctuating gross market values and project specific risk in the form of uncertain outcomes of zoning procedures. The valuation is done from the viewpoint of a land developer who wants to estimate the maximum price for which he can acquire the land, given a known portfolio of options that is available throughout the development process. The real option to defer, abandon, expand or contract and the option to switch are included in this portfolio. The model itself is based on the value creation process in land and real estate development (residual valuation) and is used to value four development scenarios with multiple underlying assets with each their own option structure and uncertain zoning procedures. The valuation process produces an Expanded NPV of the development project which is by definition the summation of the Static NPV and the total Option Value. The Real Options Growth Matrix of **Smit and Trigeorgis (2004)** is finally used to illustrate the four development scenarios by their Static NPV and total option value, providing a benchmark for strategic considerations concerning the management of the future development process.

The underlying assets in the model are specified as the gross market value per m² net floor area of four possible property types: retail, office, residential and industrial space. Gross market values are based on current property specific market rents and gross initial yields. Using the Marketed Asset Disclaimer assumption of **Copeland and Antikarov (2004)**, the discounted gross market value represents the value 'as if' the underlying asset were traded on the financial markets. The binomial option pricing framework of **Cox, Ross and Rubinstein (1979)** is subsequently used to model the market risk of the underlying assets. The fluctuations of the underlying assets are based on a Geometric Brownian Motion process, which is defined by the historical standard deviations of the property specific total returns. The exercise prices represent the land- and development outlays that are necessary to develop the project and follow a deterministic path over time.

The sensitivity analysis of the model shows that the options in the portfolio display interesting and significant interaction effects, dependent on their order of valuation and sensitivity to varying levels of volatility, time-to-maturities, moneyness, risk-free interest rates, dividend yield and cross correlations. Overall it can be concluded that the characteristics of financial options are mostly preserved when modeling the development process of real estate as a collection of real options.

Keywords:

Real Options, Land Development, Real Estate, Valuation, Capital Budgeting, Strategy, Decision Analysis, Geometric Brownian Motion, Options Portfolio, Real Options Growth Matrix

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CHAPTER 1 Introduction

1.1 Problem exploration

Thinking about corporate strategy in terms of exercising ones real options over time has led to a further integration of financial option theory in the practice of capital budgeting. **Timothy Luehrman (1998)** provided a rich analogy by suggesting that actively managing a portfolio of investments or real options is, in a way, the same as cultivating a tomato garden. Exercising options that are very 'in the money' is the same as picking the plump and ripe tomatoes while the ones that could spend some more time on the vine are analogous to options that are 'at the money'. The small green tomatoes are not edible yet but under the right conditions could possibly be picked at a later time are compared to options that are 'out of the money'. **Smit and Trigeorgis (2004)** even expand Luehrman's framework into a Real Options Growth (ROG) Matrix where potential projects are graphically placed according to their direct NPV and the Present Value of their Future Growth Opportunities (PVGO) which together form the Expanded NPV. Despite its great appeal though, the new paradigm that is Real Options Analysis (ROA) still has ways to go before becoming the preferred method of valuing and managing real investment opportunities.

This has also been the case in the area of land development as investment decisions are most commonly statically approached as a now-or-never decision or a series of now-or-never decisions. Land developers (public but also private) are producers of land that is ready for real estate development. The value chain goes as follows. Land developers procure land, temporarily operate and then remove any existing structures or pollution and prepare the site for further development. The land is subsequently sold to real estate developers who are themselves producers of real estate. The real estate is finally sold to end users or to investors who rent out the square footage to end users or are end users themselves. Land development is therefore the initial stage in a sequence of investment decisions under uncertainty by different players but is also subject to several clear phases as well.

The price of land should closely reflect the risk-adjusted net present value of future cash flows from exploiting it. The basic decision rule is that land development should be undertaken and continued whenever the residual value is positive and postponed when it is negative. The residual land value is here defined as the (discounted) market value of the developed real estate minus all costs of development. The valuation should however also incorporate the flexibility available to the land developer. The ability to postpone development when the current residual land value is negative is an example of this flexibility. Since land development consists of costly and partially irreversible investments, the flexibility of being able to react under different states of nature is valuable. A real options approach could potentially be used to make the flexibility value explicit. However, practical methods of application in this sense have been scarce. As a result, the DCF-framework is the most widely used capital budgeting tool at present but leads to a systematic underassessment of project value. How could project values look like tomorrow? How can I react to or proactively anticipate a changed state of nature? How can I fit this all in an overall strategic plan with which I can get through difficult times such as recessions? What is the value of a development right with multiple embedded options? These are all questions that standard DCF-analysis cannot answer as it relies on a single discount rate to asses all the risks of the project.

The main difficulty in extending the option framework to real investments is whether the theoretical assumptions that underlie financial option theory are valid in the real world which makes the valuation of the real option complex. The strong heterogenic character of real estate and inefficient real estate markets are a long stretch from stocks and the deep financial markets. Better and more widespread documentation of real estate performance could possibly alleviate this gap (ROZ/IPD index) but is as of yet still in its infant shoes. The practical usability of the ROG Matrix therefore rests on some major pillars such as the applicability, the assumptions and mechanics of the used real option valuation method **(Borison, 2003)** and need to be thoroughly looked at.

In this thesis I will further pave the way for practitioners in the land development field to integrate options thinking in the management of their investments and contracts. In doing so I will explore the most appropriate method for valuing real options in the land development context. After this I will structure the process of land development and identify the nested options available to management. Next, a theoretical model will be built in order to show how option value can be graphically placed in the ROG matrix under different development scenarios. Last, I will perform sensitivity analyses on the option value by varying the key option parameters.

1.2 Problem statement

The central problem I will try to remedy in this thesis will be *how Real Options Analysis can be applied and made accessible in managing land development projects*. The goal of this thesis is to help practitioners in the land development field look at their projects through the options lens. To go even further, it should provide a practical framework for selecting strategies and allocating resources in a land development context. Management should be able to use this model and manage their projects in terms of inherent option value. To use Luehrman's analogy, to be able to tell what their tomato's look like and act accordingly.

1.3 Thesis setup

The setup of the thesis is as follows. I will start by reviewing strategic and real option theory and previous applications to real estate in the literature in chapter 2 and will also result in a reconciled real option valuation approach for this thesis. To make the reader acquainted with the process and practice of land development, an introduction on land development in the Netherlands will be given in chapter 3. The focus of this chapter will be to structure the calculation process of land development into phases and to identify the key value drivers. Next I will give a clear description of the players involved and their interests in the development process. An overview of possible nested options in the development process will also be given here which will provide an oversight of the flexibilities that are generally available to management. The real option methodology will be described in depth in chapter 4, resulting in a step by step approach to quantify option value in a real estate setting. When the foregoing has been thoroughly mapped, I will start the model building in chapter 5 in which a hypothetical plot will function as a fictional land development project. With the use of different scenarios incorporating the available options described in chapter 3, the result will be a fairly complete oversight of possible strategies that can be followed in terms of options and commitments. Sensitivity analyses will also be performed here. Chapter 6 will finish with a summary of the results, final conclusions and future research recommendations.

CHAPTER 2 Literature review

2.1 Strategy as a portfolio of options

Thinking in terms of options when it comes to strategic management has produced numerous research papers. The link between Option Pricing Theory (OPT) and strategic planning was first established by **Stewart Myers (1977)** and later again by **Myers (1987)** where he considers the market value of the firm to be the sum of the present value of income generating assets-in-place and the present value of its future growth opportunities or 'real options'. The options framework, in which one has the right but not the obligation to exercise or invest, can cope with managerial flexibilities that are not being considered in a traditional DCF analysis where it is implicitly assumed that the entire project is followed through no matter what the future brings. An options lens has therefore gained wide appeal as it provides managers with additional tools to react to uncertainties that resolve over time and to proactively consider building options in real projects **(Triantis, 2005)**.

Bowman and Hurry (1993) look at strategy as the sequential striking of an option chain in the potential option bundle that constitutes the organizations resources. They also note that before any strategic choice can be made, managers first have to recognize the awaiting or 'shadow' options in the option bundle which can be a challenge in itself. **Luehrman (1998a)** suggests two ways to discover buried options in individual projects. The project's description can be analyzed to find something about the phasing or sequentiality of investments and is fairly straightforward. It is also possible to observe the cash flow patterns of the project over time. When the pattern shows a relatively large expenditure at some point, this would classify as a key moment where flexibility could have considerable value. **Bowman and Hurry (1993)** state that after recognition and acquisition of the option (which usually requires a small upfront investment or premium but free lunches are available in the real world), striking occurs after receiving either a 'opportunity-arrival signal' or an 'expiration signal'. An opportunity-arrival signal indicates that the option has entered into-the-money and could be struck although it would possibly (absent dividends) be more valuable to wait because of additional learning. An expiration signal indicates the presence of a competitor or dividends which could erode the value of waiting.

Luehrman (1998b) also published the famous tomato garden analogy. Luehrman's main contribution is the concept of an options space, where real projects can be graphically placed into six categories, based on a measure of their value-to-cost ratio (net present values) and cumulative volatility. Although the applicability and the assumptions underlying the calculated NPV's (it takes the present value calculations for granted) and the volatility metric are not discussed (it is implicitly assumed that the underlying asset returns follow a random walk), the intuitive insight that the options space provides is valuable. **Smit and Trigeorgis (2004)** integrate Luehrman's framework in what they call a Real Options Growth (ROG) Matrix and will be examined in-depth in chapter 4. In short, the ROG Matrix is a 2-dimensional grid where potential projects are placed according to their direct NPV (horizontal axis) and the Present Value of their Future Growth Opportunities (PVGO) (vertical axis). This configuration leaves more room on how to estimate the option value (PVGO) and is therefore more flexible.

While the majority of the literature on real options focuses on the valuation issues concerning a single option, there also exist interaction effects when considering a portfolio of options nested in a single project. **Trigeorgis (1993)** illustrates that multiple options embedded in a project are non-additive and that their value depend on the type, separation, order of valuation and moneyness of the options. **Anand et al. (2007)** extend the analysis of portfolios of real options and focus on the portfolio value when both growth and switching options are present which are subject to different kinds of uncertainty (market, project specific and macroeconomic). They conclude with strategy suggestions for an effective composition of real options in a portfolio.

2.2 Real option valuation approaches

The ROG matrix provides an intuitive way of looking at options on and in projects but also comes with some challenges. For the valuation of real options themselves there are several approaches and techniques. The approaches can be roughly placed in the following categories: Classic, Subjective, Marketed Asset Disclaimer, Revised Classic and Integrated approach. They differ mostly in what worldview is adhered to (efficiency and completeness of capital markets) and the source of the data that is used for calculations (market or subjective) but are alike in their goal which is maximization of shareholder wealth **(Borison, 2003)**. When the formal assumptions underlying real option valuation are not met in practice, the outcomes can be noisy and even point in the wrong direction. This, of course, justifies a thorough look at the assumptions that underlie financial option theory and its applicability to real assets and especially to real estate. The next paragraphs will do just this and will follow the classification of **Borison (2003)**. In paragraph 2.3 I will explore possible valuation methods.

2.2.1 Classic approach (no-arbitrage, market data)

The classic approach to valuing real options is the most simple and direct way of applying OPT to real investments. It readily assumes that a replicating portfolio of perfectly correlated twin securities (no-arbitrage argument) can be formed, that this portfolio can be described with Geometric Brownian Motion (GBM) and that capital markets are efficient and complete. These strong assumptions allow for the use of standard option pricing models such as the formula of **Black and Scholes (1973)** for European style options and the standard binomial option pricing model of **Cox, Ross and Rubinstein (1979)** for American options.

A good example of the classic approach is given by **Titman (1985)**. In his paper, where he explores the inherent option value of urban land, he states that the risk of vacant land can be replicated directly by a linear combination of going long in building units and going short in a risk free asset. This argument however relies heavily on the existence of complete and efficient real estate markets on which the building units can be traded and is therefore not realistic. However, directly replicating the payoffs from the real estate project in the financial markets would also be nearly impossible. The implication of this is that there will practically always be some private or idiosyncratic risk left that cannot be hedged away in the financial markets. **Amram and Kulatilaka (1999)** call this risk a tracking error but do not suggest a way of dealing with it. This leaves the classical approach as fairly inapplicable to value real options in real estate as there is no replicating portfolio that could fully mimic the real project's risk.

2.2.2 Subjective approach (no-arbitrage, subjective data)

The subjective approach is very much the same as the classic approach. The main difference is that the trouble of finding a replicating portfolio is sidestepped as the underlying value of the investment is estimated using subjective inputs from relevant indices or industry standards. However, the use of standard option pricing models such as the Black and Scholes formula is still proposed. This makes the approach internally inconsistent **(Borison, 2003)** as the assumption of a replicating portfolio (no-arbitrage argument) is still used but the underlying asset value is subjectively calculated. Like the classical approach, the subjective approach is therefore unrealistic to use in practice.

2.2.3 Marketed Asset Disclaimer approach (equilibrium based, subjective data)

Copeland and Antikarov (2003) go even further than the subjective approach and claim that it is impossible to find a perfectly correlated portfolio of twin securities to replicate the projects returns. As a solution for this problem they state that the NPV without flexibility is the best unbiased estimate of the investment if it were a traded asset. Since there is no security available that correlates with the project more than its own NPV, this should be a reasonable claim. Furthermore, they state that the MAD approach uses no more assumptions than needed to calculate a project's NPV which are valuation by arbitrage and the assumption of complete capital markets **(Arnold, 2002)**. **Laughton, Sagi and Samis (2000)** argue that all cash flows can be seen as commodities which can be priced according to their timing and risk profile. Cash flows that exhibit the same time and risk profile should be valued consistently or without arbitrage possibilities. They further claim that if it is assumed that future risk can be modeled as a tree of possible scenarios, any real asset can be valued. **Smit and Trigeorgis (2004)** also state that the DCF-value of a project can function as a proxy '*as if the asset were traded*'. The real option value should subsequently be estimated relative to the underlying project value.

Concerning the stochastic behavior of the underlying asset (the gross market value of the project), **Copeland and Antikarov (2003)** draw on **Samuelson's (1965)** proof that properly anticipated prices should fluctuate randomly and is in line with the weak form of the efficient markets hypothesis. This also has the added benefit that multiple sources of uncertainty can be combined into a single one which is the uncertainty concerning the diffusion of the project's gross market value over time. The calculated real option value would thus be an approximate value of the option if the underlying project were traded on the financial markets and followed a random walk **(Borison, 2003)**.

Since the underlying project is not exchange traded, volatility also needs to be subjectively estimated. This can be done using Monte Carlo simulations. **Copeland and Antikarov (2003)** suggest that by identifying the key value drivers of the projects gross present value and assigning probability distributions to them, Monte Carlo simulations can be run, resulting in a distribution of the returns on gross present values from which the standard deviation can be taken as input for the binomial lattice. This approach is also proposed by **Cobb and Charnes (2004)** and **Brandão et al. (2005)** but is still dependent on the distribution parameters of the key value drivers that are used as input. Another possibility would be to look at the development project as a portfolio of assets (real estate classes) that each have a certain weight (amount of square meters) in line with modern portfolio theory **(Markowitz, 1952; Smit and Trigeorgis, 2004)**. This approach would however require reliable series to estimate the historical or prospective volatility of the individual asset classes and some correlation modeling. Also, the mean-variance framework of Markowitz assumes normally and independently distributed returns in order to enable rational agents to optimize their preferred mean-variance profile **(Maurer et al, 2004)**.

The MAD approach can be applied to any real estate project where it is possible to calculate the gross present value as this is the only restriction to this approach. The use of GBM or random walk property in diffusing the calculated base value along a binomial lattice also makes it practical and computationally efficient. The downside is that the calculations are very sensitive to the subjective derivation of the project's value and its volatility. Finally, the MAD approach assumes that the calculated present value fully hedges the project's total risk so project specific risks are not explicitly considered.

2.2.4 Revised Classic approach (two investment types)

In the revised classic approach it is suggested that the risk of the real project is assigned to either a market risk or a private risk category **(Borison, 2003)**. The market risk type is then to be hedged using the classic approach as described while the private risk type should be subjectively estimated using Decision Tree Analysis (DTA). The difficulty in using this approach lies in being able to separate the two risk types as this usually is a grey area and subsequently to assign subjective probabilities to private sources of risk, discounted with the company's cost of capital.

The revised classic approach can be used if traded securities can be identified to hedge the market dominated types of risk and if the subjective input to use DTA can be justified for private dominated types of risk. The decision to place projects in either one or the other category does not make it an appealing approach as real investments usually display a mix of both risk types.

2.2.5 Integrated approach (two risk types)

The integrated approach also makes the distinction between market and private risks but, as the name suggests, integrates them into a single analysis. The explicit assumption is made that markets are partially complete. **Smith and Nau (1995)** illustrate the approach using binomial lattices and employ a roll-back procedure using risk neutral probabilities for market uncertainties and subjective or actual probabilities for private uncertainties.

The ability to accommodate both risk types is a big advantage over the revised approach and the MAD approach as well. In practice it is usually the rule instead of an exception that real projects are governed by market risk as well as technological or political risks. In a land development context the technological risk could be related to the zoning configuration of an area which has a large influence on land value. The potential end-use of a parcel in the Netherlands is usually subject to long procedures that could span several years and is therefore surrounded by a large amount of uncertainty. This kind of risk is dominated by local and national regulatory and political uncertainty and can be considered to be unrelated to any market.

The integrated approach is championed by **Borison (2003)** as it is '*based on the most accurate and consistent theoretical and empirical foundation*'. The hedging of market risk using traded securities however could still pose some practical difficulties in a land development context due to the heterogenic character of real estate and inefficient markets.

2.3 Real option valuation methods

The different techniques of real option valuation are closely related to the aforementioned approaches. The goal of this paragraph is not to describe the mechanics of the methods in detail but rather to point out their strengths and weaknesses, also in relation to its practical usability. A general distinction between methods can be made with continuous time models, discrete time models and simulation models.

2.3.1 Continuous time models

A widely known continuous time framework to value options is the formula of **Black and Scholes (1973)**. Although easy to use, for practitioners it represents a black box as they are usually not versed in stochastic asset behavior and Itô calculus. The (closed-form) formula of Black and Scholes is also only able to value European options so the formula cannot deal with rights to exercise options prior to the expiration date. For projects that involve multiple nested options, it is therefore not possible to analytically solve or write down the required set of partial differential equations so a numerical approach would be required. Continuous time models may be more 'correct' in the world of academics, in practice a lot of the intuition of 'keeping ones options open' is lost due to the mathematical skills required to arrive at a solution.

2.3.2 Discrete time models

The use of a binomial lattice to value financial options in discrete time was developed by **Cox, Ross and Rubinstein (1979)** (CRR). The original model is based on the replicating portfolio and no-arbitrage arguments in a world of stocks where the underlying is almost continuously traded. It is worth noting that as the discrete time steps become infinitely small, the CRR model converges to the continuous framework of Black and Scholes. As the binomial approach of CRR relies on the formation of a riskless portfolio it follows that the required rate of return should be the risk-free interest rate **(Hull, 2009)**. The result is that the option payoffs in the binomial lattice can be discounted in a risk neutral world using a risk-free interest rate (with a maturity that matches the duration or time-to-expiry of the option) using backward induction. A trinomial setup, as a variation of the binomial model, can also be used. The advantage is that trinomial trees provide more freedom in modeling the underlying asset's stochastic behavior such as mean-reversion **(Hull, 2009)** but also comes at a higher computational cost.

If it is assumed that capital markets are complete and that there exists a span of traded securities with which the payoffs of the option can be replicated, it's possible to use CRR's setup and risk neutral valuation in combination with the MAD approach as well.

2.3.3 Simulation models

Another possible way to value options is to use the Monte Carlo setup to simulate many random paths for the underlying asset and calculate the payoff of every sample. If the number of iterations are large enough, the result is a dispersion of expected option payoffs from which its probability weighted mean back is discounted to present time with the risk-free rate to arrive at an option value **(Hull, 2009)**. An advantage is that the number of parameters that the option value is dependent on can be increased if there are multiple key value drivers. A disadvantage is that simulation models are forward looking and cannot easily incorporate American options which are usually solved using backward looking methods. An improvement in this sense has been developed by **Longstaff and Schwartz (2001)**. They modified the Monte Carlo simulation procedure so it could value American options. What it does is simulate forward paths using Monte Carlo sampling and then performs backwards style iterations where at each step a Least-Squares approximation of the continuation function is performed. This algorithm is not able to deal with multiple embedded options though as is usually the case in practice.

2.4 Adopted valuation approach and methodology

The real option methodology used in this thesis should ideally be applicable and practical in a land development setting whilst still being true to the underlying assumptions of option pricing. As has been stated, directly searching for a portfolio of traded twin securities (classic, revised classic and integrated approach) to hedge the market risks is not feasible because of the heterogenic character of real estate. The subjective approach is also not realistic as it does not justify the use of subjective data in combination with standard option pricing models such as the Black and Scholes formula. The MAD approach, however, does justify the use of subjective data as it is claimed that option pricing uses no more restrictive assumptions than DCF analysis does. The main goal should be to value the options as if the underlying project were traded on the financial markets which is the same procedure as a DCF valuation but also to incorporate the project specific risks.

The method I will apply in this thesis is an adaptation of the general multiplicative binomial model of **Cox, Ross and Rubinstein (1979)** combined with the MAD approach of **Copeland and Antikarov (2003)** to derive the discounted gross market values of the underlying asset classes. Finally, decision tree analysis in line with the integrated approach **(Smith and Nau, 1995)** is used for handling project specific risk. The chosen methodology will be described in-depth in chapter 4.

CHAPTER 3 Land development process

3.1 Value creation in land development

3.1.1 Real estate calculation process

Land value is derived residually from the potential end use of the land. Figure 3.1 shows the development process (left to right) and the valuation process (right to left) and will be discussed next without considering any real options that might be present.

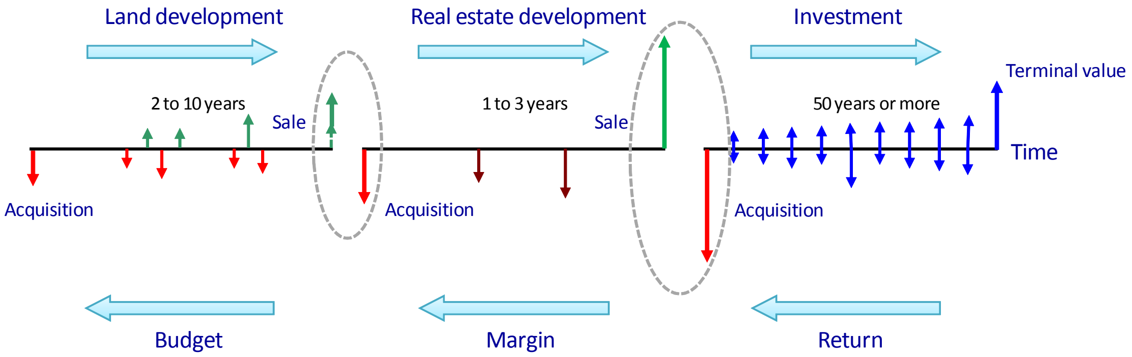


Figure 3.1 Value chain and calculation process real estate development. Three stages and their characteristic cash flows can be distinguished: The land development stage, the real estate development stage and the investment stage. The investment stage can be left out if the real estate is sold to an end user.

Starting at the right side of Figure 3.1, there is the investor who primarily is interested in making a return on his investment in excess of his cost of capital. This return is determined by the net cash flows (rents minus operating costs, building upgrades etc.) and the terminal value of the real estate at the end of his investment horizon. Real estate can, in general, be classified into either retail, office, residential, industrial or parking space. For the investor to buy the assets at the beginning of the investment stage, the following condition has to hold:

$$Gross\ Market\ Value_t = \frac{Gross\ rental\ income\ first\ operating\ year}{Gross\ Initial\ Yield_t} \geq Acq.price\ Investor \quad (3.1)$$

Market values in the investment stage are dependent on demand for square footage and investment appetite in the capital markets and are thus determined by the market level of rents and their capitalization factor or Gross Initial Yield (GIY) which functions as the inverse of a price/earnings multiple **(Geltner and Miller, 2007)**. The GIY is a very commonly used metric in the real estate valuation practice to estimate the gross market value the 'quick and dirty' way. The GIY is derived from actual market transactions and thus serves to give an indication of the market sentiment. A more detailed way to calculate gross market value would be to construct a DCF-model where all rental contracts, operating and upgrade costs and terminal values are included. Although this is definitely possible, I will use the shortcut provided by Equation 3.1 because of its simplicity. A DCF-model in the investment stage does not add significant value in illustrating the impact of options thinking in the previous stages. Also, in this thesis I do not consider any real options in the investment stage although they are of course present here as well, see for example **Grenadier (2005)**. Any consideration of options present in this stage would, a priori, lead to an increase in the Expanded NPV of the assets. Equation 3.1 essentially says nothing more than that the investor wants to earn an NPV of at least zero.

When the gross market value of the assets has been calculated this becomes the value for which the real estate developer can sell his project at the end of the real estate development stage. In this stage the real estate developer incurs all-in construction costs to develop the project. The difference between the gross market value and the all-in construction costs (including his profit margin) is the price the real estate developer is willing to pay to the land developer. This can be summarized in the following condition:

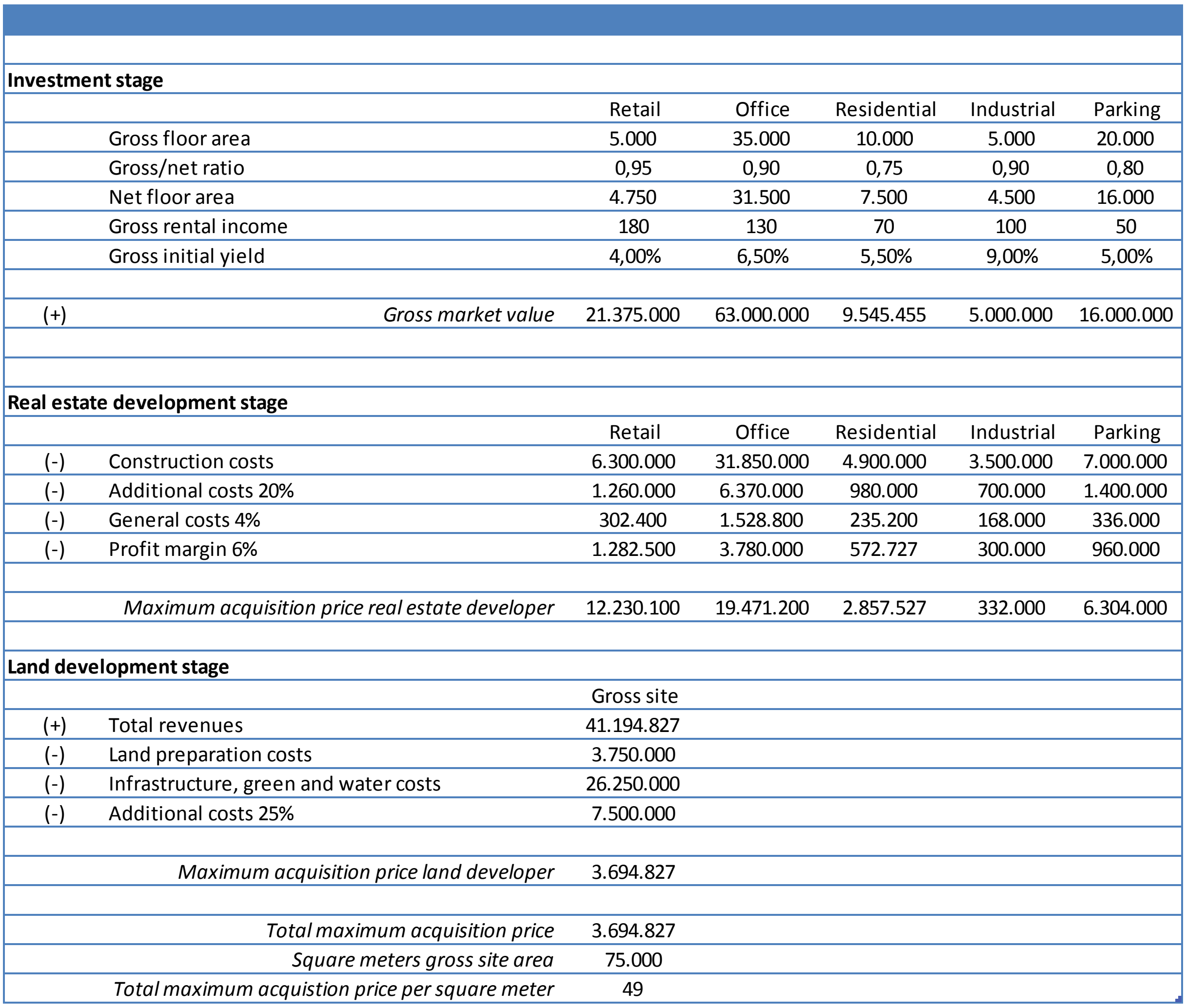
$$\frac{Acq.\ cost\ Investor}{(1+r_{red})^n} - \sum_{t=1}^{n} \frac{CC_{class,t}}{(1+r_{red})^t} - \frac{Profit_n}{(1+r_{red})^n} \geq Acq. price\ Real\ Estate\ Developer \qquad (3.2)$$

Where $Profit_n$ is the profit margin for the real estate developer to reward him for his risk in this stage, $CC_{class,t}$ the all-in construction costs including additional and general costs incurred at time t and r_{red} the cost of capital of the real estate developer. The profit is realized once the project is sold to an investor and is usually stated as a percentage of gross market value.

After the maximum amount the real estate developer is ready to pay for land that is ready for construction has been determined, the land development stage can be evaluated. As this stage is the first one it is also the most risky stage. It is here where the land developer procures the land and incurs costs to prepare the land for the real estate developer. The decision rule to start development in this stage is as follows:

$$\frac{Acq.\ cost\ Real\ Estate\ Developer}{(1+r_{ld})^n} - \sum_{t=1}^{n} \frac{C_{ld,t}}{(1+r_{ld})^t} \geq Acq. price\ Land\ Developer \qquad (3.3)$$

Here $C_{ld,t}$ represents the costs incurred at time t in the land development stage such as demolition, environmental remediation and infrastructure costs. The cost of capital of the land developing party is r_{ld}. The maximum acquisition price of the land can thus be calculated. When land has been procured for less than the left-hand side of Equation 3.3, the (speculative) land developer may earn a profit in this stage. When municipalities hold land positions though, their primary interest is not to earn profits by realizing sufficient land revenues, but to at least remain budget neutral in this stage. In the case of a municipality, Equation 3.3 should be seen as an equality where profits are not the foremost concern of the production process. It can be concluded for both commercial and public land developers that the investment decision in the land development stage ultimately depends on the dynamics in the investment and real estate development stage. Figure 3.2 summarizes the (static) calculation process for a fictional mixed-use development project with retail, office, residential, industrial and parking space.



Investment stage						
		Retail	Office	Residential	Industrial	Parking
	Gross floor area	5.000	35.000	10.000	5.000	20.000
	Gross/net ratio	0,95	0,90	0,75	0,90	0,80
	Net floor area	4.750	31.500	7.500	4.500	16.000
	Gross rental income	180	130	70	100	50
	Gross initial yield	4,00%	6,50%	5,50%	9,00%	5,00%
(+)	*Gross market value*	21.375.000	63.000.000	9.545.455	5.000.000	16.000.000
Real estate development stage						
		Retail	Office	Residential	Industrial	Parking
(-)	Construction costs	6.300.000	31.850.000	4.900.000	3.500.000	7.000.000
(-)	Additional costs 20%	1.260.000	6.370.000	980.000	700.000	1.400.000
(-)	General costs 4%	302.400	1.528.800	235.200	168.000	336.000
(-)	Profit margin 6%	1.282.500	3.780.000	572.727	300.000	960.000
	Maximum acquisition price real estate developer	12.230.100	19.471.200	2.857.527	332.000	6.304.000
Land development stage						
		Gross site				
(+)	Total revenues	41.194.827				
(-)	Land preparation costs	3.750.000				
(-)	Infrastructure, green and water costs	26.250.000				
(-)	Additional costs 25%	7.500.000				
	Maximum acquisition price land developer	3.694.827				
	Total maximum acquisition price	3.694.827				
	Square meters gross site area	75.000				
	Total maximum acquistion price per square meter	49				

Figure 3.2 Simple Static NPV calculation of the maximum acquisition price a land developer can economically pay to realize a mixed-use development project without taking time-to-build into account. When the land has already been acquired, total book value land positions and accrued interest costs should be compared to the maximum acquisition price.

The calculation process needed to arrive at an land acquisition price requires being able to forecast many years into the future as the market values in the final stage are the starting point for the valuation procedure. A static DCF analysis is not a realistic valuation approach as future developments in real estate market values are uncertain and can affect the outcome in the three stages in a negative or positive way. By actively managing the project throughout the stages, different states of nature can be reacted upon to steer the project towards a positive NPV. Before the flexibilities available to management are discussed, I will identify the phases in the land development stage next.

3.1.2 Phases in land development stage

In this paragraph I will describe how land development can be conceptualized as a sequential process within the value framework of Figure 3.1. In Figure 3.4 I again illustrate the land development stage but also show the interim phases. The phases can be even more detailed but are kept simple for the benefit of tractability.

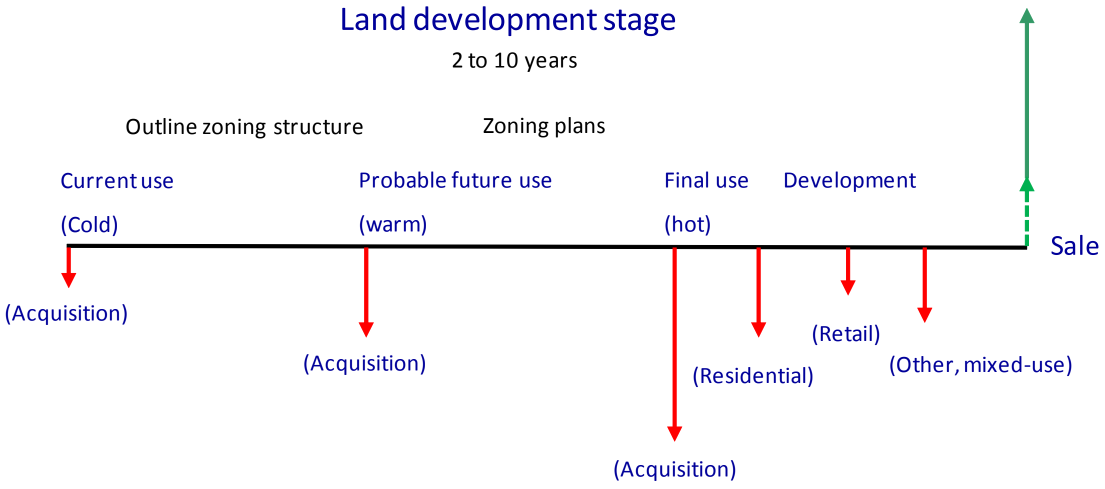


Figure 3.3 The interim phases in the land development stage. Acquisition of the land does not need to occur at the beginning of the stage (greenfield development) when the land is still cold (for example forest or agricultural land) but can also happen when the final zoning plans have been established. The (speculative) acquisition of farm land at the beginning of the stage, with the expectation that in the future zoning procedures will lead to a more profitable use such as residential, retail or a mixed-use development, can be seen as a highly uncertain venture. The multiple arrowheads at the end of the stage illustrate the potential need for governmental subsidies to make the land development break even should investment values fall below a certain threshold.

In the Netherlands the municipal zoning plans play a central role in determining the end use of land. The phases that will be described next are specific for the Netherlands and are determined by the public instruments available to government to influence and determine the use of (scarce) land **(Doorn, van and Pietermaat-Kros, 2008)**. Depending on the profitability of its current use, land can be categorized as either cold, warm or hot. The current 'temperature' of the land always functions as the reference point for the valuation procedure.

Cold land may for example represent forest or agricultural land where there is no immediate outlook on a more profitable use as documented in the outlining of the zoning structure. The acquisition of land in this phase can be seen as a strategic growth option.

An announced change in the zoning structure can lead to a more profitable development of an area and is established at the level of the Provinces and/or the municipality and causes the land to be labeled as warm. The zoning structure broadly describes the desired functions to be realized within the considered areas but is not legally binding. This phase therefore resolves the uncertainty concerning the nature of the programs that are to be developed in that area. These can in general vary from retail, office, residential or industrial real estate dominated programs. Acquisition in this phase can still be considered as a strategic growth option but there is considerably less uncertainty surrounding the potential end use which translates itself into a higher acquisition price of the land.

When the final zoning plans have been established, land is labeled as hot if and when the end use is considerably more profitable than its current or past use. Zoning plans finally define the use of the land (real estate functions, open space, infrastructure, etc.) to an even greater extent and therefore function as a central guideline for developing the land. In this phase, all project specific uncertainty concerning the development program has been resolved although (lengthy) procedures still exist to alter the plans.

It can be said that the outcome of the zoning procedures has an enormous impact on the residual land value after each phase in Figure 3.4. Residential and commercial space for example significantly differ in their income generating capacity while governmental policies are the dominant reason for their allocation. The so-called VINEX (Vierde Nota ruimtelijke ordening Extra) locations in the Netherlands are a good example of private parties acquiring land in anticipation of the outcome of zoning procedures. In the VINEX document areas in the Netherlands were appointed at the government level in cooperation with the Provinces and Municipalities for large scale residential development from the year 1995 and on. VINEX locations were usually to become sub-urban neighborhoods to accommodate population growth in major cities. As zoning procedures were mostly far from completed for these areas (cold or warm land), a large number of private parties acquired positions in these areas in anticipation of a positive change in zoning plans. This was a speculative venture as the outcomes were still uncertain but the potential rewards were significant.

The last phase in Figure 3.4 is the development or subdivision process where the raw land is transformed into commercial lots ready for specific real estate development such as retail, office, residential or industrial space and of course parking and infrastructure. It is in this phase where large costs are incurred such as outlays for land preparation and infrastructure. It is important to note that in this thesis the development of an area is split up into sub developments of specific real estate classes as in Figure 3.2. The Expanded Net Present Value from developing the entire area can then be viewed as the sum of its parts. This way it is also possible to let the ‘sweet’ parts compensate for the ‘sour’ or unprofitable segments of the project.

3.2 Risk and value drivers

As Figure 3.1 and 3.4 show, the development process can take up a substantial number of years and is therefore surrounded by a large amount of uncertainty. Looking at the entire first stage, project specific uncertainty concerning the end use of the land starts broadly and subsequently narrows down as the potential development plan becomes more and more defined in the final zoning plans. Simultaneously, investment values fluctuate and may end up adversely affecting the project’s profit potential. It is assumed that both types of uncertainty are not under the control of management (an exception would be the municipality itself as they are the ones that are involved in drawing up the zoning plans). In any case, all risk drivers will have to be reduced to a few that can be modeled as the interplay of a multitude of risks can make the model less tractable. The model should be based on a few clear value drivers and will be described next.

3.2.1 Market risks

NEPROM, the branch organization for the real estate development community in the Netherlands, identify the following three major market risk drivers in land development **(NEPROM, 2008)**:

1. Market value developed real estate
2. (All-in) construction costs
3. Interest rates

The risk concerning the gross market value therefore depends on the uncertain evolution of market rents and gross initial yields which are captured by the total returns on market value (it is common in the real estate literature to differentiate between direct returns from rents and indirect returns that are determined by changes in capitalization yields). The market value of the real estate class is assessed at the beginning of the investment stage and can therefore be seen as the value of the real estate ‘in operation’. It is the value for which the real estate developer can sell the assets at the end of the real estate development stage in Figure 3.1.

The second major risk driver mentioned are the construction costs. The effect of changes in the level of construction costs on the value creation process can be found in Equation 3.2 and 3.3. A sufficient increase in construction costs could halt the development process altogether when real estate developers cannot cover their costs in the second stage and are therefore unwilling to acquire the land from land development parties. Construction costs are therefore an important determinant of the real estate calculation process.

The third risk driver is the term structure of interest rates. The risk associated with changes in interest rates does not only lie in adverse changes in the cost of external financing but also the change in discount rates which affect the DCF-value of projects and even the value of real options present in the project. Because of this interplay and concerns of tractability of the model I consider interest rates as constant, at least throughout the considered valuation period. The sensitivity of option values to changes in interest rates are described at the end of chapter 5.

3.2.2 Project specific risks

Besides the above mentioned market type risks, the potential building program that is dependent on the outcome of zoning procedures as described in paragraph 3.1.2 can be seen as technological or project specific risk in line with **Smith and Nau (1995)**. The probability of a certain building program can thus be determined with subjective assessments and its value discounted in a risk neutral world. The project's private uncertainties are the procedures leading up to the final land use zoning configuration. These procedures are considered to be driven by political and regulatory motives and are therefore independent from the market. Figure 3.4 illustrates how the uncertainty concerning the zoning configuration of a plot *can* be resolved over time in a decision tree but is not set in stone.

When the land is acquired at the beginning of the stage this can be seen as acquiring a strategic growth option. In this early phase land is still relatively cheap as its current use is not very profitable (cold). When policy makers announce a change in land use in the outline of the zoning structure, the opportunity for a jump in value presents itself and subjective estimates are used to assess the probability of a positive change. The land is now labeled as warm. Note that the probabilities of states of nature occurring can be drawn from management's experience if it is assumed that management acts in the interest of maximizing firm value **(Smith and Nau, 1995)**. This assumption is also quite necessary as zoning procedures are completed at a very local level and cannot for example be inferred from a nationwide average. These probabilities thus need to be assessed on a project by project basis.

Contingent on the announced change in use, management can decide on the initiative to develop the land or abandon and sell the site. When the final use of the site is approved in the zoning plans, the land becomes hot and all project specific uncertainties have been resolved. From this point on the development process is dominated by market risk in the form of fluctuating gross market values. The change in use can take the form of a retail, office, residential or industrial dominated development program and thus differ in terms of asset dynamics and potential profitability.

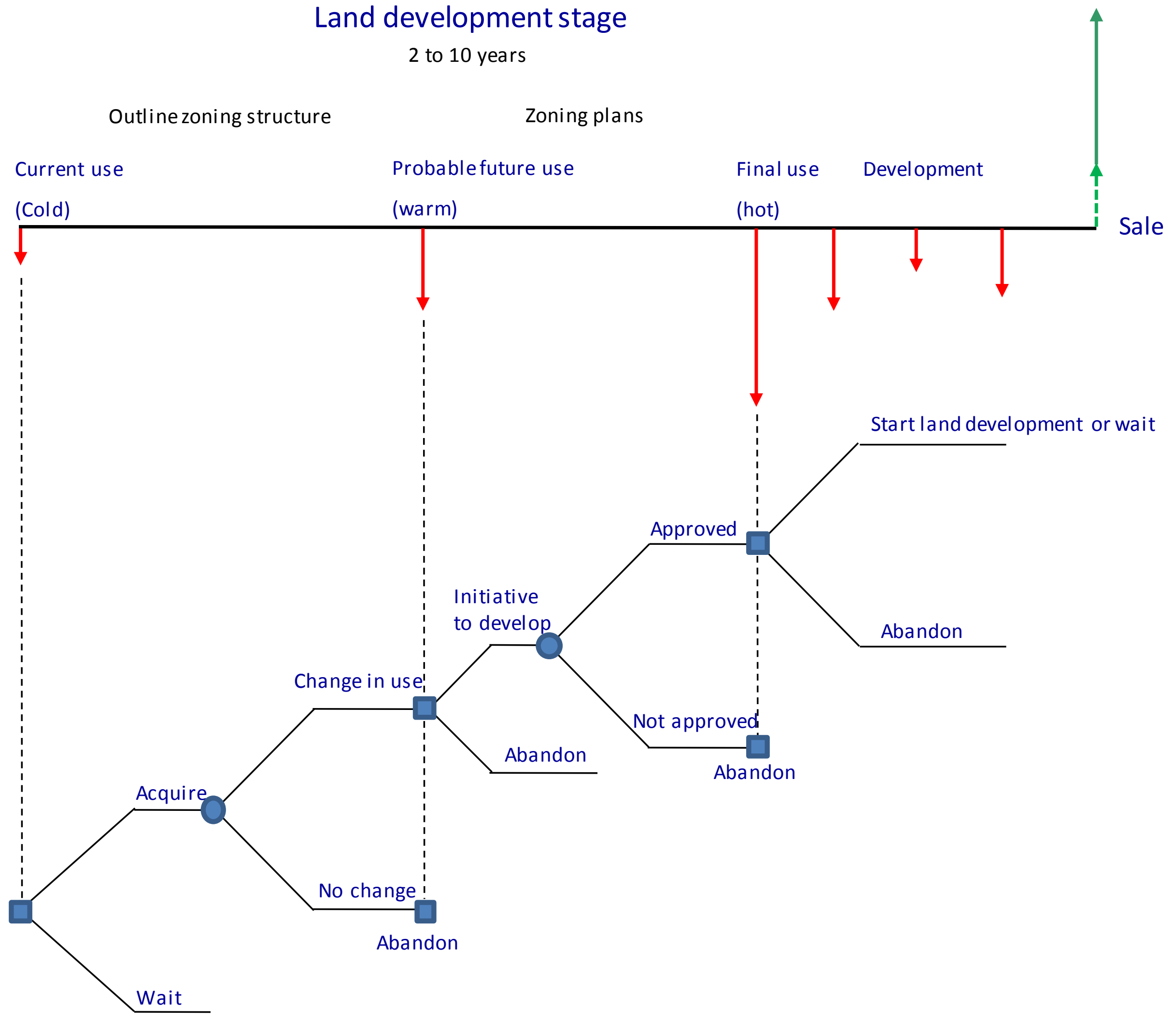


Figure 3.4 Decision tree for a simplified development project. The square nodes represent decision moments while the circular nodes illustrate the evolution of exogenous factors. The probability of a change in land use and the subsequent approval of the zoning plans can be subjectively assessed. The probable future use can be categorized as either a retail, office, residential or industrial dominated development program.

When evaluating a project, it is important to identify the phase where the project is located. From that point a decision tree is drawn up and all future project specific risks and action functions are mapped out. However, there exists no decision tree that is applicable to all projects since all real estate developments can be considered to be unique. Figure 3.5 is a simplified example and is only representative of the theoretical model in this thesis.

3.3 Embedded options in the total development process

Options can be found wherever one looks. Before they are recognized however, they are hidden in the development process and need to be dug out. The available options also depend on the stage in Figure 3.1 the project is in and even on the phase within that stage. As I mentioned in paragraph

3.1.1 I do not consider any options in the investment stage but I will cover the flexibilities that are and ‘could be’ available to management in the land and real estate development stage as they are usually intertwined. I also make a clear distinction between ‘options on land’ and ‘land as a collection of options’. An option on land means the land has not yet been acquired and deals with the option to buy the land within a certain period. Option value in this sense is the premium one pays for the right to purchase. On the other hand, land seen as a portfolio of options is about the flexibilities management has in the subsequent development stages to influence project value. In this thesis I mostly consider options available to management in the development stages and can be categorized as growth, timing and operating options. An important note however is to view the options in the two development stages as separate when ownership of the project changes hands after the land development stage. If the land developer does not develop the real estate himself, the option value and therefore the acquisition price in the second stage is subject to negotiation and should be treated as such.

3.3.1 Options in land development stage

3.3.1.1 Option to defer

The option to defer or wait is the most simple option available in this stage. It means that management has the flexibility to postpone the time-to-build and therefore defer the costs of preparing the land for the real estate developer. This option can be classified as a timing option. In this stage management also has the ability to alter the scope of the project which means that the land is developed in parts. Dependent on the current profitability of a real estate class, the land developer could give priority to selling the prepared land for residential real estate development first over, for example, the office program. This scope option (or option to phase development) can be seen as an option to defer part of total development costs and is most valuable when the area is of a significant size. It is the difference between developing the project in its entirety right now or in incremental steps. The option to defer in both of its forms is available after final zoning plans have been established in Figure 3.5 and can, in general, be summarized in the following action function:

$$C = MAX\left[invest\left(V_{LD,t} - I_{LD,t}\right), wait\left(\frac{pV_{LD,t+1}^{+} + (1-p)V_{LD,t+1}^{-}}{e^{r_f}}\right), 0\right] \tag{3.4}$$

Parameter	Land development project	Value driver option
$\boldsymbol{V_{LD,t}}$	Present value total land revenues at the end of the land development stage in year t	Underlying asset value
$\boldsymbol{I_{LD,t}}$	Present value expected investment outlays land preparation in year t	Exercise price (American call option)
$\boldsymbol{T}$	Length of period in which the option is available	Time to maturity
$\boldsymbol{r_f}$	Risk neutral discount rate	Risk free interest rate

Table 3.1 Parameters option to defer investment outlay land development. The flexibility to defer is not only applicable to the development project in its entirety, but also to segments of the project resulting in a step-by-step development of the area.

Although waiting for the investment decision to end up in-the-money is potentially valuable, deferring the project also implies a value erosion. This is expressed as a constant continuous dividend yield and is shown in Equation 4.7.

3.3.1.2 Option to abandon

The option to abandon can be seen as an option to fully let go or partially scale down the project and is an operating option. In either case the project is (partly) abandoned and a certain resale value is received. The option to sell (part of) the project is usually always present and is an important action to minimize losses should market circumstances worsen. This option is described in the following action function:

$$P = MAX\left[continue\left(\frac{pV^{+}_{LD,t+1}+(1-p)V^{-}_{LD,t+1}}{e^{r_f}}\right), abandon\left(R_{LD,t}\right)\right] \tag{3.5}$$

Parameter	Land development project	Value driver option
$\boldsymbol{V_{LD,t}}$	Present value total land revenues at the end of the land development stage in year t, including the option to defer	Underlying asset value
$\boldsymbol{R_{LD,t}}$	Resale or fallback value when the project is abandoned	Exercise price (American put option)
$\boldsymbol{T}$	Length of the period in which the option is available	Time to maturity
$\boldsymbol{r_f}$	Risk neutral discount rate	Risk free interest rate

Table 3.2 Parameters option to abandon the project. The abandonment option is available throughout the land development stage. At the end of T the project is sold at either $V_{LD,t}$ or $R_{LD,t}$.

Equation 3.5 states that the project is continued whenever $V_{LD,t}$ of, for example, the office development program stays above its resale value $R_{LD,t}$ and abandoned otherwise. This resale or fallback value is based on the notion that there should always exist a third party developer who is able to take over the development at a discount. The resale value is defined here as a percentage of the gross asset value and is therefore positively correlated with the underlying asset. This is a realistic assumption as resale values should drop in a market downturn.

3.3.1.3 Option to switch

Management also has the option to switch asset classes within the program (operating option). For example, given future market developments, certain classes like residential real estate may become unprofitable to develop which is reflected by a lower value $V_{LD,t}$. The option to switch enables the land developer to change the development program from industrial to retail space and from residential to office space and vice versa, dependent on the current development scenario (Retail, office, residential or industrial space dominated). This option is available at the moment the land is ready for property development. When the value of the alternative use $A_{LD,t}$ exceeds the value of the current use $V_{LD,t}$, it becomes valuable to be able to switch to the alternative asset class. The switch option then becomes a European call option on the relative asset values with a strike price equal to 1 **(Smit and Trigeorgis, 2004)**. As the zoning plans have already been established, the flexibility value from this option needs to be weighed against the costs of securing the zoning permissions of the alternative use and the formation of the alternative development plans which is expressed as a proportional cost of the alternative asset's land revenues. This implies that the option to switch has to be made explicitly available by the municipality. The action function below captures the available flexibility:

$$C = MAX\left[continue\ (0), switch\ \left(\frac{(1-switching\ costs)*A_{LD,t}}{V_{LD,t}} - I_{switch,t}\right)\right] \tag{3.6}$$

Parameter	Land development project	Value driver option
$\boldsymbol{V_{LD,t}}$	Present value total land revenues current use at the end of the land development stage in year t, including the option to defer and abandon	Underlying asset value
$\boldsymbol{A_{LD,t}}$	Present value land revenues alternative use $A_{LD,t}$ at the end of the land development stage	Underlying asset value
$\boldsymbol{\frac{A_{LD,t}}{V_{LD,t}}}$	Relative value alternative and current real estate class	Underlying asset value
$\boldsymbol{switching\ costs}$	Proportional switching costs as a percentage of $A_{LD,t}$	Underlying asset value
$\boldsymbol{I_{switch,t}}$ **= 1**	Switching parameter which is equal to one	Exercise price (European call option)
$\boldsymbol{T}$	Length of period in which the option is available	Time to maturity
$\boldsymbol{r_f}$	Risk neutral discount rate	Risk free interest rate

Table 3.3 Parameters option to switch to an alternative asset class in the land development stage. The option to switch is a one-time opportunity right before real estate development starts.

Here $V_{LD,t}$ represents the asset value of a certain real estate class and functions as a base case to which the value of alternative uses can be compared, represented by $A_{LD,t}$. $A_{LD,t}$ here represents an alternative development scenario.

A potential difficulty in valuing this option lies in the different volatility characteristics of the alternative asset classes. As I will show in chapter 4, the options are evaluated in a binomial framework which is determined by the volatilities of the underlying asset classes. As a switching option is very much dependent on the dynamics between the current asset class and the alternative use **(Anand et al., 2007)**, the cross-correlations also have to be modeled. The methodology I adopt is based on constructing a consolidated binomial event tree by calculating the relative volatility of the current and alternative asset class in line with modern portfolio theory **(Markowitz, 1952; Smit and Trigeorgis, 2004)**. This will be described in-depth in Chapter 4.2.3.

3.3.1.4 Option to expand or contract

From a land developer's perspective, the option to expand or contract deals with the ability to increase (e%) or decrease (c%) the density of the built area, given the total gross site area. This density is expressed as the Floor Space Index (FSI) and represents the built gross floor area in relation to the gross site area. Increasing the density has the effect of increasing the compactness of the development project and thereby effectively increasing $V_{LD,t}$ of one or more real estate asset classes. This option, which is also an operating option, can be expressed in the following action function and is available at the same time as the switching option, making this flexibility equal to both a European call and put option:

$$C, P = MAX\left[expand\left(eV_{LD,t} - I_{e,t}\right), contract\left(R_{c,t} - cV_{LD,t}\right), 0\right] \tag{3.7}$$

Parameter	Land development project	Value driver option
$V_{LD,t}$	Present value total land revenues current use at the end of the land development stage in year t, including the option to defer and abandon	Underlying asset value
e	Percentage expansion of real estate asset program	% of underlying asset value
$I_{e,t}$	Present value additional investment outlay expansion	Exercise price (European call option)
c	Percentage contraction of real estate asset program	% of underlying asset value
$R_{c,t}$	Present value saved costs through contraction	Exercise price (European put option)
T	Length of period in which the option is available	Time to maturity
r_f	Risk neutral discount rate	Risk free interest rate

Table 3.4 Parameters option to expand or contract the density of the land use. The expansion and contraction parameters are set to 5% and 10% respectively. This option is mutually exclusive to the option to switch use.

An expansion not only represents the intensification of commercial plots (also increased parking requirements) but causes less costs to be assigned to green, water and infrastructure development as well. Less open space, however, could also negatively influence the market values of properties and should also be considered. The opposite effect can be observed when contracting the density of the program. Going forward with the preconceived program means no changes in density and is represented by 0. Similar to the switching option, changing the use of the land by increasing or downsizing the development program is most likely in conflict with the zoning plans. The option to expand or contract is therefore also subject to permission by the municipality.

3.3.2 Options in real estate development stage

3.3.2.1 Option to defer

As in the land development stage, this timing option is also available to the real estate developer.

$$C = MAX\left[invest\left(V_{RED,t} - I_{RED,t}\right), wait\left(\frac{pV^{+}_{RED,t+1}+(1-p)V^{-}_{RED,t+1}}{e^{r_f}}\right), 0\right] \tag{3.8}$$

Parameter	Real estate development project	Value driver option
$V_{RED,t}$	Present value gross market value at the end of the real estate development stage in year t	Underlying asset value
$I_{RED,t}$	Present value expected investment outlays real estate development or all-in construction costs (+ infrastructure, green and water)	Exercise price (American call option)
T	Length of period in which the option is available	Time to maturity
r_f	Risk neutral discount rate	Risk free interest rate

Table 3.5 Parameters option to defer investment outlay property development.

The option to defer the present value of the all-in construction cost is usually of significant value. The all-in construction costs are, next to the market value of the developed real estate, one of the key value drivers of a development project.

3.3.2.2 Option to abandon

The real estate developer also has the option to abandon and sell the project throughout the second stage and is supported with the same argument that there should always exist a third party property developer who is able to take over the project at a discount. The real estate developer considers the option to abandon in the following action function:

$$P = MAX\left[continue\left(\frac{pV^{+}_{RED,t+1}+(1-p)V^{-}_{RED,t+1}}{e^{r_f}}\right), abandon\left(R_{RED,t}\right)\right] \tag{3.9}$$

Parameter	Real estate development project	Value driver option
$V_{RED,t}$	Present value gross market value at the end of the real estate development stage in year t, including the option to defer	Underlying asset value
$R_{RED,t}$	Resale or fallback value when the project is abandoned	Exercise price (American put option)
T	Length of the period in which the option is available	Time to maturity
r_f	Risk neutral discount rate	Risk free interest rate

Table 3.6 Parameters option to abandon the project. The abandonment option is available throughout the land development stage. At the end of T the project is sold at either $V_{RED,t}$ or $R_{RED,t}$.

As in the land development stage, the resale value $R_{RED,t}$ is defined here as a percentage of underlying market value of the real estate class and is therefore positively correlated with the underlying asset value.

3.3.3 A portfolio of options

When the development of land and real estate consists of sequential chains or portfolios of options that must be struck to complete the project, there also exist interaction effects **(Luehrman, 1998b)** that could affect option value and therefore strategy in a significant way. When future opportunities are contingent on previous investment decisions (options on options), the entire option chain must be taken into account as the individual options are nonadditive **(Trigeorgis, 1993 and Anand et al., 2007)**. The interaction effects depend for example on the moneyness, the separation and the order of the options and need to be taken into account. When switching options are part of the portfolio, the correlations between the performance of real estate classes must also be modeled. Figure 3.6 summarizes the available options in the two development stages.

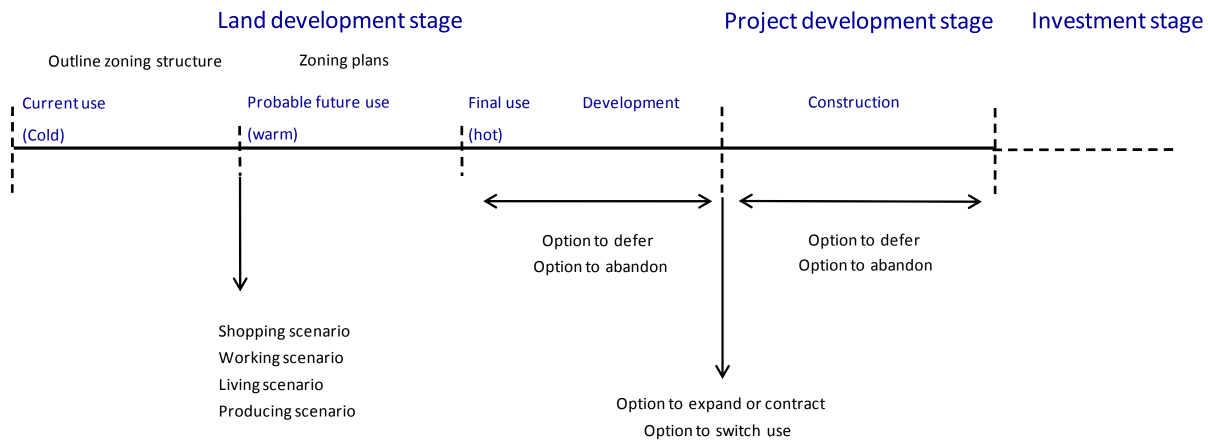


Figure 3.5 A portfolio of options embedded in the total development process. The option to expand or contract and the option to switch are mutually exclusive and are exercised (or left unexercised) prior to the project development stage. The option to defer investment outlays and abandon the project are available in both the land and project development stage.

The land development process is subdivided into the development of the desired real estate functions per scenario. In this thesis I differentiate between retail, office, residential, industrial and parking space which makes the total development project equivalent to the development of its parts. The options in Figure 3.6 are applicable to each of the asset classes which results in separate outputs of Expanded NPV's that sum up to form the Expanded NPV of the total project.

As I will describe in paragraph 4.3, I use a roll-back procedure to value the available options throughout the stages. This way, interaction effects can be dealt with numerically as I evaluate the action functions one at a time, starting at the end of the real estate development stage using backward induction. The increase in project value or Expanded NPV by adding a single option can therefore be attributed to that option. Dealing with the options in another order or separately would make the valuation process increasingly more complex or even impossible.

CHAPTER 4 Methodology and data

4.1 A classification of assumptions

The goal of Real Options Analysis (ROA) is to calculate the financial market value of a real project that exhibits option characteristics. In order to extend ROA to real estate some simplifying assumptions need to be made about the worldview that is adhered to.

4.1.1 Nature of capital markets

I assume that capital markets are partially complete so both market risk and project specific risk are valued in real estate markets in line with **Smith and Nau (1995)**. Along with the MAD approach this enables the use of risk neutral valuation to price market uncertainties as market completeness here implies that there are no arbitrage opportunities available that would compromise the existence of unique and constant risk neutral probabilities.

Project specific risk is evaluated using subjective probabilities from management as is common in DTA and is assumed to bear no relation to the market. This independence property allows to discount project values using the risk-free rate while using subjective assessments for private risk assessments. **Smit and Trigeorgis (2004)** also adopt this view in valuing an oil concession where project specific risk reflects the uncertainty of oil reserve quantities.

4.1.2 Stochastic behavior underlying asset

Related to the assumption of partial market completeness, it is assumed that the market risk of the underlying asset) can be described with Geometric Brownian Motion (GBM), a model widely used to describe stock price movements. This is formally shown in discrete time as:

$$\frac{\Delta V}{V} = (\mu - Div)\Delta t + \sigma_V \, \varepsilon \sqrt{\Delta t} \tag{4.1}$$

The underlying asset V represents the gross market value per m² Net Floor Area as calculated in Equation 3.1. ΔV represents the change in gross market value V or total return in the time interval Δt and has an expected rate of return of $(\mu - Div)$. Div represents a constant and continuous dividend yield and is deducted from the expected rate of return μ. Asset values evolve randomly over time with volatility σ_V where ε has a standard normal distribution (with mean zero and a standard deviation of 1,0).

The parameters on the right-hand side of Equation 4.1 are assumed to be constant and are another way of stating that project values follow a random walk over time and thus exhibit no autocorrelation (project values follow a Markov process). This is also closely related to the weak form of the Efficient Markets Hypothesis (EMH) which states that past prices give no information on future prices. These assumptions are common in the real options literature.

4.2 Valuation mechanics

4.2.1 A binomial setup

The model as initially described by **Cox, Ross and Rubinstein (1979)** provides a flexible setup which can accommodate multiple embedded options and dividend payments. It is also easy to track as the discrete time-steps are usually in the order of one year but can be specified otherwise. It is assumed that the underlying asset follows a random walk so the tree also becomes recombining. Figure 4.1 illustrates the possible evolution of project values in a recombining binomial event tree.

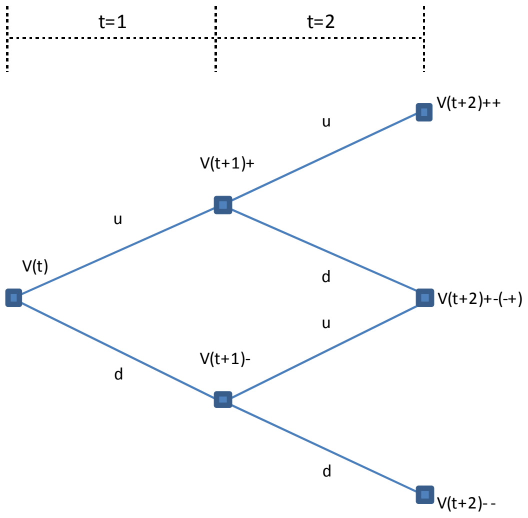


Figure 4.1 A binomial event tree where V(t) stands for gross market value of the project without flexibility at present time. Gross market values evolve with Geometric Brownian Motion as described in Equation 4.1. The up and down factors are subsequently determined by the volatility σ_V of the different real estate classes.

The input parameters needed to construct the binomial setup above are the base case value of the asset (gross market asset value as determined by Equation 3.1) and the up and down factors which are chosen to match the volatility of the underlying asset of Equation 4.1 (see also Girsanov's theorem which states that although the expected return of the underlying asset changes when moving from the real to the risk neutral world, its volatility remains the same):

$$u = e^{\sigma_V \sqrt{\Delta t}} \tag{4.2}$$

$$d = e^{-\sigma_V \sqrt{\Delta t}} = \frac{1}{u} \tag{4.3}$$

And:

$$uV_t = V_{\Delta t}^{+} \tag{4.4}$$

$$dV_t = V_{\Delta t}^{-} \tag{4.5}$$

It can be noted that all that is required to construct the event tree is an estimate of the real estate asset's gross market value and its volatility σ_V.

The option value or PVGO is determined using dynamic programming in a roll-back procedure with risk neutral valuation. Starting at the end-states of the binomial event tree (the start of the investment stage), the tree is worked through backwards and the action functions of paragraph 3.3 are evaluated at each time period in which they are available. Having arrived at the land development stage, option values are corrected for the subjective probabilities of that state occurring (change of land use) as described in Figure 3.5.

Risk neutral valuation is used to discount future payoffs as it gives the same results as the replicating portfolio method but is more straightforward and consistent with the assumption that no twin security exists to replicate the potential project values. A very crude way to determine project values would be to adjust discount rates when the riskiness of the project differs over time (because of nested options) and provide subjective probabilities for the occurrence of these values as in DTA. Risk neutral valuation holds the discount rate constant (at the risk free rate) and subsequently uses risk neutral probabilities (based on σ_V) to assess the probabilities of these values occurring in a risk free world. This risk neutral probability is determined as follows **(Cox, Ross and Rubinstein, 1979)**:

$$p = \frac{e^{\left(r_f - Div\right)\Delta t} V_t - V_{\Delta t}^{-}}{V_{\Delta t}^{+} - V_{\Delta t}^{-}} = \frac{e^{\left(r_f - Div\right)} - d}{u - d} \tag{4.6}$$

Where p stands for the risk neutral probability of the project value evolving to the up-state in the next period. Subsequently, the risk neutral probability of ending up in the down-state in the next period is $(1 - p)$ as they should sum up to 1. The maturity of the risk free interest rate r_f should match the maturity of the project and is held constant throughout the valuation period. Div represents a proportional (constant and continuous) dividend parameter and is deducted from the risk free interest rate. It here represents the forgone value by delaying the completion date. The expected return of the development project in a risk neutral world is therefore equal to $\left(r_f - Div\right)$. It is also possible to adjust the initial gross market value $V(t)$ by multiplying with e^{-Div}, de facto correcting for a lifetime of forgone dividends **(Trigeorgis, 1996)**. Both methods give equivalent results. As p should lie in the interval $[0,1]$, there are limits to the input values of Div. From Equation

4.6 it can be seen that whenever the following condition holds, the risk-neutral probability turns negative and is therefore nonsensical.

$$e^{(r_f - Div)} < d \tag{4.7}$$

Since d is equal to $e^{-\sigma_V \sqrt{\Delta t}}$, it can be concluded that the dividend parameter should always meet the following condition:

$$Div < r_f + \sigma_V \tag{4.8}$$

Div can also represent a value erosion caused by competitors **(Smit and Trigeorgis, 2004)** as they could for example move in and start developing a comparable project adjacent to the development site. Elements from competition are not considered in this thesis though.

4.2.2 Estimating volatility gross market value real estate assets

As described in the previous paragraph, all that is needed to construct the event tree is the gross market value of the real estate classes and an estimate of its volatility σ_V. The volatility parameter is the most difficult one to estimate however as the underlying asset is not traded.

There are several ways to estimate and forecast volatility of the individual property classes such as the historical method, the Exponentially Weighted Moving Average model (EWMA), the Autoregressive Conditional Heteroscedasticity model (ARCH) and Generalized ARCH or GARCH models **(Hull, 2008)**. While more sophisticated models may do more justice to the stochastic and mean reverting properties of variances, the workability and intuitiveness of the model may suffer from the increased complexity. For this reason I choose the (simple) historical method of Equation 4.9 to estimate the prospective volatility of the individual property classes i:

$$\sigma_i = \sqrt{\sum_{t=1}^{n} \frac{1}{n} \left(r_{i,t} - \mu\right)^2} \tag{4.9}$$

Where $r_{i,t}$ represents the historical total return of real estate class i at time t and μ the mean return over the last n periods. It is hereby also assumed that the historical volatilities of the total returns are representative for the future and remain constant throughout the valuation period.

4.2.3 Estimating cross-correlations

Rents and yields and therefore total return dynamics differ substantially between for example residential and retail space. Therefore, some correlation modeling is necessary to value the option to switch accurately. The flexibility to switch between asset classes should increase when the cross-correlations decrease or even turn negative. The intuition is easily provided when two asset classes are negatively correlated with each other through time. When one asset suffers a market downturn, the alternative asset should perform much better due to its opposite dynamics, making the option to switch to the alternative asset valuable. There exists, however, a problem of dimensionality which arises when two or more (partially correlated) stochastic processes drive option value **(Smit and Trigeorgis, 2004)**. Risk neutral valuation cannot be applied correctly when the variances of multiple risk drivers differ as the risk neutral probabilities will not be the same. The solution I adopt is to construct a single binomial event tree where the ratio's of the current and alternative asset values (see Table 3.3) are diffused. To be able to apply risk neutral valuation correctly, the combined volatility is estimated as follows **(Christofferson, 2003)** in line with **Markowitz (1952)**:

$$\sigma_{V,t} = \sqrt{w' \textstyle\sum_t w} \tag{4.10}$$

Where w' is the n by 1 vector of geometric portfolio weights (gross floor area of current asset class divided by total gross floor area current and alternative asset) and $\sum_t w$ the n by n covariance matrix of total returns times the 1 by n vector of portfolio weights. For example, as the switching decision is made between two real estate asset classes, the variance of the relative values is estimated as follows:

$$\sigma^2{}_{V,t} = \begin{bmatrix} w_1 & w_2 \end{bmatrix} \begin{bmatrix} \sigma^2{}_{1,t} & \sigma_{12,t} \\ \sigma_{12,t} & \sigma^2{}_{2,t} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \end{bmatrix} \tag{4.11}$$

And:

$$\sigma_{ij,t} = \sigma_{i,t}\sigma_{j,t}\rho_{ij,t} \tag{4.12}$$

Where $\rho_{ij,t}$ is the correlation between the total returns of real estate class i and j (for example residential and retail space). The covariance matrix can also be further broken down in terms of the variances and correlations of total returns as follows:

$$\textstyle\sum_t = \begin{bmatrix} \sigma_{1,t} & 0 \\ 0 & \sigma_{2,t} \end{bmatrix} \begin{bmatrix} 1 & \rho_{12,t} \\ \rho_{12,t} & 1 \end{bmatrix} \begin{bmatrix} \sigma_{1,t} & 0 \\ 0 & \sigma_{2,t} \end{bmatrix} \tag{4.13}$$

4.2.4 Estimating project specific risk

As described in chapter 3.2.2, project specific risks deal with the jump in land values when municipalities announce a change in zoning plans. First the zoning structure outline gives insight into the probable future use which is subsequently finalized when the zoning plans are approved. Therefore there are two specific value adjustments which can be subjectively made in the following way **(Smit and Trigeorgis, 2004)**:

$$ENPV^{Warm} = \frac{[P(Approval)|\ Change\,]*ENPV^{Hot}+[P(Not\ approved)|\ Change\,]*0}{e^{r_f(T-t)}} \qquad (4.14)$$

Where $ENPV^{Warm}$ is the Expanded NPV of the development program when the probable development program is announced but is not yet approved in the final zoning plans. This value can also be seen as the maximum acquisition price of ‘warm’ land. $[P(Approval)|\ Change]$ is the probability that the zoning plans will be approved by the municipality, conditional on an announced change of use in the zoning structure outline and $[P(Not\ approved)|\ Change\,]$ the probability that the zoning plans will be rejected. $ENPV^{Hot}$ is the maximum price the land developer is willing to pay for acquiring all necessary land positions, given the development program that is allowed for in the final zoning plans. $T-t$ stands for the time lag between the approval of the final zoning plans and the announcement of a change in use. Although I consider four possible development programs in the zoning structure (retail, office, residential or industrial space dominated) The probability of an approval is considered to be the same for all programs as to not overcomplicate the model. The possible development programs (given a gross site area of 100.000 m^2) can be characterized as follows:

Spatial breakdown	Shopping	Working	Living	Producing
Retail (m² Gross Floor Area)	100.000	20.000	20.000	0
Office (m² Gross Floor Area)	20.000	100.000	0	20.000
Residential (m² Gross Floor Area)	0	0	100.000	0
Industrial (m² Gross Floor Area)	0	0	0	100.000
Infrastructure, green and water (m² Gross Site Area)	30.000	30.000	45.000	20.000
Gross Site Area	100.000	100.000	100.000	100.000
Ground Space Index	0,70	0,70	0,55	0,80
Floor Space Index	1,20	1,20	1,20	1,20
Open Space Ratio	0,25	0,25	0,38	0,17
Average number of layers	1,71	1,71	2,18	1,50

Table 4.1 Possible development scenarios that can be announced in the zoning structure outline. Each scenario has its own potential profitability and market risk dynamics. A change in zoning plans can therefore have significant consequences for the maximum price a developer is willing to pay for land. The development scenarios can be seen as a linear scaling factor for the underlying asset (gross market value per m² Net Floor Area). Experts in urban planning from Fakton B.V. have been consulted to ensure the realism of the development scenarios.

After the maximum acquisition price of the warm land has been determined, the next step can be taken to arrive at the Expanded NPV of the land where it is still uncertain whether a change in its current unprofitable use will even occur. This can be calculated as follows:

$$ENPV^{Cold} = \frac{[P(Change\ in\ use) = x] * ENPV^{Warm} + P(No\ change) * 0}{e^{r_f(T-t)}} \tag{4.15}$$

Where $ENPV^{Cold}$ is the Expanded NPV of the land where it can only be subjectively estimated whether a profitable change in use will occur. This is the maximum price a developer should pay for 'cold' land. $[P(Change\ in\ use) = x]$ stands for the probability of an announcement by the municipality that one of the four programs (represented by x) in Table 4.1 will be developed in the future and $P(No\ change)$ that its current zoning configuration will be maintained. In this thesis, the value of cold land is therefore entirely made up of the possible development of program x, which is itself subject to the probability of approval by the municipality. $T - t$ is the expected time lag between now and the announcement of a change in use.

4.3 Data and descriptive statistics

The figures and tables in this section represent aggregated data for the Netherlands.

4.3.1 Gross market value real estate assets

Following Equation 3.1 for determining the gross market value of the assets, data on market rents and gross initial yields is needed. While these figures are highly dependent on the location of the site and current market circumstances, I use aggregated market data from the ROZ/IPD (Raad voor Onroerende Zaken / Investment Property Databank) Netherlands Key Centres Rapport 2009. ROZ/IPD keeps track of the returns made on real properties and real estate portfolios and gets this information from the voluntary disclosure of valuation and management records by publicly exchanged real estate investment companies. I realize that this could possibly introduce a bias in the data as there could be an incentive for investors to only participate in the ROZ/IPD program when their portfolios have performed above average. However, since I cannot check whether certain investors left the program after experiencing a bad year, this potential bias is accepted and noted. Also, privately held real estate is not represented in the data which represents a significant part of the real estate investment markets in the Netherlands but are unfortunately not made public. While market data other than the ROZ/IPD can be used as input to calculate market values in line with the MAD assumption, in this thesis the data should only be seen as representative for real estate held by publicly traded investment companies.

To determine the gross market value I collected the following variables from the Key Centres Rapport for residential, office, retail and industrial properties and are available on a city, regional and aggregated National level:

- Market rental values per m^2 Net Floor Area (NFA) for 2009 on an annual basis;
- Gross initial yields for 2009 on an annual basis.

Property type	Rents	Unit	Gross Initial Yield
Retail	188	rent per m^2 NFA per year	6,62%
Office	153	rent per m^2 NFA per year	7,82%
Residential	86	rent per m^2 NFA per year	5,10%
Industrial	63	rent per m^2 NFA per year	8,52%

Table 4.2 Aggregated market rents and gross initial yields for all four major property types in the Netherlands per m^2 Net Floor Area (NFA) for the year 2009. The data is based on the Key Centres Report 2009 from the ROZ/IPD. Rents divided by the matching Yield produces the gross market value per m^2 NFA.

Figure 4.2 shows the resulting current gross market values per m^2 NFA for the different property types in the Netherlands.

Figure 4.2 Average Gross Market Values per m² NFA for the four major property types in the Netherlands based on ROZ/IPD data. Retail and office space show the greatest market value per m^2 NFA in 2009. The impact on land value of a change in zoning plans from agricultural to commercial use is therefore the highest. Industrial space has the lowest market value per m² NFA.

Total gross market value is not only dependent on total NFA and property types but also on the number of parking spots which can be let. The amount of parking space is based on the following ratios and are considered to be industry standards:

- 1 parking spot for every 125 m^2 Gross Floor Area (GFA) of office space;
- 3 parking spots for every 100 m^2 GFA of retail space.

The revenues created by providing parking facilities are also estimated using industry averages. Parking space for offices generate € 1.350,- per spot per year. Parking space for retail generates € 2,- (including VAT of 19%) per spot per occupied hour for an average of 1.600 hours per year. The parking space for industrial and residential real estate is assumed to be part of the open space in the area and do not generate additional revenue for the investor. The market rents and yields are summarized in table 4.3.

Property type	Rents	Unit	Gross Initial Yield
Parking offices	1.350	rent per spot per year	7,82%
Parking retail	2.689	rent per spot per year	8,50%

Table 4.3 Market rents and capitalization yields per parking spot per year. The data is provided by Fakton B.V. and should be interpreted as expert opinions.

4.3.2 Historical time series and data issues

The historical performance of developed real estate serves as a starting point for assessing its future performance and the data generating process of Equation 4.1. There are several international indices available which track the performance of real estate held in investment portfolios such as the IPD Index in the UK and the NCREIF Index in the USA. Since this thesis is directed at the Netherlands, I collected samples of the performance series as published by the ROZ/IPD.

There are, however, some documented problems with the use of historical series published by the ROZ/IPD or similar indices which are called the smoothing and lagging effect **(Hordijk, 2005; Geltner and Miller, 2007)**. The origin of these effects lie in the appraisal process for property values, which acts as a replacement for the continuous price forming process that is seen on the financial markets. **Hordijk (2005)** mentions that *'such appraisals fail to capture the true market volatility (smoothing effect) and tend to lag the underlying performance'*. The smoothing effect relates to the underestimation of true market fluctuations and is caused by the appraisal method of looking at comparable historical transactions and previous valuations of the asset. As historical valuations are used, this introduces serial correlation in the return series causing the performance to be smoothed. The lagging effect is caused by a mismatch between the recording and the actual occurrence of the market change.

As the lagging and smoothing effect cause the empirical series by the ROZ/IPD to be noisy and violate the assumed random walk property, these errors should be corrected. The implications for correlation estimation are also a cause for concern as the historical covariances should represent unbiased estimates of the true covariances **(Giliberto, 1988)**. **Geltner (1993)** and **Stevenson (2000)** provide a way to correct for the described smoothing effect in appraisal based return series and recover the true underlying performance. The unsmoothing procedure is as follows:

$$r_t^u = \frac{(r_t^* - (1-a) r_{t-1}^*)}{a} \tag{4.16}$$

Where r_t^u stands for the unsmoothed true return, r_t^* the empirical return as published by the ROZ/IPD at time t and a a parameter that lies in the interval $[0,1]$. a is dependent on the amount of autocorrelation and appraisal frequency in the data and was fixed by **Geltner (1993)** at $a = 0{,}40$ for the purposes of his paper. The arguments to fix the a parameter were based on the assumption of real estate investors that the volatility of direct investments in real estate is approximately one half of the volatility of equity investments. This argument can be subject to discussion but is adopted in this thesis to correct the empirical returns. It is thereby assumed that the unsmoothed returns better approximate the true underlying performance and are used to estimate the individual asset volatilities. To check for the removal of (first order) serial correlation in the total return series, the following regression is run for all property types:

$$r_t^* = \alpha + \beta r_{t-1}^* + \varepsilon \tag{4.17}$$

Figure 4.3 illustrates the smoothed historical performance for all four property types from 1995 to 2009.

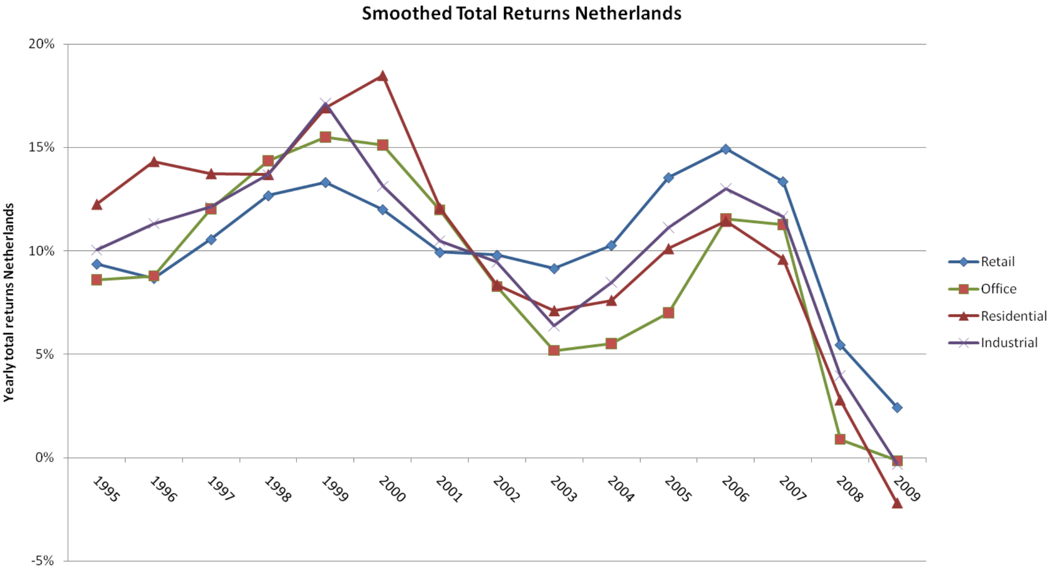


Figure 4.3 Historical performance of the property classes from 1995 to 2009 in the Netherlands based on ROZ/IPD data. Yearly total returns are a consolidated performance measure and consists of income returns from rental revenues and capital returns from changes in capitalization yields. The figure clearly shows that the performance of all property types suffered from the economic downturn from 2007 and on.

Table 4.4 shows the summary statistics of the smoothed yearly total returns of the property types. At first glance, the yearly volatility of the property classes appears to be quite low, ranging from 3,27% for retail space to 5,30% for residential property. This would indicate a relatively low value for real options with investment properties as their underlying asset.

Summary Statistics smoothed total returns				
	Retail	**Office**	**Residential**	**Industrial**
Mean	10,36%	9,06%	10,42%	10,11%
Median	10,27%	8,78%	11,43%	11,13%
Minimum	2,44%	-0,15%	-2,20%	-0,31%
Maximum	14,93%	15,50%	18,49%	17,12%
Standard Deviation	**3,27%**	**4,77%**	**5,30%**	**4,24%**
Skewness	-0,908	-0,492	-0,785	-0,934
Kurtosis	3,542	2,377	3,447	3,826
Jarque-Bera Statistic	2,245	0,848	1,664	2,606
Probability	0,325	0,655	0,435	0,272
Beta Coefficient Regression 4.16	**0,796**	**0,810**	**1,056**	**0,925**
Probability	**0,026**	**0,007**	**0,001**	**0,008**
Durbin-Watson Statistic	0,894	1,277	1,076	1,093

Table 4.4 Descriptive statistics smoothed total return series property types for the Netherlands from 1995 until 2009 on an annual basis.

The figures in Table 4.4 suffer from the described autocorrelation though, which can be confirmed by the large and significant beta coefficients from Regression 4.17. The Durbin-Watson statistic to measure the degree of first order autocorrelation is also included but is actually not an appropriate measure as Regression 4.16 includes lags of the dependent variable in the regression itself. **Brooks (2008)** mentions that the result of such a regression would be that the DW-statistic is biased towards 2,0 which could result in not rejecting the null hypothesis that there is no autocorrelation present when it should be rejected.

Figure 4.4 illustrates the effect of the procedure on the empirical time series.

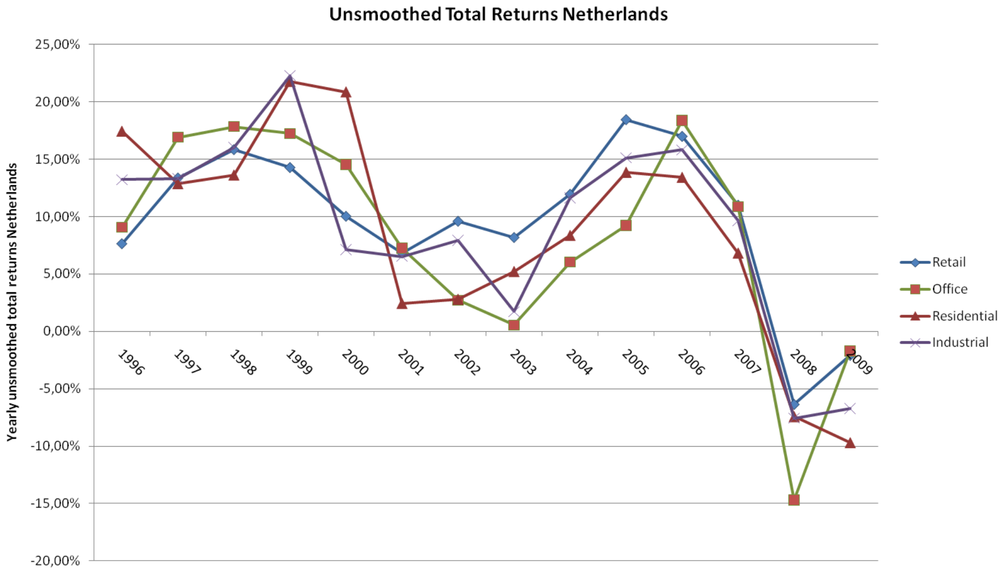


Figure 4.4 The unsmoothed historical total returns using Equation 4.12. These series are used to estimate the consolidated project volatility.

Subsequently, Table 4.5 shows the unsmoothed summary statistics.

Summary Statistics unsmoothed total returns				
	Retail	**Office**	**Residential**	**Industrial**
Mean	9,69%	8,15%	8,74%	9,00%
Median	10,51%	9,14%	10,61%	10,63%
Minimum	-6,38%	-14,71%	-9,68%	-7,56%
Maximum	18,46%	18,36%	21,77%	22,29%
Standard Deviation	**6,92%**	**9,28%**	**9,50%**	**8,50%**
Skewness	-1,055	-0,983	-0,551	-0,708
Kurtosis	3,513	3,584	2,489	2,816
Jarque-Bera Statistic	2,751	2,455	0,861	1,191
Probability	0,253	0,293	0,650	0,551
Beta Coefficient Regression 4.13	**0,638**	**0,488**	**0,762**	**0,640**
Probability	**0,048**	**0,109**	**0,015**	**0,053**
Durbin-Watson Statistic	1,342	1,626	1,416	1,696

Table 4.5 Summary statistics unsmoothed total return series property types for the Netherlands from 1996 until 2009 on an annual basis.

It can be concluded that the unsmoothing procedure of **Geltner (1993)** and **Stevenson (2000)** has a significant effect on the calculated volatility, almost doubling the standard deviations for all property types. Unsmoothing the data also has an effect on the mean total returns of real estate for the past 15 years, lowering it by approximately 1,0% for all property types. The impact of the larger negative returns seen in 2008 and 2009 in Figure 4.4 are the major causes of this. It can be concluded that residential space is the most volatile asset class with a yearly standard deviation of 9,50%, followed by office, industrial and retail space respectively.

The increase of the DW-Statistic towards 2,0 after unsmoothing for all property types suggests that serial correlation in the returns has at least partly been removed. It is, however, discouraging to note that the beta coefficients of retail and residential space in Table 4.5 still remain significant at the 95% confidence level despite the small sample size $(n = 14)$. The regression outputs for the smoothed and unsmoothed series can be found in **Appendix A**.

On a nationwide aggregated level, the smoothed as well as the unsmoothed total returns seem to approach the normal distribution fairly well, although the number of observations is quite low ($n = 15$ and $n = 14$ respectively). For all four property types the null-hypothesis of the Jarque-Bera test for normality is not rejected which is encouraging since a portfolio of assets that behave normally also adheres to the normal distribution itself. This in turn, alongside the (partly) removed autocorrelation using Equation 4.16, strengthens the argument for the use of GBM in diffusing the underlying gross asset values.

4.3.3 Volatilities and correlations

Using the historical method, Table 4.6 shows the standard deviations for the property classes from the series for the Netherlands.

Historical standard deviations property types				
	Retail	**Office**	**Residential**	**Industrial**
Volatility smoothed	3,27%	4,77%	5,30%	4,24%
Volatility unsmoothed	6,92%	9,28%	9,50%	8,50%
Difference	+3,65%	+4,51%	+4,20%	+4,26%

Table 4.6 Yearly standard deviations for the considered property types in the Netherlands. The standard deviations are measured over the period 1996 until 2009. The volatilities of the unsmoothed series are used as the input for the consolidated project volatility. The unsmoothing procedure reveals the assumed true volatility to be higher for all property types.

Next to the individual volatilities I also need to construct the correlation matrix of the unsmoothed series which is shown in Table 4.7.

Historical correlations				
	Retail	**Office**	**Residential**	**Industrial**
Retail	1	0,86	0,78	0,90
Office	0,86	1	0,83	0,87
Residential	0,78	0,83	1	0,86
Industrial	0,90	0,87	0,86	1

Table 4.7 Correlations between the total return series (unsmoothed) for the Netherlands. The correlation matrix is needed alongside the yearly volatilities as an input for the covariance matrix of Equation 4.12 and 4.14.

The performance of the property types are all strongly and significantly correlated with each other which implicates that the option value of switching between property types may be low **(Anand et al., 2007)**. It also implicates that the combined volatility may not differ much from the simple weighted average of the individual asset volatilities.

Now that the market values, market risk and cross-correlations of the property types have been determined, the investment outlays in the land and real estate development stages need to be estimated.

4.3.4 Land and real estate development costs

Land and real estate development costs determine the size of the investment outlays or exercise prices of the option to defer, to expand or contract and to switch and are defined per m^2 GFA. It is assumed that these costs do not behave stochastically but follow a deterministic path. The costs are based on the most recent data as published by the 'Bouwkostenkompas' **(Kengetallen kompas Bouwkosten, 2010)** which is an agency that keeps track of the most recent figures on land development and construction costs in the Netherlands, including additional costs. The deterministic paths take the form of an index and are based on historical costs data as registered by the BDB **(Bureau Documentatie Bouwwezen)**.

In the land development process I differentiate between land preparation costs, costs for completing infrastructure, green and water requirements and additional costs. Land preparation generally consists of demolition of unneeded buildings, environmental remediation and putting in the underground infrastructure and is necessary before actual construction can take place. Costs for infrastructure, green and water are made when the property development stage is nearing completion and are incurred to finish the site. Additional costs represent costs for insurance, fees, financing, administration and oversight and account for 30% over land development costs and are incurred simultaneously.

Cost type	Costs	Unit	Yearly Index
Land preparation (LP)	50	per m^2 GSA	2,20%
Infrastructure, green and water (IGW)	300	per m^2 GSA	1,70%
Additional costs	30%	% of LP and IGW costs	-

Table 4.8 Costs that are incurred in the land development stage based on average figures as published in **Kengetallen Kompas Bouwkosten (2010)**. The indices are based on the BDB index.

In the real estate development stage all-in construction costs are incurred and are made up of construction costs, additional and general costs and a profit margin. Additional costs represent a 20% increase over construction costs while general costs are calculated over construction costs including additional costs. The real estate developer's profit margin is dependent on the uncertain evolution of the gross market value and represents 6% hereof. These percentages are considered industry averages.

Cost type	Costs	Unit	Yearly Index
Retail	700	per m^2 GSA	2,80%
Office	1.200	per m^2 GSA	3,00%
Residential	700	per m^2 GSA	2,50%
Industrial	700	per m^2 GSA	2,80%
Parking	25.000	per built parking spot	2,80%
Additional costs	20%	% of construction costs	-
General costs	4%	% of construction and additional costs	-
Profit margin	6%	% of gross market value	-

Table 4.9 Costs that are incurred in the real estate development stage based on average figures as published in **Kengetallen Kompas Bouwkosten (2010)**. The indices are based on the BDB index.

4.3.4 Risk free interest rates

Risk neutral valuation calls for a risk free interest rate with a time-to-maturity that matches the valuation period of the project. Since this thesis is directed at the Netherlands I decided to use Dutch zero coupon bonds as a proxy for the risk free interest rate. Figure 4.5 shows the nominal term structure of the average rate for Dutch zero coupon bonds from December 2001 to May 2010.

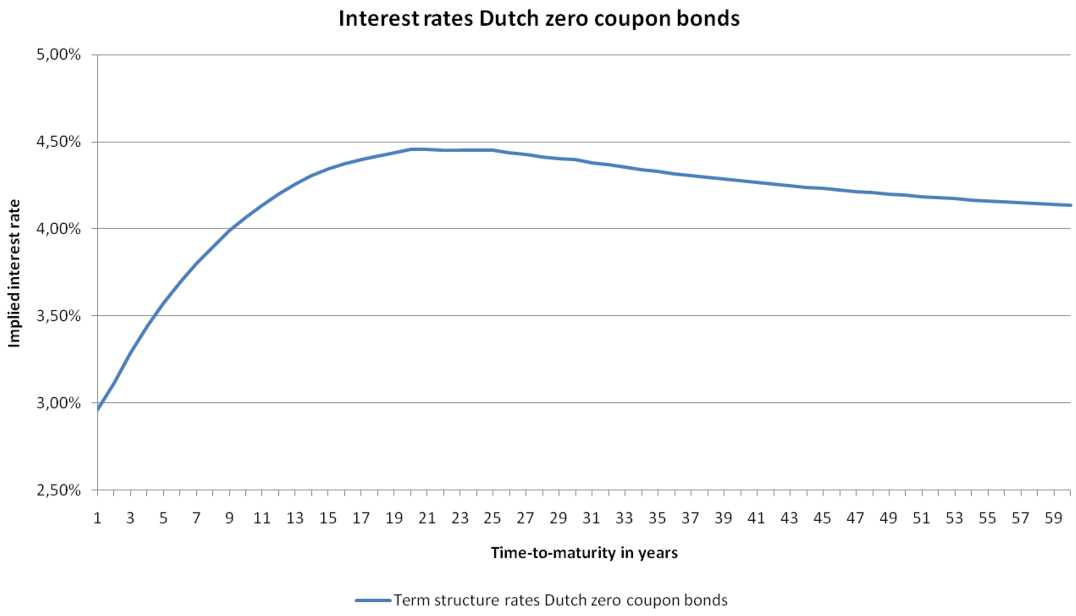


Figure 4.5 Average implied nominal interest rates of Dutch zero coupon bonds with maturities that range from 1 to 60 years. The average rates have been calculated over December 2001 until May 2010.

When the total length of the land development and real estate development stage is estimated, the relevant discount rate is chosen based on maturity of the zero coupon bonds.

4.4 Real Options Growth Matrix

When the total project's static NPV and its option value has been determined, the project can be placed in the ROG matrix. With this matrix, important questions can be answered such as: Which developments can be commercialized in the short term and which ones are to be held on to for strategic purposes in the long term? Two metrics determine the place of a project. The first one is a short term profitability metric or the project's static NPV and represents the net value of the project when it is assumed that the world is completely certain. The second one is a growth potential metric or the project's option value **(Smit and Trigeorgis, 2006)** and represents the value of the flexibilities that are (still) available in the project's time to completion.

Using the ROG matrix as a valuation framework, any project can be categorized throughout the development cycle by its current profitability and its future potential. The financial value of this potential should always be greater than zero if there are still options left in the development process that have not yet been exercised. The ROG matrix consists of six regions but the borders of the vertical axis are not absolute. Projects that are placed in the framework should be evaluated relative from each other in order to prioritize them. The static NPV *is* absolute however, only positive NPV projects add value to the development firm over and above its own cost of capital.

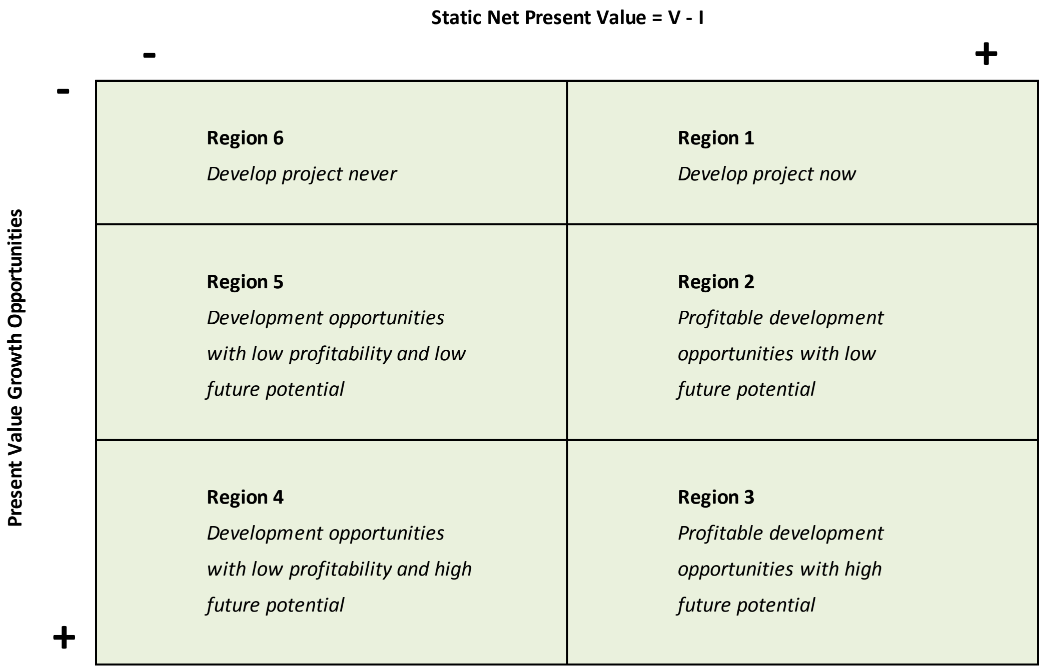


Figure 4.6 Real Options Growth Matrix as proposed by **Smit and Trigeorgis (2004)**, adapted to the project development context. The horizontal axis is determined by the project's static net present value. The vertical axis is determined by the present value of the project's embedded options or the Present Value of Growth Opportunities (PVGO). The Static NPV is calculated by subtracting the present value of total development costs from total current gross market value while the PVGO is calculated using the proposed binomial method in this thesis.

The ROG matrix considers six regions. Projects in region 4 are characterized by a (large) negative NPV but possess considerable option value. This option value could for example stem from a long sequential option chain that has not yet been struck which is the case for projects that are still in the very beginning of the land development stage. The amount of options left thus depends on the stage the project is in but also on the nature of the commitments the developer has already put into contracts with third party real estate developers or investors.

Region 5 labels projects with a negative NPV as well as low option value. Although these projects could still end up in-the-money, this would require a significant amount of 'luck' for market values to successively move upward for a number of periods.

In Region 6 projects should be abandoned or subsidized if possible as there is very low to no option value left for managers to steer the project towards a positive NPV. Losses should be taken and write-offs ought to be recognized. When option values become depleted in the upper regions of the ROG matrix, decisions to go through with development or not boil down to a now-or-never decision. This is the only context where DCF valuations are considered to be meaningful.

The same reasoning that holds for region 6 is also applicable to region 1 with the only difference that projects in this region are in-the-money and therefore add value when followed through with the necessary outlays for development.

Regions 2 and 3 hold projects that are profitable to develop right now but have the potential to end up further to the right as time goes by and the action functions are optimally exercised. All projects need to be carefully managed however as the ROG matrix is not a passive framework, no matter how far in the money a project may be. At all points in time the action functions need to be optimally 'cultivated', not unlike a gardener who looks after his tomato's to the best of his abilities.

4.5 Managing a portfolio of options

The ROG matrix essentially provides a framework for a strategic plan of action contingent on future information, a set of rules of how to act as the uncertain future unfolds itself over time. To determine the strategy, the value of the options has to be known as well as the levers that can be pulled to 'steer' that value into the right direction in the ROG matrix. **Leslie and Michaels (1997)** state that real options can be proactively managed (and therefore the evolution of project values in the ROG matrix) by pulling the key option levers. That's why it is crucial, after the real options have been identified and/or acquired, to identify the parameters that determine total option value and their translation to the world of real estate. As I've shown in Chapter 3.3, the options derive their value from the following key factors, including their translation to real estate contracts:

Real option parameter	Translation to real estate contracts	Ability to influence
T	Time in which the manager can flexibly decide on incurring the investment outlays, abandon the project, alter the scale or switch between real estate classes	Yes, directly
σ_V	Market risk of the individual real estate classes	Yes, indirectly
V	Gross market value of the developed real estate class as estimated by market rents, gross initial yields and development program	Yes, indirectly
I	Necessary investment outlays for land or/and real estate development as estimated by the FSI, GSI and development program	Yes, indirectly
D	Cost of delaying the inflow of revenues and/or interest costs on debt financed development sites	No, exogenous factor
R_f	Risk-free discount rate of the project	No, exogenous factor
ρ	Correlation or dynamics between real estate classes	No, exogenous factor

Table 4.10 Real option parameters and their translation to real estate contracts.

Negotiating flexibilities in real estate contracts provide the basis for managing the inherent risk in land and real estate development. When these flexibilities are not present, the future profitability of the project is dependent on the whims of the market. Looking at Table 4.10, it seems that there are only four parameters that can logically be influenced by management.

The most obvious and also the most important parameter is the time-to-maturity of the options. For example, it could be possible to negotiate a longer time-to-maturity of a deferral option to increase option value, taking into account that dividends may justify an early exercise decision in case of an American call option.

A perhaps counterintuitive way to increase the value of a development position would be to try and increase the market risk which can be done by incorporating relatively more 'riskier' functions in the development program such as office space. In other words, increasing the relative weight of a risky real estate class increases the value of the options on that asset.

Within the boundaries of the zoning plans, market values and investment outlays can also be influenced by increasing or decreasing the volume of the development program and infrastructure outlays. It is important to realize however, that as municipalities set the constraints for developing a plot in the final zoning plans, they possess the most important instrument that determines the flexibilities that are available to the land and real estate developer.

In paragraph 5.5, sensitivity analyses are performed to illustrate the impact of changes in the real option parameters in Table 4.10 on the Expanded NPV of the development project.

4.6 Summary: A step-by-step valuation approach

Consistent with the described methodology in this chapter, the following route needs to be taken from start to finish to arrive at the Expanded NPV of hot, warm or cold land.

Step 1	Calculate the Static NPV, given four possible development programs

Input requirements:

1. Gross market value real estate assets
    a. Market rents per m^2 net floor area per asset class, including parking revenues for office and retail space;
    b. Gross initial yields per asset class, including parking.
2. Investment outlays real estate development
    a. Construction costs retail, office, residential and industrial per m^2 gross floor area;
    b. Construction costs parking requirements per spot;
    c. Percentage additional and general costs;
    d. Profit margin real project developer;
    e. Yearly indexation construction costs.
3. Investment outlays land development
    a. Costs land preparation per m^2 total gross site area;

    b. Cost infrastructure, land and water per m^2 non-built site area;
    c. Percentage additional costs.
4. Development programs and site characteristics (see Table 4.1)
    a. Total m^2 gross site area development site;
    b. Total m^2 non-built area, i.e. infrastructure, green and water;
    c. Development program per asset class in terms of m^2 gross floor area;
        i. Parking requirements for retail and office space;
    d. Gross/net ratio's floor area's;
    e. Site characteristics.
5. Project phasing
    a. Total number of periods outline zoning structure and final zoning plans;
    b. Estimation of time-to-completion land and real estate development stage and final sale to of the project to the investor.

For each of the four development programs, the Static NPV at the start of the land development phase at time t is calculated as follows:

$$Static\ NPV_t^{Hot} = PV\ gross\ market\ value_t - PV\ investment\ outlays_t \qquad (4.18)$$

Step 2	Model market risk real estate classes

Input requirements:

1. Volatility underlying real estate assets
    a. Historical performance real estate classes ROZ/IPD;
    b. Correction for autocorrelation in time series using Equation 4.16;
    c. Cross-correlations;
2. Binomial event trees for each asset class
    a. Up and down factors;
    b. Period interval (years, months, quarters, weeks).

Step 3	Option chains and total project phasing for each asset class

Input requirements:

1. Time-to-maturity options to defer and abandon (American options) and period in which the options to expand, contract or switch can be exercised (European options);

2. Parameters option to expand and contract;
3. Flexibility to switch dominant asset class.

Step 4	Calculate the Expanded NPV, given four possible development programs

Input requirements:

1. Risk-neutral valuation parameters
    a. Term structure proxy risk-free interest rates;
    b. Percentage continuous dividend yield;
    c. Risk neutral probabilities up and down state.
2. Project specific risk
    a. Probability of approval final zoning plans;
    b. Probability of a change of use to the four possible development programs.

When the binomial event trees of the underlying real estate asset classes are mapped, the flexibilities available to management have been determined and the investment outlays have been indexed throughout time, the Expanded NPV of the land at the start of the land development phase at time t can be calculated using backward induction and risk neutral valuation.

$$Expanded\ NPV_t^{Hot} = Static\ NPV_t^{Hot} + Present\ Value\ Growth\ Opportunities_t \qquad (4.19)$$

Subsequently, Equations 4.14 and 4.15 can be used to arrive at the Static NPV and Expanded NPV of warm and cold land.

Step 5	Real Options Growth Matrix

Input requirements:

1. Land values at start land development phase, before approval final zoning plans and before an announced change of use
    a. Expanded NPV metric;
    b. Static NPV metric;
    c. PVGO metric.

When the ROG matrix has been constructed, strategies can be formulated to optimally manage the portfolio of options. The tomato garden of Luehrman has now been brought to life with a full real options valuation apparatus at its core, ready to be tweaked and optimized.

CHAPTER 5 Model application and results

In this chapter I will apply the proposed model to a scenario that land developers could face in the current market downturn in the Netherlands. The final result of this chapter will be an oversight of consequences in terms of option values and their categorization in the ROG matrix when varying key value drivers of the options in the portfolio. The model is built using Microsoft Excel as this is the most widely used spreadsheet program among real estate practitioners and follows the step-by-step approach of the previous chapter. For simplicity I assume that the investor, real estate developer and land developer act as a single entity, meaning that possible game theoretic elements are internalized and that the optimal development of the project stands central. In other words, the investor always pays gross market value as a zero NPV transaction and the real estate developer is always only interested in receiving his profit margin. This way all added value trickles down to the land developer.

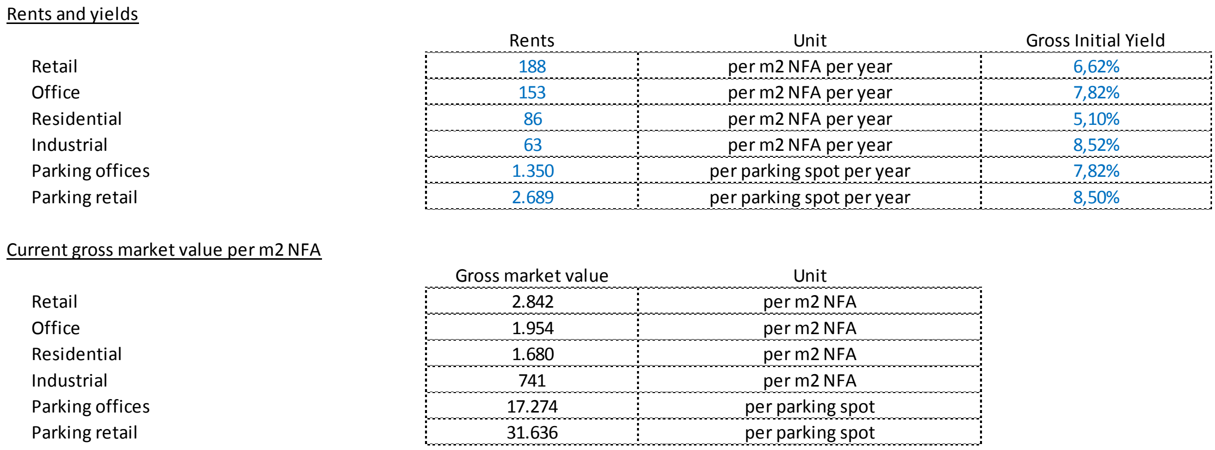
5.1 Land is cold and no acquisitions are made

The goal here is to estimate the maximum price for which the land developer can acquire cold land for potential development and to determine what strategies in terms of flexible contracts are or should be available to the land developer. This scenario serves as a showcase and illustrates the entire procedure to calculate the ENPV from start to finish in Figure 3.1 and 3.5.

5.1.1 Static NPV

5.1.1.1 Gross market value real estate assets

The input data for gross market asset values is based on aggregated market data for the Netherlands from the ROZ/IPD Key Centers Report and is shown in figure 5.1. All input cells are marked blue.



Rents and yields

	Rents	Unit	Gross Initial Yield
Retail	188	per m2 NFA per year	6,62%
Office	153	per m2 NFA per year	7,82%
Residential	86	per m2 NFA per year	5,10%
Industrial	63	per m2 NFA per year	8,52%
Parking offices	1.350	per parking spot per year	7,82%
Parking retail	2.689	per parking spot per year	8,50%

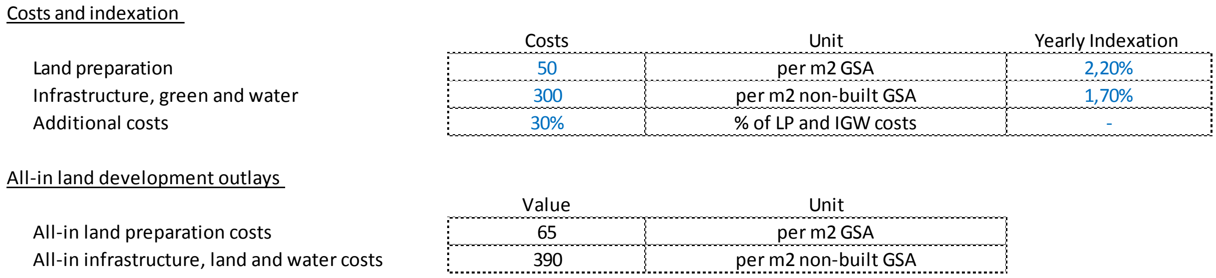
Current gross market value per m2 NFA

	Gross market value	Unit
Retail	2.842	per m2 NFA
Office	1.954	per m2 NFA
Residential	1.680	per m2 NFA
Industrial	741	per m2 NFA
Parking offices	17.274	per parking spot
Parking retail	31.636	per parking spot

Figure 5.1 Input current gross market values real estate classes per m^2 NFA and per parking spot in the investment stage.

5.1.1.2 Investment outlays land and real estate development

The investment outlays are assumed to be fully incurred in the year they are first due. This would seem to pose a problem when the development period is for example 3 years. In this case the development costs represent the present value of those 3 years of development outlays. The cost figures are based on the **Kengetallen Kompas Bouwkosten (2010)**. The indices are based on the BDB index.



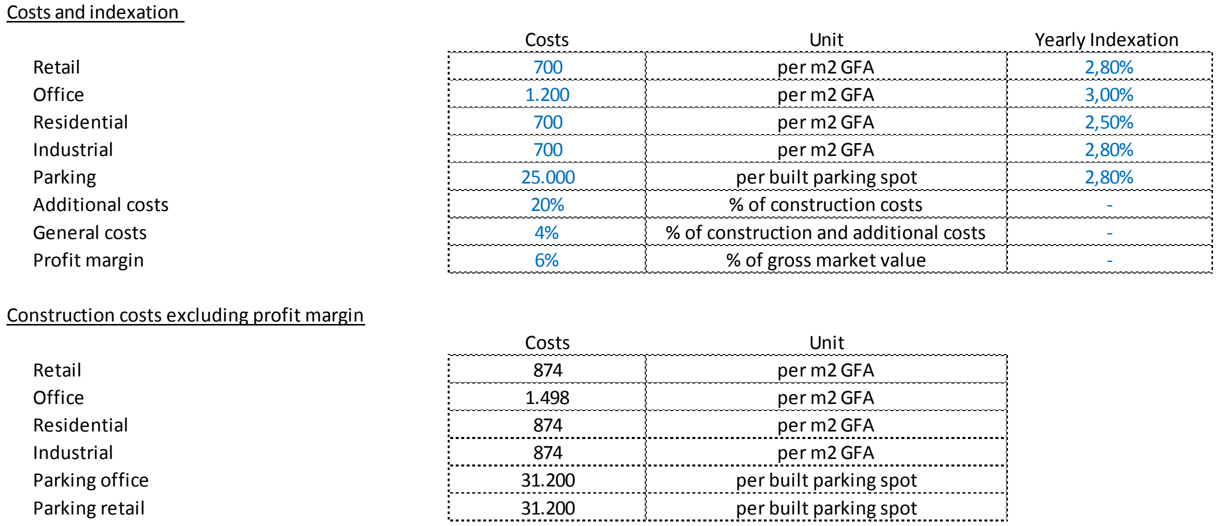
Costs and indexation

	Costs	Unit	Yearly Indexation
Land preparation	50	per m2 GSA	2,20%
Infrastructure, green and water	300	per m2 non-built GSA	1,70%
Additional costs	30%	% of LP and IGW costs	-

All-in land development outlays

	Value	Unit
All-in land preparation costs	65	per m2 GSA
All-in infrastructure, land and water costs	390	per m2 non-built GSA

Figure 5.2 Input data current investment outlays land development stage.



Costs and indexation

	Costs	Unit	Yearly Indexation
Retail	700	per m2 GFA	2,80%
Office	1.200	per m2 GFA	3,00%
Residential	700	per m2 GFA	2,50%
Industrial	700	per m2 GFA	2,80%
Parking	25.000	per built parking spot	2,80%
Additional costs	20%	% of construction costs	-
General costs	4%	% of construction and additional costs	-
Profit margin	6%	% of gross market value	-

Construction costs excluding profit margin

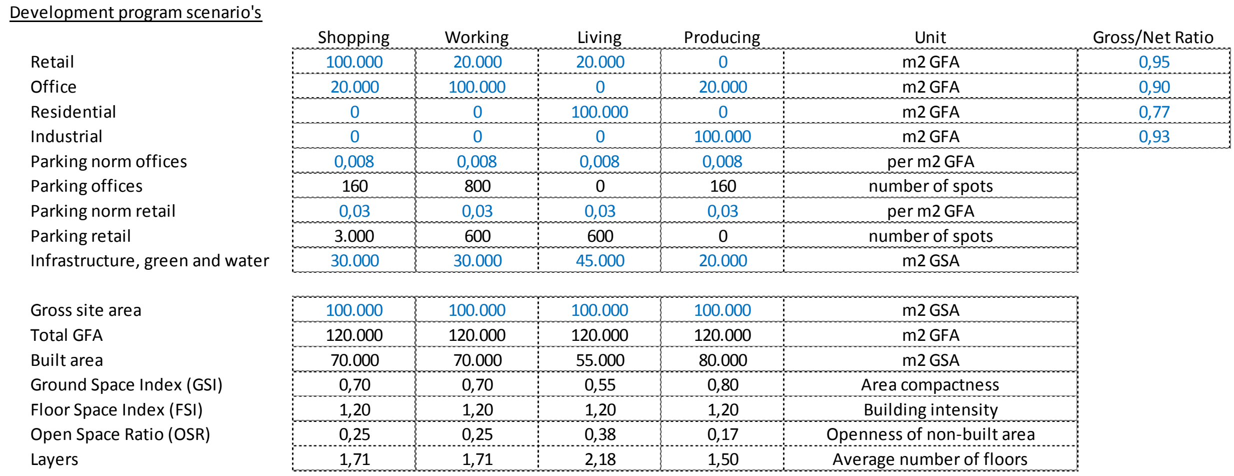
	Costs	Unit
Retail	874	per m2 GFA
Office	1.498	per m2 GFA
Residential	874	per m2 GFA
Industrial	874	per m2 GFA
Parking office	31.200	per built parking spot
Parking retail	31.200	per built parking spot

Figure 5.3 Input data current investment outlays real estate development stage.

5.1.1.3 Development programs and site characteristics

The possible development scenarios are either retail, office, residential or industrial space dominated and each have their own site characteristics. Each scenario is therefore unique in terms of spatial breakdown and potential profitability. The amount of non-built area is dependent on the dominant real estate class. It can be imagined that a residential development program (Living scenario) would require more open space than an industrial program (Producing scenario) would. Although there are much more detailed ways to describe a development program, the focus in this thesis lies on the methodology. Figure 5.4 summarizes the possible scenarios. The density of land use is here characterized by the GSI, FSI, OSR and average number of layers **(Pont and Haupt, Spacemate, 2004)**.

Along with the data on gross market values and total necessary investment outlays, the static NPV of the project if it were to be developed right now can be derived.



Development program scenario's

	Shopping	Working	Living	Producing	Unit	Gross/Net Ratio
Retail	100.000	20.000	20.000	0	m2 GFA	0,95
Office	20.000	100.000	0	20.000	m2 GFA	0,90
Residential	0	0	100.000	0	m2 GFA	0,77
Industrial	0	0	0	100.000	m2 GFA	0,93
Parking norm offices	0,008	0,008	0,008	0,008	per m2 GFA	
Parking offices	160	800	0	160	number of spots	
Parking norm retail	0,03	0,03	0,03	0,03	per m2 GFA	
Parking retail	3.000	600	600	0	number of spots	
Infrastructure, green and water	30.000	30.000	45.000	20.000	m2 GSA	
Gross site area	100.000	100.000	100.000	100.000	m2 GSA	
Total GFA	120.000	120.000	120.000	120.000	m2 GFA	
Built area	70.000	70.000	55.000	80.000	m2 GSA	
Ground Space Index (GSI)	0,70	0,70	0,55	0,80	Area compactness	
Floor Space Index (FSI)	1,20	1,20	1,20	1,20	Building intensity	
Open Space Ratio (OSR)	0,25	0,25	0,38	0,17	Openness of non-built area	
Layers	1,71	1,71	2,18	1,50	Average number of floors	

Figure 5.4 Input data possible development scenarios and site characteristics.

Noteworthy to mention is that the available switching option operates between the four scenarios in Figure 5.4. When the current scenario is ‘Shopping’, management is able to switch the retail program for the industrial program, de facto switching from the ‘Shopping’ to the ‘Producing’ scenario. The same construct is applied to the ‘Working’ and ‘Living’ scenario when for example the office program is switched for the Residential program.

5.1.1.4 Static NPV

The static NPV is derived by subtracting all necessary current investment outlays from gross market values. Figure 5.5 summarizes the calculations to arrive at the Static NPV per scenario.

As can be seen, the Shopping and Living scenarios are the most profitable programs to develop currently, followed by the Working and Producing scenario. The negative NPV from the industrial space dominated Producing scenario can be directly linked to the relatively low market rents and high capitalization yields for that type of asset. Parking requirements for both retail and office space are unprofitable to develop and therefore negatively impact the NPV in the scenario they are present. It is straightforward that higher market rents, lower yields and lower development outlays all increase the static NPV. Altering the development programs has an ambiguous effect on the static NPV, dependent on the profitability metrics of the real estate classes in the program. Land development outlays are spread across the asset classes based on gross floor areas.

Real estate development stage

	Shopping	Working	Living	Producing
Retail program	146.288.869	29.257.774	28.408.544	0
Office program	-905.256	-4.526.279	0	-339.103
Residential program	0	0	22.039.452	0
Industrial program	0	0	0	-25.004.767
Total static NPV per scenario	**145.383.613**	**24.731.495**	**50.447.996**	**-25.343.870**

Land development stage

	Shopping	Working	Living	Producing
Retail program	141.158.694	28.231.739	27.382.509	0
Office program	-1.931.291	-9.656.454	0	-1.365.138
Residential program	0	0	16.909.277	0
Industrial program	0	0	0	-30.134.942
Total static NPV per scenario	**139.227.403**	**18.575.285**	**44.291.787**	**-31.500.079**

Figure 5.5 Static NPV per scenario and real estate class, based on expected gross market values and present value total investment outlays.

5.1.2 Modeling market risk underlying assets

The following parameters are needed to diffuse the starting values of the four asset classes and subsequently to apply risk-neutral valuation.

General parameters

	Value	Unit	Notes
Periods	1	year	≥ T project
Δt	1,00	years	
Risk neutral discount rate	3,99%	per year	
Cost of waiting / dividends	1%	Value erosion	< rf + sigma

Binomial event tree

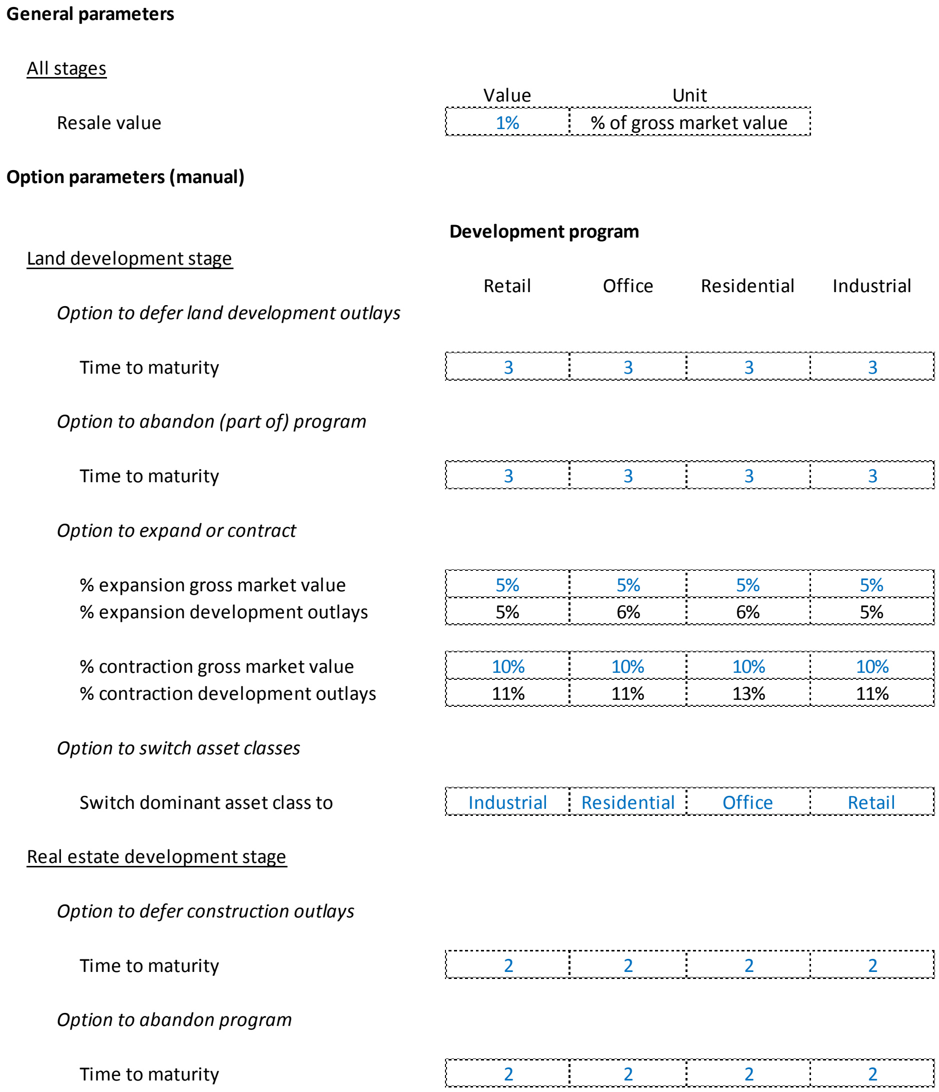
	Retail	Office	Residential	Industrial	Notes
Yearly volatility	6,92%	9,28%	9,50%	8,50%	> Rf
Up factor	1,07	1,10	1,10	1,09	≥ 1
Down factor	0,93	0,91	0,91	0,92	0 ≥ 1
Risk neutral probability up-state	0,70	0,64	0,64	0,66	0 ≥ 1
Risk neutral probability down-state	0,30	0,36	0,36	0,34	0 ≥ 1

Figure 5.6 Input data market risk and the resulting parameters to construct the binomial event trees of the real estate classes.

The risk-free discount rate matches the total length of the development project up until it is sold to the investor. The dividend parameter is set to 1%.

5.1.3 Option chains and total project phasing

To make the scenarios comparable, the dominant and non-dominant asset types all share the same compound option structure as illustrated in Figure 3.6. Per scenario, I will assume the following parameters for the available options. The reason why the percentage expansion and contraction for development outlays are greater than for market values lies in the gross-net ratios of the real estate type. While market values are based on net floor areas, development outlays are based on gross floor areas. When a project is expanded or contracted, the percentage change needs to be corrected for this.



General parameters

All stages

	Value	Unit
Resale value	1%	% of gross market value

Option parameters (manual)

Land development stage

	Development program			
	Retail	Office	Residential	Industrial
Option to defer land development outlays				
Time to maturity	3	3	3	3
Option to abandon (part of) program				
Time to maturity	3	3	3	3
Option to expand or contract				
% expansion gross market value	5%	5%	5%	5%
% expansion development outlays	5%	6%	6%	5%
% contraction gross market value	10%	10%	10%	10%
% contraction development outlays	11%	11%	13%	11%
Option to switch asset classes				
Switch dominant asset class to	Industrial	Residential	Office	Retail

Real estate development stage

	Retail	Office	Residential	Industrial
Option to defer construction outlays				
Time to maturity	2	2	2	2
Option to abandon program				
Time to maturity	2	2	2	2

Figure 5.7 Time-to-maturities of the American options, expansion and contraction parameters and available switching flexibility per asset class. Switching costs have been set to 0%. An increase in switching costs would, de facto, lower the value of the altenrative development scenario and therefore the option value of switching.

The time needed for the completion of zoning procedures and the time-to-maturities of the available options are shown in Figure 5.8.

Pre-development phasing

Land development stage: zoning procedures

	Start	Periods	End	Notes
Outline zoning structure	0	2	2	
Final zoning plans	2	1	3	

Development program phasing

Retail, office, residential and industrial space

Land development stage: development outlays

	Start	Periods	End	Notes
Start project	3	1	4	= 1
Option to defer land development outlays	3	3	6	
Option to abandon (part of) program	3	3	6	
Land preparation	6	1	7	= 1
Option to switch asset classes	6	1	7	= 1
Option to expand or contract	6	1	7	= 1
Sale to real estate developer	6	1	7	= 1
Infrastructure, green and water	8	1	9	= 1

Real estate development stage

	Start	Periods	End	Notes
Acquisitions	6	1	7	= 1
Option to defer construction outlays	6	2	8	
Option to abandon (part of) program	6	2	8	
Construction	8	1	9	= 1
Sale to investor	8	1	9	= 1

Figure 5.8 Length of zoning procedures and total project phasing. For the European type options and specific events such as transaction moments and incurring development outlays the period is set to 1.

5.1.4 Expanded NPV

5.1.4.1 Expanded NPV 'Hot' land

Since there are four possible scenarios, with each their own compound option structure, the ENPV of each scenario must be estimated which results in a residual land value per scenario. At this stage, the calculated values are based on approved zoning plans and can therefore be seen as the ENPV of 'hot' land. As the individual option values are non-additive in a compound option chain, the additional value from each option is derived by looking at its contribution to total project value. A check is also incorporated in the model to ensure that the sum of all 'additional' option values is equal to the Expanded NPV minus the Static NPV (total PVGO) of a scenario, which should be the case.

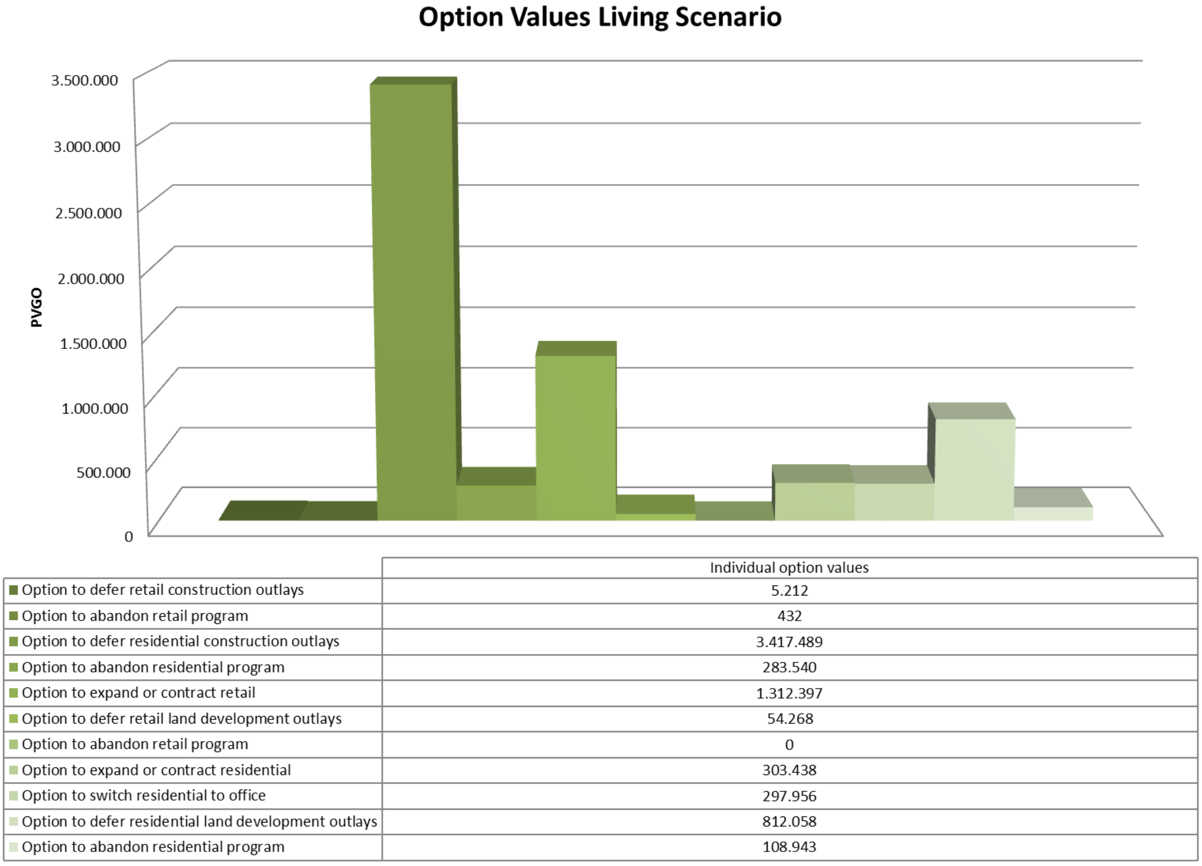
The Living scenario is used to show the results of the model. Based on the input parameters for the Living scenario, the following option values have been estimated.

Living scenario

	Total	Retail	Office	Residential	Industrial
Hot Static NPV	**44.291.787**	28.408.544	0	22.039.452	0
Hot PVGO	**6.297.776**	346.274	0	-204.708	0
Hot Expanded NPV	**50.589.563**	28.754.819	0	21.834.745	0

Figure 5.9 Hot Static NPV, PVGO and Expanded NPV of the Living scenario at t=0.

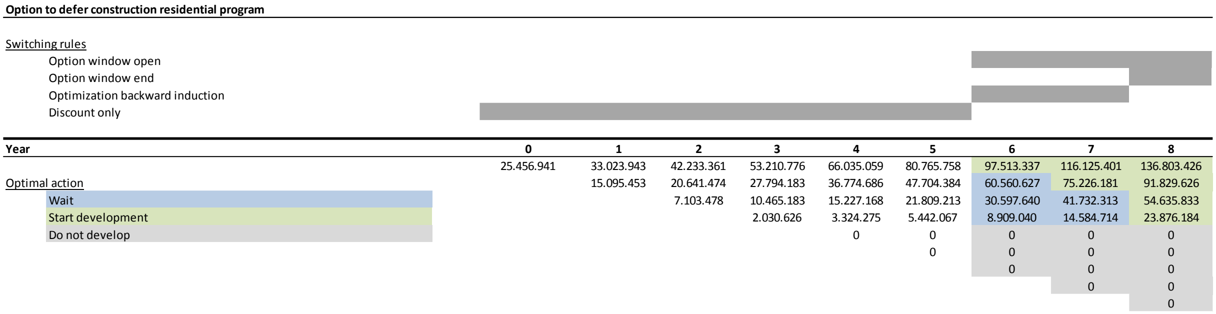
The total embedded option value in the Living scenario amounts to 6.297.776, subdivided into 1.372.309 for the retail program and 4.925.467 for the residential program and accounts for almost 15% of the Static NPV. A further breakdown of option values produces Figure 5.10. Option values for the Shopping, working and Producing scenario can be found in **Appendix B**.



	Individual option values
■ Option to defer retail construction outlays	5.212
■ Option to abandon retail program	432
■ Option to defer residential construction outlays	3.417.489
■ Option to abandon residential program	283.540
■ Option to expand or contract retail	1.312.397
■ Option to defer retail land development outlays	54.268
■ Option to abandon retail program	0
■ Option to expand or contract residential	303.438
■ Option to switch residential to office	297.956
■ Option to defer residential land development outlays	812.058
■ Option to abandon residential program	108.943

Figure 5.10 Individual option values in total development cycle for the Living scenario. The values from top to bottom correspond to the bars from left to right in the chart. As the option to expand or contract and the option to switch are mutually exclusive, the former is chosen as its value is (slightly) above the value of the option to switch the residential program to office space.

As can be seen, the option to defer residential construction outlays is with 3.417.489 the most valuable option in the portfolio and is worth around 20% of developing the residential program right now. As this option makes up more than half of total PVGO in this scenario, this merits a closer look as to where this value comes from precisely by digging deeper into the model. Figure 5.11 shows the binomial tree where the option to defer residential construction outlays is evaluated. At the end of the time-to-maturity in year 8, the now-or-never decision is made to either incur all-in construction costs and infrastructure, green and water outlays or do nothing, consistent with Equation 3.8. As the time-to-maturity of this American type option has been set to 2 years, during year 6 and 7 the project developer has the added flexibility to wait-and-see.



Option to defer construction residential program

Switching rules									
Option window open							▨	▨	▨
Option window end									▨
Optimization backward induction							▨	▨	
Discount only	▨	▨	▨	▨	▨	▨			

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	25.456.941	33.023.943	42.233.361	53.210.776	66.035.059	80.765.758	97.513.337	116.125.401	136.803.426
Optimal action		15.095.453	20.641.474	27.794.183	36.774.686	47.704.384	60.560.627	75.226.181	91.829.626
Wait			7.103.478	10.465.183	15.227.168	21.809.213	30.597.640	41.732.313	54.635.833
Start development				2.030.626	3.324.275	5.442.067	8.909.040	14.584.714	23.876.184
Do not develop					0	0	0	0	0
						0	0	0	0
							0	0	0
								0	0
									0

Figure 5.11 Valuation tree option to defer construction and infrastructure outlays residential program.

Looking at the above figure, it can be said that in 1 out of 7 possible states of nature, given the input of the model, the project is developed in year 6. In 3 out of 7 states, waiting is the optimal strategy and in the other 3 states the project is not developed at all. Depending on the 'entry' into the option window, the optimal development strategy can be directly derived from the valuation tree as shown in Figure 5.11. From year 5 to year 0 the expanded project values are discounted using risk neutral valuation to arrive at a value of 25.456.941. Considering the static NPV of the residential program at this stage of 22.039.452, this particular option value is equal to 3.417.489 as shown in Figure 5.10.

It can be noticed for all scenarios that the deferral options in the real estate development stage are considerably more valuable than in the land development stage. The fact that the options to defer all-in construction outlays increases the Expanded NPV, also increases the moneyness of the deferral options in the land development stage. As call option values, ceteris paribus, monotonically decrease in moneyness, this is as expected.

The extremely low value for the option to defer retail construction outlays should also be explained, as this option represents only 0,02% of the Static NPV of the retail program in the real estate development stage. This is again the outcome of a call option that is very much 'in-the-money' in all states of nature. In the case of an option with a large intrinsic value, the value to wait is not very significant, especially as the value of the underlying asset is eroded year after year due to the dividend effect. For an option to produce option value it should encounter states of nature low enough so that the flexibility to choose 'do not develop' can become valuable. When the time-to-maturity is not long enough to encounter these states of nature, waiting is not very valuable so the program should be developed as soon as possible.

A check to see whether the model functions correctly, is to set all key option parameters such as the time-to-maturity and volatility to zero and see if the expanded NPV reduces to the Static NPV. This is however not the case and can be explained by the fact that the minimum value of the Expanded NPV is zero. A negative Static NPV always carries an equivalent amount of absolute option value of the opposite sign with itself as there is no prior commitment to develop the project. The goal of the model is calculate the maximum price for which land in different stages in the zoning procedures can be acquired and to recognize that this maximum price is highly determined by the available flexibilities in the total development process. An Expanded NPV that is equal to zero means that you do not acquire the land and that you should simply walk away.

5.1.4.2 Project specific risk

When the hot Expanded NPV of the Living scenario has been estimated, this would equal the residual land value at $t = 0$, given the approval of the final zoning plans. To arrive at the current value of warm land where it is still uncertain whether the zoning plans will be approved, this value needs to be multiplied with the probability that final zoning plans will be finalized. This is done for the other three scenarios as well. Subsequently, cold land is valued by multiplying the probabilities of a change in use with the corresponding value of warm land and summing this value for all four scenarios. The subjective probabilities used in this thesis are shown in Figure 5.12.

Outline zoning structure

	Probability
Shopping	2%
Working	3%
Living	10%
Producing	5%
No change	80%

Final zoning plans

	Probability
Approval	60%
No approval	40%

Figure 5.12 Probability approval of the development program, given one of four possible scenario's and the probabilities of a change in use, given the current use of the land. The input can be based on the subjective opinion of management. The probabilities in this model are such that the Living scenario is most likely to materialize from a cold land perspective.

5.1.5 ROG matrix

Now that all Expanded NPV's and the expectations of the outcomes of zoning procedures have been determined, the development projects can be illustrated in the ROG Matrix which can be seen as the top level visualization. Considering the relative complexity of the option valuation model, the ROG Matrix provides an intuitive oversight of land development projects that require an optimal strategic policy. Of course it is the underlying valuation model that gives insight into what that strategy should be. Figure 5.13 illustrates the four development scenarios in their 'hot', 'warm' and converged 'cold' state.

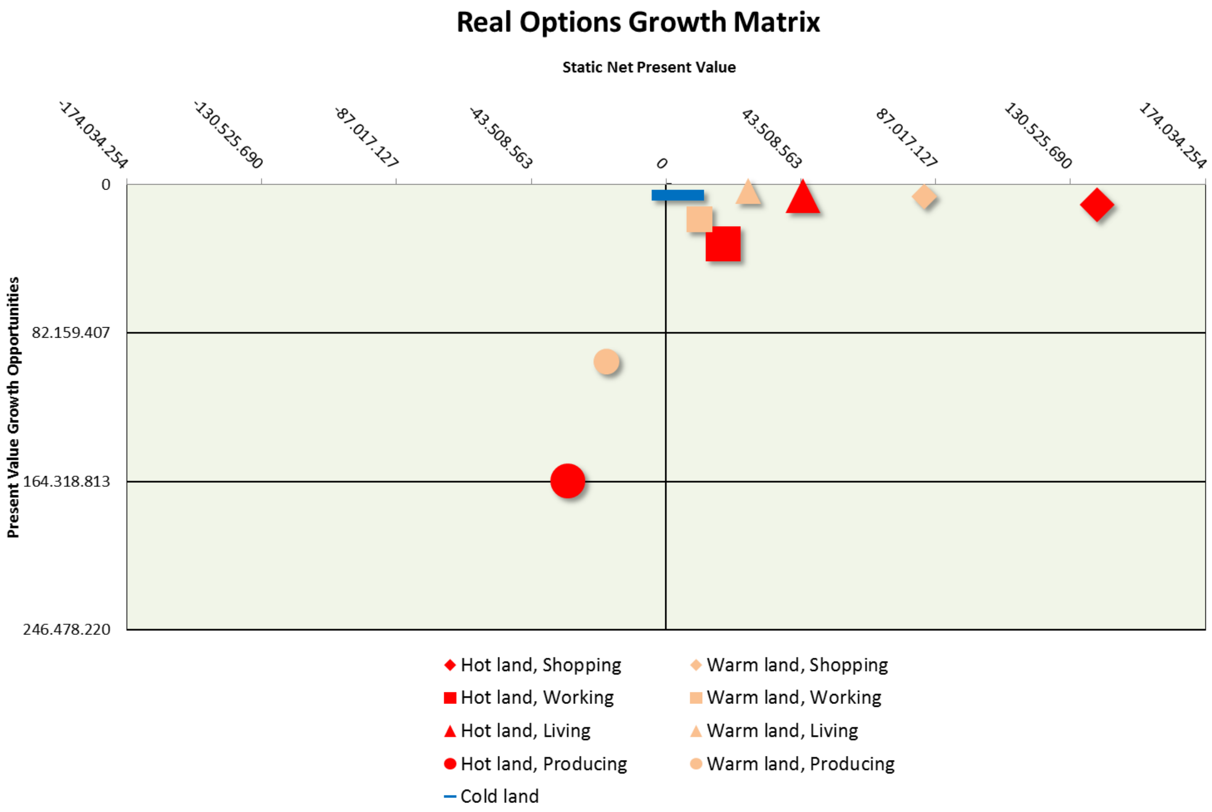


Figure 5.13 Real Options Growth Matrix, showing all possible future development scenario's and the ultimate convergence to the residual value of cold land by taking the expectations over zoning procedures.

The Shopping scenario (diamond) can be found in upper right corner of the matrix and is characterized by a large immediate profitability of 150.858.706 and relatively low option value of 11.631.303, given the final zoning plans. The option value is almost entirely due to the option to expand the retail program (6.786.729) and the option to defer office construction outlays (3.926.400). The option to defer retail construction outlays is extremely low (15.364), indicating that there is almost no point in waiting any longer to start construction.

The working scenario (square) shows a relatively small immediate profitability (18.575.285) but is also characterized by a large option value of 33.067.019, mostly coming from the option to defer office construction outlays (19.631.999) and the option to switch the office program to a residential program of equal size (10.244.125). It is in fact the market value of 20.000 m^2 GFA retail space that draws the working scenario from a negative to a positive Static NPV which also explains why the option to defer the construction and sale of the office program is greatly valuable. Per m^2, the immediate development of office space only destroys value which is why it is valuable to wait and see what the office market will do in the future.

The Living scenario (triangle) is profitable to develop right now (44.291.787) but could also benefit from deferring residential construction outlays (25.456.941). Residential space is a somewhat middle-of-the-road development program in terms of profitability, making options written on this asset class more at-the-money and therefore relatively more valuable.

The Producing scenario (circle) is the most extreme scenario in terms of Static NPV and option value. Industrial space is per m^2 so unprofitable to develop, given the input of the model, that in year 8 only in the most positive state of nature the decision to incur all-in construction outlays is made. The Static NPV of developing 100.000 m^2 GFA of industrial space and 20.000 m^2 of office space amounts to -31.500.079, despite the lower outlays for infrastructure, green and water. The option value of the Producing scenario, however, is the largest of all scenarios (164.318.813) and stems from the option to switch the industrial program (most unprofitable asset class) to a retail program (most profitable asset class). The switching option is worth 133.925.633. Without the switching option though, this scenario still embeds an option value of 30.393.180 but mostly originates from the option to abandon the project for a resale value of 1% of gross market value which always caps the Expanded NPV at slightly above zero.

From Figure 5.13 it can be concluded that the maximum price for which the land developer can acquire the land in a cold state is 9.759.802, or 97,60 per m^2 given a total gross site area of 100.000 m^2. Compared to 1.508,59 per m^2 for an approved Shopping development program the future value of the land can increase by more than 15 times, dependent on the outcome of the zoning procedures. This shows that a speculative acquisition of cold land can have a significant pay-off, which is the characteristic of acquiring a strategic growth option.

For management to be able to create the value maximizing portfolio of options and proactively enter the development process, insight is also needed into the sensitivity of the PVGO to all option parameters. This will provide the basis for determining the added value of tweaking the option levers that are under managements control, see also Table 4.10.

5.2 Sensitivity analysis and interaction effects

5.2.1 Sensitivity PVGO to option parameters

The hot PVGO of the Living scenario is used to illustrate the sensitivity of the joint option value of a portfolio of options to the option parameters. These parameters are the volatility of the underlying assets, the time-to-maturity of the American options, the risk-free interest rate, the moneyness, dividend yield and the correlations (depends on switching possibility). The impact on the warm and cold PVGO is not discussed as this is fairly straightforward.

5.2.1.1 Volatility

It would be expected that, ceteris paribus, an increase in volatility of the underlying asset increases the value of any options on that asset. Table 5.1 shows the impact of a change in volatility of residential and retail space on the PVGO of the Living scenario. The values in bold are in accordance with the original input of the model.

Volatility residential vs. retail on PVGO Living scenario

Volatility residential space	Volatility retail space											
	5%	6%	6,92%	7%	8%	9%	10%	11%	12%	13%	14%	15%
5%	14.353.410	14.353.680	14.357.053	14.357.624	14.368.910	14.396.457	14.451.040	14.550.631	14.673.801	14.819.027	14.994.942	15.188.042
6%	8.680.904	8.681.173	8.684.546	8.685.118	8.696.404	8.723.950	8.778.533	8.878.124	9.001.294	9.146.520	9.322.435	9.515.535
7%	6.124.089	6.124.358	6.127.731	6.128.302	6.139.588	6.167.135	6.221.718	6.321.309	6.444.479	6.589.705	6.765.620	6.958.720
8%	5.600.400	5.600.669	5.604.042	5.604.614	5.615.900	5.643.446	5.698.029	5.797.621	5.920.790	6.066.016	6.241.931	6.435.031
9%	5.593.229	5.593.499	5.596.871	5.597.443	5.608.729	5.636.276	5.690.858	5.790.450	5.913.620	6.058.846	6.234.761	6.427.861
9,50%	6.294.134	6.294.403	**6.297.776**	6.298.348	6.309.634	6.337.181	6.391.763	6.491.355	6.614.524	6.759.751	6.935.666	7.128.766
10%	6.459.361	6.459.630	6.463.003	6.463.574	6.474.860	6.502.407	6.556.990	6.656.581	6.779.751	6.924.977	7.100.892	7.293.992
11%	7.413.533	7.413.803	7.417.175	7.417.747	7.429.033	7.456.580	7.511.162	7.610.754	7.733.924	7.879.150	8.055.065	8.248.165
12%	8.391.167	8.391.436	8.394.809	8.395.381	8.406.667	8.434.213	8.488.796	8.588.387	8.711.557	8.856.783	9.032.698	9.225.798
13%	9.396.937	9.397.207	9.400.580	9.401.151	9.412.437	9.439.984	9.494.566	9.594.158	9.717.328	9.862.554	10.038.469	10.231.569
14%	10.417.364	10.417.633	10.421.006	10.421.578	10.432.864	10.460.411	10.514.993	10.614.585	10.737.754	10.882.981	11.058.895	11.251.996
15%	11.544.013	11.544.282	11.547.655	11.548.226	11.559.512	11.587.059	11.641.642	11.741.233	11.864.403	12.009.629	12.185.544	12.378.644

Table 5.1 Sensitivity PVGO Living scenario to volatility residential and retail space.

An important observation is that although PVGO increases monotonically with the volatility of retail space, it does not for the residential program. This can be explained by the existence of the option to switch residential to office and the mutual excludability with the option to expand or contract the residential program. As residential volatility decreases, the expansion option becomes relatively less valuable to the switching option. A turning point appears when the more valuable switching option takes over from the expansion option and further increases in value when residential volatility decreases even more. Further evidence for this characteristic is shown in Table 5.2 where the volatility parameter of office space is manually set to 12,00% which increases the value of the office program and therefore the value of the switching option. It can be observed that the turning point has shifted to even higher levels of residential volatility, indicating that the mutual excludability is indeed responsible for this phenomenon.

Volatility residential vs. retail on PVGO Living scenario

Volatility residential space	Volatility retail space											
	5%	6%	6,92%	7%	8%	9%	10%	11%	12%	13%	14%	15%
5%	33.901.238	33.901.507	33.904.880	33.905.452	33.916.738	33.944.285	33.998.867	34.098.459	34.221.628	34.366.855	34.542.769	34.735.870
6%	23.291.222	23.291.491	23.294.864	23.295.436	23.306.722	23.334.268	23.388.851	23.488.442	23.611.612	23.756.838	23.932.753	24.125.853
7%	17.313.856	17.314.125	17.317.498	17.318.069	17.329.356	17.356.902	17.411.485	17.511.076	17.634.246	17.779.472	17.955.387	18.148.487
8%	13.575.069	13.575.338	13.578.711	13.579.283	13.590.569	13.618.115	13.672.698	13.772.289	13.895.459	14.040.685	14.216.600	14.409.700
9%	11.127.532	11.127.801	11.131.174	11.131.745	11.143.031	11.170.578	11.225.161	11.324.752	11.447.922	11.593.148	11.769.063	11.962.163
9,50%	10.229.420	10.229.689	**10.233.062**	10.233.633	10.244.919	10.272.466	10.327.049	10.426.640	10.549.810	10.695.036	10.870.951	11.064.051
10%	9.479.748	9.480.017	9.483.390	9.483.962	9.495.248	9.522.795	9.577.377	9.676.969	9.800.138	9.945.365	10.121.280	10.314.380
11%	8.609.331	8.609.600	8.612.973	8.613.545	8.624.831	8.652.377	8.706.960	8.806.552	8.929.721	9.074.947	9.250.862	9.443.963
12%	8.917.597	8.917.867	8.921.239	8.921.811	8.933.097	8.960.644	9.015.226	9.114.818	9.237.988	9.383.214	9.559.129	9.752.229
13%	9.396.937	9.397.207	9.400.580	9.401.151	9.412.437	9.439.984	9.494.566	9.594.158	9.717.328	9.862.554	10.038.469	10.231.569
14%	10.417.364	10.417.633	10.421.006	10.421.578	10.432.864	10.460.411	10.514.993	10.614.585	10.737.754	10.882.981	11.058.895	11.251.996
15%	11.446.666	11.446.936	11.450.308	11.450.880	11.462.166	11.489.713	11.544.295	11.643.887	11.767.057	11.912.283	12.088.198	12.281.298

Table 5.2 Sensitivity PVGO Living scenario to volatility residential and retail space with office volatility set to 12,00%. The PVGO increases from 6.297.776 to 10.233.062 due to a higher switching option value.

Last it is worthwhile to note that, besides the discussed turning point, the options portfolio behaves as expected by increasing or decreasing the volatility of the underlying asset.

5.2.1.2 Time-to-maturity

Increasing the time-to-maturity of the American options should have the effect of increasing the PVGO of the Living scenario. Table 5.3 shows that the effects on PVGO is ambiguous and can be explained by the change in Static NPV when increasing time-to-completion of the project. Looking at the first column of Table 5.3, as the time-to-maturity of the option to defer land preparation increases, this also increase the time-to-completion for the Static NPV. The longer the project takes, the more the underlying gross market value can increase at the expected growth rate of $(r_f - Div)$, which is equal to 2,99% (3,99%-1%). Because the cost index of the investment outlays in the real estate development stage is low enough for the expected growth rate to overpower the yearly risk neutral discount rate of 3,99%, the Static NPV increases as the time-to-completion increases. A higher Static NPV, or increased moneyness of the option, lowers the option value of deferring land preparation outlays. This result is therefore supported by theory. The time-to-maturities of the retail program have been kept constant.

Time-to-maturity option to defer residential investment outlays land and real estate development stage

	Option to defer construction										
Option to defer land preparation	0	1	2	3	4	5	6	7	8	9	10
0	3.741.930	6.112.093	6.112.093	6.192.561	6.408.894	6.684.155	7.478.478	8.312.683	8.748.591	9.828.950	10.557.470
1	6.135.845	6.135.845	6.171.816	6.353.992	6.600.435	7.216.981	7.902.943	8.264.332	9.331.359	10.030.844	10.618.078
2	6.089.827	6.089.827	6.203.687	6.392.493	6.894.404	7.608.339	7.941.786	8.921.789	9.562.461	10.095.948	10.861.678
3	5.791.592	6.012.909	**6.297.776**	6.806.517	7.404.619	7.675.392	8.522.423	9.087.542	9.552.328	10.292.782	10.734.106
4	5.728.556	6.137.041	6.391.081	6.930.514	7.152.819	7.954.663	8.481.358	8.912.994	9.632.098	10.054.643	10.655.033
5	6.435.572	6.453.980	6.764.260	6.934.114	7.761.397	8.299.291	8.737.718	9.430.767	9.834.336	10.386.754	10.937.347
6	5.606.315	6.034.779	6.165.760	6.882.588	7.337.049	7.706.466	8.385.547	8.772.922	9.342.065	9.900.620	10.598.340
7	5.606.015	5.700.351	6.377.163	6.797.727	7.138.056	7.798.390	8.169.324	8.723.892	9.269.515	10.122.147	10.720.834
8	5.246.268	5.887.737	6.279.437	6.592.077	7.234.444	7.589.669	8.130.371	8.663.651	9.635.288	10.191.815	10.595.301
9	5.414.370	5.776.025	6.064.393	6.691.207	7.033.280	7.560.844	8.082.351	9.147.395	9.767.145	10.163.535	10.479.716
10	5.291.826	5.555.875	6.166.510	6.495.007	7.011.018	7.522.118	8.770.353	9.357.307	9.741.374	10.044.117	10.503.066

Table 5.3 Sensitivity PVGO Living scenario to time-to-maturity options to defer investment outlays residential program in land and real estate development stage.

Another effect that can be distilled out of Table 5.3 is found in the first row where in the second and third column the PVGO remains the same, although the time-to-maturity of the option to defer construction outlays have increased, indicating an inertia. The effect can be traced back to the option to expand or contract the residential program which operates independently from the Expanded NPV from the deferral and abandonment option in the real estate development stage. Given a time-to-maturity of the option to defer land preparation of zero, the expanded residential program has a greater value (equal to 6.112.093) than the Expanded NPV that originates from the option to defer retail construction outlays and/or abandoning the program. It is not until the time-to-maturity increase to 3 years, given the upper row of Table 5.3, that the gross market value of residential space reaches high enough possible states of nature for the deferral option to become more valuable than the expanded version of the retail program. It can be seen that by increasing the time-to-maturity of this option even further than 3 years, the PVGO increases monotonically.

5.2.1.3 Risk-free interest rate

Although in the model, the risk-free rate automatically adapts to the length of the development project, the sensitivity analysis here deals with a vertical up- or downward shift in the implied term structure of Dutch zero coupon bonds, also see Figure 4.5. Table 5.5 shows that the PVGO is very sensitive to changes in the risk-free rate, given a fixed number of periods to develop the project. The effect of a change in interest rates works through in both the risk-neutral probability of the up-state (decreases as the risk-free rate decreases) and the present value of future cash flows (decreases as the risk-free rate increases). The net effect is shown in Table 5.5.

Risk-free interest rates and PVGO, ENPV and Static NPV of the Living scenario

Risk-free interest rate	PVGO	ENPV	Static NPV
1%	13.158.821	31.613.762	18.454.940
2%	9.712.521	37.330.340	27.617.819
3%	7.287.619	43.540.419	36.252.800
3,99%	**6.297.776**	**50.589.563**	**44.291.787**
4%	6.288.605	50.679.064	44.390.459
5%	6.060.113	58.119.705	52.059.592
6%	6.478.932	65.766.259	59.287.326
7%	7.280.169	73.379.381	66.099.212
8%	8.509.618	81.028.935	72.519.317
9%	10.542.716	89.113.028	78.570.312
10%	13.836.474	98.110.024	84.273.550

Table 5.4 Sensitivity PVGO, ENPV and Static NPV of the Living scenario to varying levels of the risk-free interest rate as implied by Dutch zero coupon bonds that match the time-to-maturity of the development project.

It can be concluded that by increasing the risk free rate, the expected growth rate $(r_f - Div)$ of the underlying increases sufficiently to overpower the negative effects of a higher discount rate. A higher expected gross market value of the underlying project and unchanged development outlays thus causes the Static NPV to increases monotonically with increasing risk free rates. As this effect is strongest in the lower regions of 1% to 4%, the greater increase of the Static NPV here first causes the PVGO to decrease and then increase.

5.2.1.4 Moneyness

The moneyness of an option deals with the intrinsic value. The higher the moneyness, the higher the intrinsic value of the option and the lower the value of flexibility should become. In Table 5.6 the impact of varying levels of market rents and construction costs on the PVGO of the Living scenario is shown.

Market rents vs. construction cost residential program and PVGO Living scenario

Construction costs per square meter GF.	Market rents per square meter NFA per year									
	50	60	70	80	86	90	100	110	120	130
500	21.642.794	9.632.490	4.350.671	3.315.003	3.364.687	3.433.952	3.824.165	4.386.384	5.007.633	5.649.200
575	32.326.301	16.856.193	7.201.508	4.398.551	3.753.079	3.497.590	3.606.415	3.964.861	4.508.513	5.120.341
650	39.312.309	25.401.226	12.583.468	5.969.418	5.036.023	4.446.431	3.680.177	3.778.878	4.110.416	4.646.563
700	47.252.162	33.575.526	17.766.280	8.583.846	**6.297.776**	5.378.949	4.161.577	3.831.288	3.986.973	4.379.689
725	50.975.201	35.784.842	20.614.625	10.026.102	6.970.549	5.906.466	4.517.814	3.862.764	3.951.341	4.284.390
800	56.843.720	43.075.468	29.329.375	15.828.023	11.067.938	8.622.603	5.893.087	4.604.786	4.045.350	4.133.511
875	64.605.816	55.348.669	39.375.708	24.373.056	16.880.112	12.850.695	8.360.357	5.940.968	4.760.217	4.227.937
950	73.305.364	61.506.016	46.853.610	33.515.143	25.404.976	19.586.455	11.624.794	8.104.060	5.988.848	4.929.930
1.025	81.850.398	68.375.827	57.754.189	43.036.165	34.588.300	28.131.488	16.031.730	11.010.642	7.847.763	6.036.728
1.100	90.395.431	77.066.183	65.946.276	50.650.064	44.168.627	38.581.335	23.344.887	14.736.872	10.557.952	7.591.465
1.175	98.940.464	85.611.216	72.665.746	60.592.673	51.779.965	46.729.460	31.991.177	19.620.787	14.002.484	10.301.654

Table 5.5 Sensitivity PVGO Living scenario to varying levels of market rents and construction costs residential program.

The results are interesting as there does not exist a linear relationship between the intrinsic value of the residential program and its option value. This effect can be explained due to the presence of the option to switch the residential program to an office program and the option to expand or contract. When the intrinsic value of developing the residential program becomes negative because market rents have declined, the relative value of the office program increases and thus the option value of switching increases. It can be seen from Table 5.6 that in the first row and first and second column, as the market rents increase from 50 to 60, PVGO decreases by more than 10.000.000. Half of this drop is caused by a decrease in switching option value from 7.302.766 to 2.129.547. The option value of switching continues to drop, strengthened with the effect increased moneyness, until a turning point exists around a market rent of 86 per m² NFA. From this point, the intrinsic value of the residential program has increased sufficiently to make expansion of the program profitable. In the first row this expansion option value dominates the decreased option value from an increase in moneyness. This effect lessens as construction costs per m² increase, causing the moneyness to have a larger impact on PVGO.

5.2.1.5 Dividends

Increasing dividends has the effect of decreasing the risk-neutral probability of the up-state in the valuation tree, therefore lowering the value of both call and put options on the underlying asset. Table 5.7 illustrates the impact of different levels of the dividend yield. However, it also has the effect of lowering the Static NPV as the expected growth rate decreases.

Dividend yield and PVGO, ENPV and Static NPV Living scenario

Dividend yield	PVGO	ENPV	Static NPV
0,50%	6.268.463	56.015.055	49.746.591
1,00%	**6.297.776**	**50.589.563**	**44.291.787**
1,50%	6.313.720	45.311.916	38.998.196
2,00%	7.032.614	40.893.668	33.861.054
2,50%	7.893.244	36.768.982	28.875.738
3,00%	8.956.266	32.994.027	24.037.760
3,50%	10.163.656	29.506.422	19.342.767
4,00%	11.476.077	26.262.607	14.786.531
4,50%	12.889.136	23.254.088	10.364.952
5,00%	14.397.637	20.471.687	6.074.051

Table 5.6 Sensitivity PVGO Living scenario to different levels of the dividend yield.

The above table shows that the PVGO increases as the dividend yield increases, which is not as expected from theory but it has to be kept in mind that the PVGO is derived by the difference of the ENPV and the Static NPV. It can be seen that the Static NPV is highly sensitive to a change in the dividend yield which should be the case as a higher dividend yield decreases the expected return of the underlying asset $(r_f - Div)$, thereby lowering the risk-neutral probability of the up-states in the binomial valuation trees. The net effect of increasing the dividend yield on the residual land value (ENPV) is negative. The ENPV declines as the dividend yield increases.

In the model I have assumed that there exists a value erosion of 1% for each year you delay incurring the investment outlays to develop the project but is actually a crude estimation. In practice, this parameter is difficult to estimate but can also be directly modeled with accruing interest costs when, for example, the land has already been acquired.

5.2.1.6 Correlations

The correlation between the total returns of two real estate classes are an important input parameter for the option to switch the dominant development program in a scenario to another asset class. The value of the option to switch the residential program to an office program of equal size, subject to various levels of correlations, is shown in Table 5.8. The results are as expected. The Static NPV is unaffected at all levels of correlations as a static valuation cannot take switching flexibilities into account.

Correlation between total returns office and residential space and PVGO Living scenario

	PVGO	ENPV	Static NPV
-1,00	6.310.922	50.602.709	44.291.787
-0,80	6.284.902	50.576.689	44.291.787
-0,60	6.256.109	50.547.895	44.291.787
-0,40	6.223.769	50.515.556	44.291.787
-0,20	6.186.751	50.478.538	44.291.787
0,00	6.143.296	50.435.082	44.291.787
0,20	6.090.482	50.382.269	44.291.787
0,40	6.022.971	50.314.758	44.291.787
0,60	5.994.339	50.286.126	44.291.787
0,83	**6.297.776**	**50.589.563**	**44.291.787**
1,00	740.768.515	785.060.302	44.291.787

Table 5.7 Sensitivity value option to switch residential for office space to cross correlations between the asset types.

The extreme value when the correlation is equal to 1 can be explained by looking at Equation 4.8. When σ_V falls beneath $(r_f - Div)$, the risk neutral probability of the up-states increases beyond unity and is therefore nonsensical. More important to note is that, within plausible ranges of σ_V, the switching option gains value when correlations decrease, which is as expected.

CHAPTER 6 Conclusions

The main goal of this thesis is to find out *how Real Options Analysis can be applied and made accessible in managing land development projects*. In this thesis a model has been developed that can value real estate development projects with multiple embedded real options. With this model, land development projects can be characterized by their Static NPV and embedded option value or PVGO. Subsequently, by these value metrics, projects can be placed in the Real Options Growth (ROG) Matrix where the trade-off between immediate development and future flexibility in the development process can be evaluated. This trade-off forms the basis of setting up an optimal strategic plan of action in striking the option chain during the development stages. The model is based on the value creation process in land and real estate development and is able to value scenarios with multiple underlying assets with each their own option structure. The development programs as well as the spatial breakdown of the development site can be altered, de facto varying the characteristics of the underlying assets and strike prices. The options portfolio has been predetermined for a fictional land development project but can, with some additional modeling, be changed to suit any project with embedded operational and timing flexibilities. Also, the value of warm and cold land can be estimated by taking the expectations over the outcome of zoning procedures. Last, the consistency of the model has been tested by performing sensitivity analyses on the option value or Present Value of Growth Opportunities (PVGO) of a specific development scenario with multiple embedded options.

6.1 Summary and results

As real options in a real estate setting differ substantially from financial options, the appropriate approach and methodology had to be identified. Financial option valuation relies on the formation of a hedging portfolio which perfectly mimics the payoffs of the option. The value of this portfolio should, through the absence of arbitrage possibilities, be equal to the value of the option. Real estate assets differ from financial assets in that they are not exchange-traded, are not homogeneous and are not liquid. A solution to this problem is to value real estate assets ‘as if’ they were traded, which is actually the same procedure as a DCF-valuation. This results in being able to use the gross market value of the project as the underlying asset on which options can be valued, also known as the Marketed Asset disclaimer assumption by **Copeland and Antikarov (2003)**. If it is further assumed that the weak form of the Efficient Markets Hypothesis can be applied and market prices are log-normally distributed, binomial option pricing frameworks such as the one developed by **Cox, Ross and Rubinstein (1979)** can be used to diffuse and value the underlying asset.

Value creation in land and real estate development can be split up in three clear stages: the land development stage, the real estate development stage and the investment stage. As the market value of a developed real estate asset is determined in the investment stage, the value of the land can be residually derived by subtracting the all-in construction costs and land development costs from final market value. The created value after a multi-year development process is always subject to fluctuating market values and development costs though. Uncompleted zoning procedures also add further, non-systematic, risk to the profitability of the land development project. Project specific risk is incorporated in the model as follows. Given a current (unprofitable) use of the land, there is a chance that in the future the land will be developed with a retail, office, residential or industrial dominant program. These scenarios are called the Shopping, Working, Living and Producing scenario. When one of the four scenarios materialize, the zoning plans are subject to an uncertain final approval by the municipality. The progress in zoning procedures causes the land to be labeled as cold, warm or hot.

To manage both market and project-specific risks in the development process, operational and timing flexibilities can be negotiated. In this thesis a predetermined portfolio of options is assumed to exist. In both the land and real estate development stage the option to defer investment outlays and/or abandon the project is considered. Also, after preparing the land for the project developer, the option to expand or contract the project and the option to switch is available. The options portfolio is available for each asset class in the development scenario. The value of the options are subsequently dependent on the moneyness, the volatility of gross market value, the time-to-maturity, risk-free interest rates, dividend payments.

To estimate the volatility of the underlying asset classes, the historical standard deviation of the total return series from the ROZ/IPD has been determined for each asset class in the development scenario. As the time series suffer from a smoothing and lagging effect which is caused by serial correlation in the returns, the data under represents the true volatility. The series were corrected using a formula provided by **Geltner (1993)** and **Stevenson (2000)**. There also exists a possible bias in data from ROZ/IPD due to the voluntary nature of the disclosed data by publicly exchanged real estate investors. However, since the total return series are only used to estimate the historical standard deviation, this bias should be limited. The ROZ/IPD data reveals a fairly low volatility across all considered property types, ranging from 6,29% for retail and 9,50% for residential space on an annual basis. As the total returns series are all highly correlated with each other, strategic shifting or switching between asset classes has limited potential when the current profitability of the alternative asset class is similar.

The model has been built using Microsoft Excel as this is the most widely used spreadsheet program amongst real estate practitioners. The valuation procedure has been split up in steps to structure the calculation process. Determining initial gross market values, investment outlays in the land and real estate development stage and development program and site characteristics are the first four necessary steps to arrive at the Static NPV of the scenario. Subsequently the historical volatility, setup of the binomial trees, option parameters and project specific risks represent the following four steps to arrive at the Expanded NPV. When the valuation procedure is completed, the scenarios are placed in the ROG Matrix. The following conclusions can be made with respect to the model itself and the sensitivity analyses.

The final categorization of projects in the ROG Matrix can be seen as a summary of the individual options that are present in the development process. However, it is the composition of total PVGO is what gives insight into the optimal strategy over time. The model shows that options that are available in the early stages of development are highly dependent on the value of the options that are present later on. This is also where the sub-additivity of individual options comes from. Extremely valuable deferral options in the real estate development stage, for example, increases the moneyness of all prior options, de facto lowering their option value.

With respect to the performed sensitivity analyses some interesting observations can be made. Due to the setup of the option chain, total PVGO does not always monotonically increase with the volatility of the underlying asset and the time-to-maturity and moneyness of the available options. For example, as the option to expand or contract and the option to switch are mutually exclusive, the more valuable option is included in total PVGO. Since the option to switch is dependent on the characteristics of the alternative asset class, this option may increase in value as the volatility of the current asset class decreases. Since the Static NPV is also sensitive to varying levels of the risk-free rate, dividends and the time-to-completion, the net effect on PVGO can be ambiguous. The sensitivity of PVGO to varying levels of dividends and correlations is as expected from theory. Another way to incorporate dividends is to model them directly as negative cash flows. Overall it can be concluded that the characteristics of financial options are mostly preserved when modeling the development process of real estate as a collection of real options.

6.2 Implications for the practice of land valuation

The ROG Matrix shows that when static derivations of project NPV's turn out negative, negotiating flexibilities in development contracts can provide the possibility for the project to end up 'in-the-money'. Options are instruments to manage project risk. Timing and operating options provide the manager with tools to steer projects through difficult times. The application of a real option valuation model such as the one developed in this thesis can be found in a couple of areas.

First, it can provide a quantification of the value of flexibility and therefore a better impression of what a development right is really worth, opposed to a point-estimate of a DCF-valuation. The additional worth may tip the scale to follow through with projects where they would otherwise have halted. Real estate developers may be found willing to acquire the prepared land from the land developer when they have the flexibility to phase the development process and are able to switch asset classes, expand or contract building programs or abandon the project for a contractually agreed resale value. Especially municipalities who see their land revenues fall and are burdened with land positions they cannot sell because gross market values have declined, can benefit from an options perspective.

Second, as land positions held by large project developers are difficult to value with DCF models due to their inherent option characteristics, they are also difficult to finance on a project basis. Real options analysis gives insight into the value of the inherent option features of holding a land position and may justify a higher value in the developer's balance sheets. This would subsequently increase his solvability and therefore his resilience against negative economic shocks.

Third, inner city redevelopments are one of the major challenges in the Netherlands when it comes to the future of real estate development. Re-use of developed land, opposed to Greenfield developments, is one of the major themes the coming decades. Inner city developments, however, often have a large negative Static NPV as the acquisition prices are significant. The market values of the developed projects usually do not justify these large, upfront costs. Options thinking in these important and complex development projects may help to justify the necessary investment outlays made by public and private parties by increasing the size of the pie.

Fourth, the modeling process as proposed in this thesis naturally forces managers to consider the possible range of future project values and to think how they would act if a particular state of nature were to materialize. This thinking process automatically reveals the need to see projects through an options lens as multiple future states of nature require a similar amount of strategies which can only be provided by flexibility in contractual agreements. As the importance of option values becomes more widespread and 'real', option valuation methodologies may become common practice in the management of real projects.

6.3 Recommendations for future research

A central assumption in the model has been that the land developer, project developer and investor act as a single entity with only one purpose: to maximize the total land revenues. Although joint ventures or public-private-partnerships exist that internalize possible opposing interests, this is usually not the case in practice. In reality the land developer, project developer, investor and also the financier all want to minimize their risk and maximize their share of the project's profit potential. An extension of the model can therefore be to apply game theory to model the interaction of the different players in the development stages.

Another extension is to model the relationships between segments of the total project. Inter-project dependencies have not been considered in this thesis although they certainly exist. Usually, real estate classes complement each other and therefore display synergistic relationships. The value of a residential development area adjacent to industrial ground is significantly different then when it is complemented with shopping malls, office buildings or a large recreational facility. These relationships may provide further insight into the optimal development strategy in light of the options portfolio.

Further, financial market value is not the only dimension that should be looked at in development projects, especially in the case of inner city redevelopments. The societal benefits from a redeveloped obsolescent city area often cannot be easily measured in financial terms while it’s obvious that the image of the city and its inhabitants benefit. The ROG Matrix can be useful in providing a financial benchmark to evaluate projects but to fully realize its potential in a real estate setting it should be viewed in the light of other dimensions such as societal returns in the long run. A challenge could therefore exist to make the ROG Matrix multi-dimensional when reliable methods exist to measure non-financial benefits.

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APPENDIX A Regression output

Smoothed historical total returns Netherlands

```
Dependent Variable: RETAIL
Method: Least Squares
Date: 08/05/10   Time: 13:06
Sample (adjusted): 1996 2009
Included observations: 14 after adjustments
=========================================================================
        Variable          Coefficient    Std. Error    t-Statistic   Prob.
=========================================================================
           C               0.017328      0.035025      0.494730     0.6297
       RETAIL(-1)          0.796152      0.312862      2.544742     0.0257
=========================================================================
R-squared                  0.350499    Mean dependent var          0.104351
Adjusted R-squared         0.296374    S.D. dependent var          0.033776
S.E. of regression         0.028332    Akaike info criterion      -4.158063
Sum squared resid          0.009633    Schwarz criterion          -4.066769
Log likelihood             31.10644    F-statistic                 6.475712
Durbin-Watson stat         0.893608    Prob(F-statistic)           0.025713
=========================================================================
```

Figure A.1 Regression output Equation 4.17. The dependent variable is the smoothed total returns retail and independent variable the one-year lagged total returns retail.

```
Dependent Variable: OFFICE
Method: Least Squares
Date: 08/05/10   Time: 13:07
Sample (adjusted): 1996 2009
Included observations: 14 after adjustments
=========================================================================
        Variable          Coefficient    Std. Error    t-Statistic   Prob.
=========================================================================
           C               0.012184      0.026140      0.466101     0.6495
       OFFICE(-1)          0.810281      0.248434      3.261552     0.0068
=========================================================================
R-squared                  0.469911    Mean dependent var          0.090915
Adjusted R-squared         0.425737    S.D. dependent var          0.049527
S.E. of regression         0.037531    Akaike info criterion      -3.595718
Sum squared resid          0.016903    Schwarz criterion          -3.504424
Log likelihood             27.17003    F-statistic                 10.63772
Durbin-Watson stat         1.276640    Prob(F-statistic)           0.006809
=========================================================================
```

Figure A.2 Regression output Equation 4.17. The dependent variable is the smoothed total returns office and independent variable the one-year lagged total returns office.

```
Dependent Variable: RESIDENTIAL
Method: Least Squares
Date: 08/05/10   Time: 13:08
Sample (adjusted): 1996 2009
Included observations: 14 after adjustments
==========================================================================
        Variable          Coefficient    Std. Error    t-Statistic    Prob.
==========================================================================
            C              -0.016709      0.027609     -0.605203     0.5563
     RESIDENTIAL(-1)        1.056370      0.230075      4.591418     0.0006
==========================================================================
R-squared                   0.637255   Mean dependent var            0.102858
Adjusted R-squared          0.607027   S.D. dependent var            0.054735
S.E. of regression          0.034312   Akaike info criterion        -3.775089
Sum squared resid           0.014128   Schwarz criterion            -3.683795
Log likelihood              28.42562   F-statistic                   21.08112
Durbin-Watson stat          1.075541   Prob(F-statistic)             0.000620
==========================================================================
```

Figure A.3 Regression output Equation 4.17. The dependent variable is the smoothed total returns residential and independent variable the one-year lagged total returns residential.

```
Dependent Variable: INDUSTRIAL
Method: Least Squares
Date: 08/05/10   Time: 13:09
Sample (adjusted): 1996 2009
Included observations: 14 after adjustments
==========================================================================
        Variable          Coefficient    Std. Error    t-Statistic    Prob.
==========================================================================
            C               0.000745      0.032645      0.022816     0.9822
     INDUSTRIAL(-1)         0.925000      0.289151      3.199023     0.0076
==========================================================================
R-squared                   0.460280   Mean dependent var            0.101136
Adjusted R-squared          0.415303   S.D. dependent var            0.044015
S.E. of regression          0.033656   Akaike info criterion        -3.813673
Sum squared resid           0.013593   Schwarz criterion            -3.722379
Log likelihood              28.69571   F-statistic                   10.23375
Durbin-Watson stat          1.093124   Prob(F-statistic)             0.007646
==========================================================================
```

Figure A.4 Regression output Equation 4.17. The dependent variable is the smoothed total returns industrial and independent variable the one-year lagged total returns industrial.

Unsmoothed historical total returns Netherlands

```
Dependent Variable: RETAIL
Method: Least Squares
Date: 08/31/10   Time: 08:44
Sample (adjusted): 1997 2009
Included observations: 13 after adjustments
========================================================================
         Variable         Coefficient    Std. Error    t-Statistic   Prob.
========================================================================
             C              0.030898      0.034893      0.885502    0.3948
         RETAIL(-1)         0.637824      0.286191      2.228661    0.0476
========================================================================
R-squared                   0.311076   Mean dependent var           0.098503
Adjusted R-squared          0.248447   S.D. dependent var           0.071717
S.E. of regression          0.062173   Akaike info criterion       -2.577143
Sum squared resid           0.042521   Schwarz criterion           -2.490228
Log likelihood              18.75143   F-statistic                  4.966930
Durbin-Watson stat          1.342110   Prob(F-statistic)            0.047638
========================================================================
```

Figure A.5 Regression output Equation 4.17. The dependent variable is the unsmoothed total returns retail and independent variable the one-year lagged unsmoothed total returns retail.

```
Dependent Variable: OFFICE
Method: Least Squares
Date: 08/31/10   Time: 08:45
Sample (adjusted): 1997 2009
Included observations: 13 after adjustments
========================================================================
         Variable         Coefficient    Std. Error    t-Statistic   Prob.
========================================================================
             C              0.037349      0.035171      1.061908    0.3110
         OFFICE(-1)         0.488071      0.280253      1.741535    0.1094
========================================================================
R-squared                   0.216130   Mean dependent var           0.080846
Adjusted R-squared          0.144869   S.D. dependent var           0.096551
S.E. of regression          0.089284   Akaike info criterion       -1.853359
Sum squared resid           0.087687   Schwarz criterion           -1.766443
Log likelihood              14.04683   F-statistic                  3.032944
Durbin-Watson stat          1.625756   Prob(F-statistic)            0.109445
========================================================================
```

Figure A.6 Regression output Equation 4.17. The dependent variable is the unsmoothed total returns office and independent variable the one-year lagged unsmoothed total returns office.

```
Dependent Variable: RESIDENTIAL
Method: Least Squares
Date: 08/31/10   Time: 08:46
Sample (adjusted): 1997 2009
Included observations: 13 after adjustments
============================================================================
        Variable              Coefficient    Std. Error   t-Statistic   Prob.
============================================================================
            C                   0.003358      0.034051     0.098612    0.9232
     RESIDENTIAL(-1)            0.761552      0.264944     2.874384    0.0151
============================================================================
R-squared                       0.428930   Mean dependent var          0.080682
Adjusted R-squared              0.377014   S.D. dependent var          0.095359
S.E. of regression              0.075266   Akaike info criterion      -2.194926
Sum squared resid               0.062315   Schwarz criterion          -2.108011
Log likelihood                  16.26702   F-statistic                 8.262085
Durbin-Watson stat              1.415983   Prob(F-statistic)           0.015122
============================================================================
```

Figure A.7 Regression output Equation 4.17. The dependent variable is the unsmoothed total returns residential and independent variable the one-year lagged unsmoothed total returns residential.

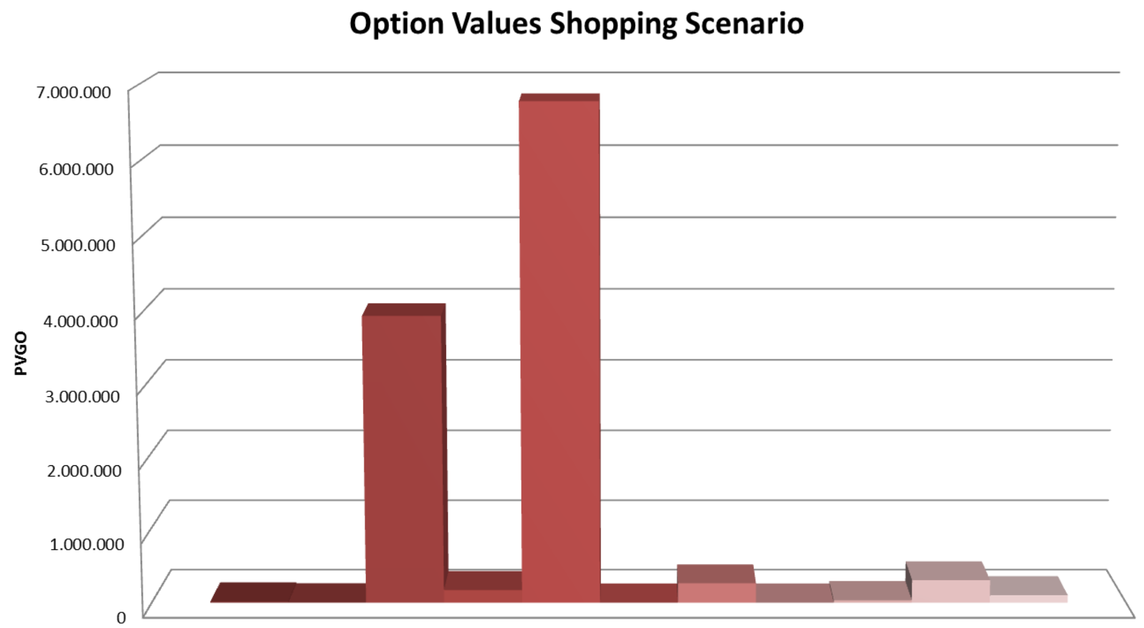
```
Dependent Variable: INDUSTRIAL
Method: Least Squares
Date: 08/31/10   Time: 08:48
Sample (adjusted): 1997 2009
Included observations: 13 after adjustments
============================================================================
        Variable              Coefficient    Std. Error   t-Statistic   Prob.
============================================================================
            C                   0.021420      0.036884     0.580739    0.5731
     INDUSTRIAL(-1)             0.640053      0.295255     2.167794    0.0530
============================================================================
R-squared                       0.299333   Mean dependent var          0.086803
Adjusted R-squared              0.235636   S.D. dependent var          0.087554
S.E. of regression              0.076547   Akaike info criterion      -2.161197
Sum squared resid               0.064453   Schwarz criterion          -2.074282
Log likelihood                  16.04778   F-statistic                 4.699332
Durbin-Watson stat              1.696149   Prob(F-statistic)           0.052980
============================================================================
```

Figure A.8 Regression output Equation 4.17. The dependent variable is the unsmoothed total returns industrial and independent variable the one-year lagged unsmoothed total returns industrial.

APPENDIX B Option values Shopping, Working and Producing Scenario

Shopping Scenario

Shopping Scenario	Total	Retail	Office	Residential	Industrial
Hot Static NPV	**139.227.403**	141.158.694	-1.931.291	0	0
Hot PVGO	**11.631.303**	7.075.593	4.555.711	0	0
Hot Expanded NPV	**150.858.706**	148.234.286	2.624.420	0	0
Probability approval conditional on program	60%	60%	60%	60%	60%
Warm Static NPV	**83.536.442**	84.695.216	-1.158.774	0	0
Warm PVGO	**6.978.782**	4.245.356	2.733.426	0	0
Warm Expanded NPV	**90.515.224**	88.940.572	1.574.652	0	0

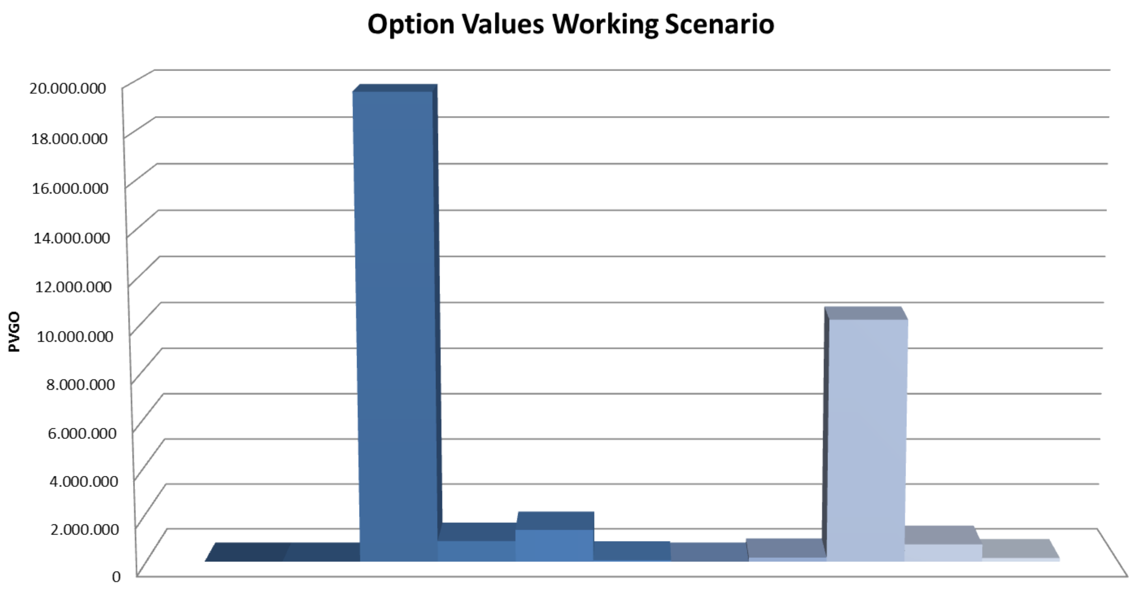


	Individual option values
■ Option to defer retail construction outlays	15.364
■ Option to abandon retail program	2.160
■ Option to defer office construction outlays	3.926.400
■ Option to abandon office program	175.726
■ Option to expand or contract retail	6.786.729
■ Option to switch retail to industrial	0
■ Option to defer retail land development outlays	271.339
■ Option to abandon retail program	0
■ Option to expand or contract office	35.454
■ Option to defer office land development outlays	313.155
■ Option to abandon office program	104.975

Figure B.1 Hot and Warm Static and Expanded NPV and individual option values in compound option chain Shopping scenario.

Working Scenario

Working scenario	Total	Retail	Office	Residential	Industrial
Hot Static NPV	**18.575.285**	29.257.774	-4.526.279	0	0
Hot PVGO	**33.067.019**	389.084	26.521.726	0	0
Hot Expanded NPV	**51.642.304**	29.646.857	21.995.447	0	0
Probability approval conditional o	60%	60%	60%	60%	60%
Warm Static NPV	**11.145.171**	17.554.664	-2.715.767	0	0
Warm PVGO	**19.840.211**	233.450	15.913.035	0	0
Warm Expanded NPV	**30.985.382**	17.788.114	13.197.268	0	0

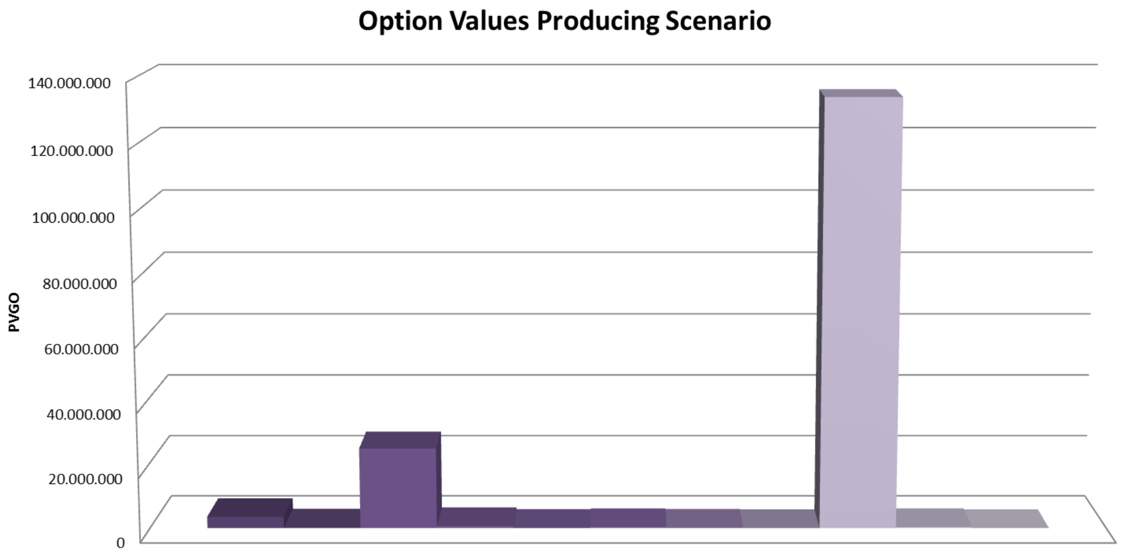


	Individual option values
■ Option to defer retail construction outlays	3.073
■ Option to abandon retail program	432
■ Option to defer office construction outlays	19.631.999
■ Option to abandon office program	878.632
■ Option to expand or contract retail	1.357.346
■ Option to defer retail land development outlays	54.268
■ Option to abandon retail program	0
■ Option to expand or contract office	177.269
■ Option to switch office to residential	10.244.125
■ Option to defer office land development outlays	742.458
■ Option to abandon office program	154.687

Figure B.2 Hot and Warm Static and Expanded NPV and individual option values in compound option chain Working scenario.

Producing Scenario

Producing scenario	Total	Retail	Office	Residential	Industrial
Hot Static NPV	**-31.500.079**	0	-339.103	0	-25.004.767
Hot PVGO	**164.318.813**	0	3.187.806	0	154.974.798
Hot Expanded NPV	**132.818.734**	0	2.848.703	0	129.970.031
Probability approval conditional on program	60%	60%	60%	60%	60%
Warm Static NPV	-18.900.048	0	-203.462	0	-15.002.860
Warm PVGO	98.591.288	0	1.912.684	0	92.984.879
Warm Expanded NPV	**79.691.240**	0	1.709.222	0	77.982.018



	Individual option values
■ Option to defer office construction outlays	3.582.369
■ Option to abandon office program	175.726
■ Option to defer industrial construction outlays	25.294.399
■ Option to abandon industrial program	613.601
■ Option to expand or contract office	37.615
■ Option to defer office land development outlays	313.155
■ Option to abandon office program	104.975
■ Option to expand or contract industrial	0
■ Option to switch industrial to retail	133.925.633
■ Option to defer industrial land development outlays	271.339
■ Option to abandon industrial program	0

Figure B.3 Hot and Warm Static and Expanded NPV and individual option values in compound option chain Producing scenario.