Department of Real Estate, Planning and Geoinformatics

Is There Hidden Value in Real Estate Investments?

Real Options Analysis Provides Rationale to Contingent Investment Decisions

Jussi Vimpari

Aalto University

DOCTORAL DISSERTATIONS

Aalto University publication series
DOCTORAL DISSERTATIONS 204/2014

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A doctoral dissertation completed for the degree of Doctor of Science (Technology) to be defended, with the permission of the Aalto University School of Engineering, at a public examination held at the lecture hall E of the school on 23rd January 2015 at 12:00.

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Aalto University publication series
DOCTORAL DISSERTATIONS 204/2014

ISBN 978-952-60-6007-1 (printed)
ISBN 978-952-60-6008-8 (pdf)
ISSN-L 1799-4934
ISSN 1799-4934 (printed)
ISSN 1799-4942 (pdf)
http://urn.fi/URN:ISBN:978-952-60-6008-8

Unigrafia Oy
Helsinki 2014

Finland

441 697
Printed matter

Author
Jussi Vimpari

Name of the doctoral dissertation
Is There Hidden Value in Real Estate Investments? Real Options Analysis Provides Rationale to Contingent Investment Decisions

Publisher School of Engineering

Unit Department of Real Estate, Planning and Geoinformatics

Series Aalto University publication series DOCTORAL DISSERTATIONS 204/2014

Field of research Real Estate Business

Manuscript submitted 22 September 2014 **Date of the defence** 23 January 2015

Permission to publish granted (date) 10 November 2014 **Language** English

☐ **Monograph** ☒ **Article dissertation (summary + original articles)**

Abstract

The understanding of real options analysis (ROA) has been claimed by academics to be extremely valuable for the real estate industry; yet adoption of the method in practice has been very slow. The aim of this dissertation is to examine opportunities that ROA opens in real estate investment analysis and decision-making as well as to demonstrate the actual real option value in some topical areas of real estate investment.

The study utilizes a mixed method research strategy with both quantitative and qualitative data. Case study research is used to collect data and to amount evidence to the research questions. Case studies conducted in this dissertation address the research problem from current areas causing uncertainties in the traditional discounted cash flow valuation of real estate investments, i.e. green building certificates, building flexibility, real estate portfolio management and public private partnerships.

The dissertation finds that ROA can enhance real estate investment analysis and decision-making and proposes that i) ROA should be used in real estate investment analysis and management because it can identify value elements missed by standard valuation practices, ii) lifecycle performance of real estate assets can be enhanced with real options and iii) ROA can produce results that can encourage investments necessary for long-term success in the real estate industry. The calculated real option values for different demonstration cases were a 8.8 % premium in the green building certificate case, a range from €8/sqm to €195/sqm in the building flexibility case, a 6.6 % premium in the residential real estate portfolio case and an added value of €1,580,000 in the public private partnerships case.

This dissertation contributes to the body of knowledge in the real estate investment field. The categorisation of previous research and building upon it new applications form a coherent whole of the method's potential in the real estate industry. The results enhance real estate investment analysis and decision-making by highlighting the role of uncertainty through different application levels. It points out that ROA can reveal new information and lines of actions, which can supplement or replace results of traditional DCF analysis. This is important for directing limited resources in long-term investments into right positions. The results presented in the papers enhances lifecycle performance of real estate investments from different viewpoints, which serves as a guidance for professionals in similar decisions as well as a starting point for developing new applications. The dissertation also discusses the practical adaptability of real options valuation techniques through different cases.

Keywords real options analysis, real estate investment, investment analysis, decision-making, lifecycle performance

ISBN (printed) 978-952-60-6007-1 **ISBN (pdf)** 978-952-60-6008-8

ISSN-L 1799-4934 **ISSN (printed)** 1799-4934 **ISSN (pdf)** 1799-4942

Location of publisher Helsinki **Location of printing** Helsinki **Year** 2014

Pages 137 **urn** http://urn.fi/URN:ISBN:978-952-60-6008-8

Tekijä
Jussi Vimpari

Väitöskirjan nimi
Reaalioptioanalyysi parantaa kiinteistösijoitusten analyysia ja päätöksentekoa

Julkaisija Insinööritieteiden korkeakoulu

Yksikkö Maankäyttötieteiden laitos

Sarja Aalto University publication series DOCTORAL DISSERTATIONS 204/2014

Tutkimusala Kiinteistöliiketoiminta

Käsikirjoituksen pvm 22.09.2014 **Väitöspäivä** 23.01.2015

Julkaisuluvan myöntämispäivä 10.11.2014 **Kieli** Englanti

☐ **Monografia** ☒ **Yhdistelmäväitöskirja (yhteenveto-osa + erillisartikkelit)**

Tiivistelmä

Tutkimustulosten perusteella reaalioptioanalyysin ymmärtämisen on havaittu tuovan merkittävää lisäarvoa kiinteistöalalle. Teollisuudessa menetelmän käyttöönotto on kuitenkin ollut hyvin hidasta. Tämän väitöskirjan tavoitteena on tutkia mahdollisuuksia mitä reaalioptioanalyysi avaa kiinteistösijoitusten analyysissa ja päätöksenteossa sekä näyttää toteen reaalioptioiden arvoja ajankohtaisissa kiinteistösijoitusalaa koskevissa aihepiireissä.

Tutkimuksessa käytetään mixed method -tutkimusstrategiaa hyödyntäen sekä kvantitatiivista että kvalitatiivista dataa. Tapaustutkimusta käytetään datan keräämiseen ja johtopäätöksiin, joilla vastataan tutkimuskysymyksiin. Väitöskirjassa toteutetut tapaustutkimukset käsittelevät tutkimusongelmaa aihepiireissä, joissa epävarmuuden on huomattu aiheuttavan haasteita perinteisessä kassavirta-analyysissa. Käsitellyt aihepiirit ovat ympäristösertifikaatit, rakennusten joustavuus, kiinteistöportfolioiden johtaminen sekä elinkaarimallit.

Tämä väitöskirja näyttää toteen että reaalioptioanalyysi parantaa kiinteistösijoitusten analyysia ja päätöksentekoa sekä ehdottaa että i) reaalioptioanalyysia tulisi käyttää kiinteistösijoitusten analyysissa ja johtamisessa, koska sen avulla voidaan löytää arvoelementtejä, joita perinteiset laskentamenetelmät eivät huomaa, ii) kiinteistöomaisuuden elinkaaren suorituskykyä voidaan parantaa reaalioptioilla ja iii) reaalioptioanalyysi kannustaa investointeihin, jotka ovat välttämättömiä pitkäntähtäimen onnistumiseen kiinteistösijoittamisessa. Lasketut reaalioptioiden arvot eri tapaustutkimuksissa olivat 8.8 % preemio ympäristösertifikaatille, vaihteluväli 8 €/m2 - 195 €/m2 rakennuksen joustavuudelle, 6.6 % preemio asuntosijoitusrahaston portfoliolle sekä 1 580 000 € lisäarvo elinkaarimallille.

Väitöskirja edistää kiinteistösijoittamisen tieteenalan tietämystä. Aiheen kirjallisuuden kategorointi ja sen päälle uusien sovellusten rakentaminen muodostaa kokonaisuuden menetelmän potentiaalista kiinteistöalalla. Löydökset parantavat kiinteistösijoitusten analysointia ja päätöksentekoa korostamalla epävarmuuden roolia eri näkökulmista. Väitöskirja näyttää toteen, että reaalioptioanalyysi voi paljastaa uutta informaatiota ja toimintatapoja, joilla voidaan täydentää tai korvata kassavirta-analyysin tuloksia. Tämä on tärkeää, jotta rajallisia resursseja saadaan kohdistettua oikeisiin paikkoihin pitkäntähtäimen investoinneissa. Väitöskirjan löydökset parantavat kiinteistösijoitusten elinkaaren suorituskykyä eri näkökulmista. Tämä toimii sekä ohjauksena alan ammattilaisille vastaavanlaisissa tilanteissa että aloituspisteenä vastaavien sovellusten kehittämisessä. Väitöskirja myös käsittelee reaalioptiolaskennan käytännön soveltuvuutta eri tapauksissa.

Avainsanat reaalioptioanalyysi, kiinteistösijoittaminen, investointianalyysi, päätöksenteko, elinkaaritehokkuus

ISBN (painettu) 978-952-60-6007-1 **ISBN (pdf)** 978-952-60-6008-8

ISSN-L 1799-4934 **ISSN (painettu)** 1799-4934 **ISSN (pdf)** 1799-4942

Julkaisupaikka Helsinki **Painopaikka** Helsinki **Vuosi** 2014

Sivumäärä 137 **urn** http://urn.fi/URN:ISBN:978-952-60-6008-8

Acknowledgments

The idea for writing a doctoral dissertation came to my mind in spring 2012. I had worked the past year as a real estate analyst at one of the largest real estate investors in Finland. There I learned a lot about real estate investment business in practice; for which I am especially thankful to Marja Mäki-Lohiluoma. Nevertheless, I had started to wonder whether the real estate and construction industry practices in investment analysis produce the best results for long-term decision-making in a fast changing world. I coincidentally told Matti Sivunen about these thoughts and he said we should sit down together with his company co-founder Juho-Kusti Kajander; they had just recognized the potential of real options in the built environment. I immediately realized that this is the topic I have been looking for, as it well suited my background, and more importantly the potential of practical implications was very encouraging. Thus, in the following autumn, I would join their company Boost Brothers Oy to start working on the topic as well as start my doctoral research at Aalto University School of Engineering. Thank you Matti and Kusti for this and for your input to the research. I appreciate your work as entrepreneurs greatly.

I am very grateful to Professor Seppo Junnila for taking me on board at Aalto, for his excellent guidance and ideas as well as for his role in creating a great atmosphere in the Real Estate Business research group. I cannot remember having a bad day at the office, so thank you fellow colleagues at the group for your presence; it has been a great environment to work as well as to discuss everything related/non-related to our research. Furthermore, I want to thank Professor Kauko Viitanen for the interesting discussions about real estate in general and especially for arranging this six-month visit to the University of Cambridge. As the research could not have been done without proper data, I appreciate all the participants who helped with the data and research. I also want to thank my pre-examiners, Professor Thomas Lützkendorf from Karlsruhe Institute of Technology and Associate Professor Baabak Ashuri from Georgia Institute of Technology for their valuable comments to the dissertation.

I want to thank my family, friends and relatives for the good times, sweet memories we have had; they have been a great balance to the research and

have helped me to overcome related problems along the way. I also want to thank our dog Shira, who has always been happy to welcome you home. I am especially grateful to my parents Antti and Irmeli for supporting and encouraging me throughout my life; it has been easy for me to follow my engineer's heart in all aspects of my life.

Last but not least, I want to express my sincere gratitude to my dear wife Susanna who has been a great inspiration and a source of energy to me over the past eight years. She has definitely made me a better person in so many ways of which I appreciate her enormously.

I want to end the acknowledgments with a quote, because I think it describes something that is very important for the topic of this dissertation: *"everything should be as simple as possible, but no simpler" -Einstein*

Cambridge, 19th November 2014
Jussi Vimpari

The dissertation is based on research funded by:

RYM Oy Indoor Environment Program – WP3: Business Logic of Knowledge Intensive Space Markets (*Aalto University, Boost Brothers Oy, Icecapital REAM Oy, Lassila ja Tikanoja Oyj, Newsec Oy, Skanska Oy and TEKES – the Finnish Funding Agency for Technology and Innovations*)
RAKLI - Confederation of Finnish Construction Industries
RYM-TO – Doctoral Programme in the Built Environment
Marcus Wallenbergin Liiketaloudellinen Tutkimussäätiö
TES - Finnish Foundation for Technology Promotion
SKOL - Finnish Association of Consulting Firms
Aalto University School of Engineering
KIINKO - Real Estate Education
Tutkijat maailmalle –ohjelma
KAUTE Foundation

The support of the organisations is gratefully acknowledged.

Papers of the dissertation

Paper I
Vimpari, J. and Junnila, S. (2014), "Value influencing mechanism of green certificates in the discounted cash flow valuation", *International Journal of Strategic Property Management*, Vol. 18 No. 3, pp. 238-252.

Paper II
Vimpari, J. and Junnila, S. (2014), "Valuing green building certificates as real options", *Journal of European Real Estate Research*, Vol. 7 No. 2, pp. 181-198.

Paper III
Vimpari, J., Kajander, J. and Junnila, S. (2014), "Valuing flexibility in a retrofit investment", *Journal of Corporate Real Estate*, Vol. 16 No. 1, pp. 3-21.

Paper IV
Vimpari, J. and Junnila, S. (2014), "Value of waiting - option pricing as a tool for residential real estate fund divestment management", *Property Management,* Vol. 32 No. 5, pp. 400-414.

Paper V
Vimpari, J., Sivunen, M., Kajander, J. and Junnila, S. (2014), "Risk management with real options in public private partnerships", *CIB International Conference on Construction in a Changing World, Sri Lanka 3-7.5.2014.*

Author's contribution to the papers

Paper I
Jussi Vimpari is responsible for initiating, executing and writing the paper. Seppo Junnila provided comments and suggestions on the paper.

Paper II
Jussi Vimpari is responsible for initiating, executing and writing the paper. Seppo Junnila provided comments and suggestions on the paper.

Paper III
Jussi Vimpari had the primary responsibility for initiating, executing and writing the paper. Seppo Junnila provided comments and suggestions on the paper.

Paper IV
Jussi Vimpari is responsible for initiating, executing and writing the paper. Seppo Junnila provided comments and suggestions on the paper.

Paper V
Jussi Vimpari had the primary responsibility for initiating, executing and writing the paper. Seppo Junnila provided comments and suggestions on the paper.

Table of contents

1 Introduction

1.1 Motivation and background

Megatrends, such as sustainable development, digitalization, technological innovation and resource scarcity are profoundly changing industries across the globe. Growing uncertainty intensifies the division between successful and unsuccessful businesses. In the real estate investment industry, the uncertainty has concretized in less predictable cash flows. In the UK, the average lease duration for office buildings has declined from 6.7 years to 4.5 years between 1999 and 2011 (BPF-IPD, 2012). In the US, the average office lease duration was 4.7 years between 2000 and 2010 (Titman and Twite, 2013). This phenomenon increases both the role of active management in the real estate business as well as the importance of building qualities that need to be adaptable into the fast changing circumstances of the 21st century.

Qualities, such as sustainability and flexibility, have been identified as important value elements for real estate investors in the future (Chegut et al., 2012; Sayce et al., 2013). Yet it appears that these kinds of qualities are not systematically accounted for in real estate investment analysis because it is difficult to quantify a value that is a contingent claim into an event in the future. For example, the value of a building flexibility investment depends on whether the flexibility is actually exercised into use and worth the extra investment; it is hard to valuate this kind of a contingent claim alone with the dominant discounted cash flow (DCF) valuation. In fact, researchers, such as Myers (1984), Trigeorgis and Mason (1987) and Dixit and Pindyck (1995) have argued that DCF valuation alone cannot properly value contingent claims, or as better known, *options*. This can be explained by the nature of an option: it limits the downside but retains the upside potential, which can asymmetrically transform the risk profile of an investment.

Option pricing was originally adopted by financial industry for valuing options used to hedge financial risk. Later on it was proposed that embedded options, such as option to wait or defer investment, have a notable value in real capital investments and should be accounted for in investment analysis

(Trigeorgis, 1988; Dixit and Pindyck, 1995). Option pricing methods from the financial industry were applied into options in real assets, i.e. *real options*, which Myers (1977) originally defined as *"opportunities to purchase real assets on possibly favourable terms"*.

Real options analysis (ROA) can be described as a method that connects financial and engineering analysis in order to identify and promote (market) value of embedded options in physical investments (de Neufville, 2003). The aim is to enhance lifecycle performance of a real asset, i.e. how an asset performs in fluctuating market conditions throughout its lifecycle.

Real options have proven to enhance lifecycle performance of many assets across different industries (Kemna, 1993; Grenadier and Weiss, 1997; de Neufville et al., 2006). Many top experts in academia have praised the potential of real options in sustainable decision-making; Professors Copeland (2010), Geltner and de Neufville (2012) have stated that real options may be the solution for encouraging investors to demand for a more sustainable design in long-term capital-intensive systems. Within the real estate field, past research have, for example, proven to provide valuable insight into strategic decision-making (Grenadier, 1996), enhance understanding in land valuation and building flexibility analysis (Quigg, 1993; Greden and Glicksman, 2005), highlight the importance of embedded options in lease contracts (Hendershott and Ward, 2000) and help justifying investments into renewable energy solutions (Ashuri and Kashani, 2011). However, past research have pointed out that real-life cases are needed for validating the findings.

1.2 Research problem

The understanding of real options analysis has been claimed by academics to be extremely valuable for the real estate industry; yet adoption of the method in practice has been very slow. The aim of this dissertation is to examine opportunities that ROA opens in real estate investment analysis and decision-making as well as to demonstrate the actual real option value in some topical areas of real estate investment. The dissertation aims to answer the following research questions:

RQ1: How can real options analysis enhance real estate investment analysis and decision-making?

RQ2: How the real option value of a real estate investment can be determined in topical areas of real estate industry, specifically in green building certificates, building flexibility, real estate portfolio management and public private partnerships?

The first research question explores both quantitatively and qualitatively shortcomings in mainstream investment analysis methods and how ROA can contribute to the shortcomings. The scope includes comparison of main investment analysis theories in order to position ROA as an individual method as well as a supplementing method. The second research question is addressed from different topical perspectives of real estate industry, namely green building certificates, building flexibility, portfolio management and public private partnerships. The different perspectives were chosen to highlight the difference between successful and unsuccessful lifecycle performances in different types of real estate investment decisions.

The dissertation aims to contribute mainly to the knowledge of real estate investment field with the following research objectives:

i. Examine the role of uncertainty in real estate investment analysis and decision-making
ii. Apply real options theory into lifecycle performance enhancing applications in real estate investments
iii. Discuss practical adaptability of real options valuation techniques in real estate context

1.3 Structure

The research structure is presented in Figure 1. It illustrates how the research questions, the papers, a summarizing literature review and this summary are linked together.

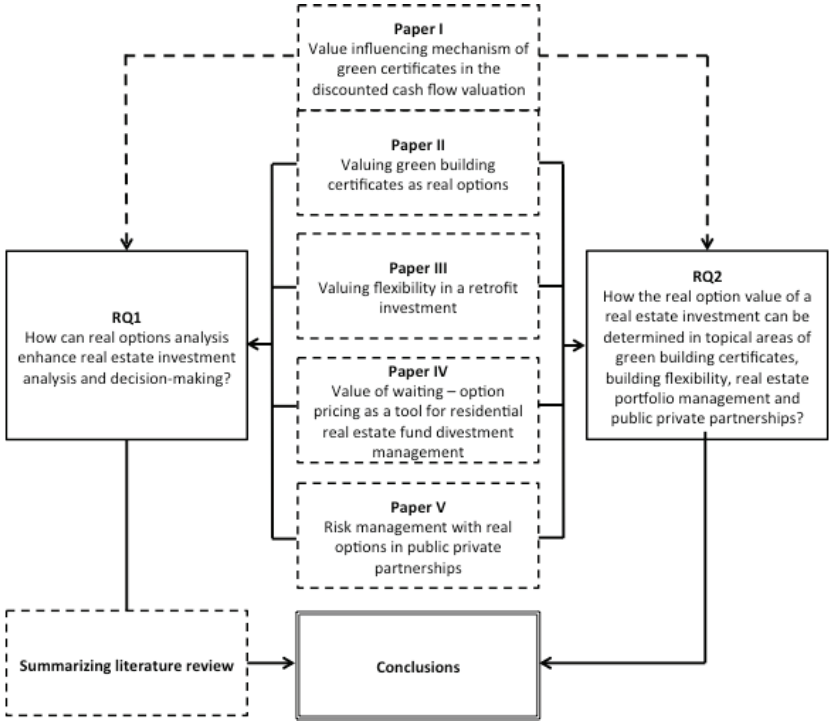

Figure 1 Research structure

The dissertation consists of four appended articles that have been reviewed and published in academic journals, and of one appended article that have been reviewed and published in a scientific conference as well as of a summarizing literature review of real options in the real estate industry.

The first empirical setting in the dissertation was split into two papers, Papers I and II, because it serves two specific goals. The purpose of Paper I is to deepen the understanding of current state of investment valuation practices in industry by discussing uncertainty assessment in the dominant DCF valuation in a sustainability context. This concluded in identifying the need for a new method for investment analysis and decision-making. Accordingly, Paper II evaluates whether ROA is suitable for valuing green building certificates, and calculates the real option value of a green certificate in a typical office building setting. The exact data gathered in Paper I was also used for the quantitative analysis in Paper II.

Paper III explores how ROA can be used for valuing flexibility in a real retrofit investment case, presents a research process for valuing the flexibility in the retrofit investment case and evaluates the empirical usability of real options valuation results compared with traditional DCF valuation results.

Paper IV tests option pricing to quantify the option to wait in a residential real estate fund divestment case. The paper argues that standard industry valuation practices miss the value of active fund management that should be included when planning a fund divestment strategy.

Paper V demonstrates how ROA can enhance risk management of a PPP project with specific characteristics of flexible contract and long contract period. The paper uses ROA for identifying and valuing uncertainties from the provider's perspective in a large healthcare facility investment case.

A literature review is conducted throughout the study, and towards the end a collective review attempts to organize previous real options literature in the real estate industry into major application domains and stated benefits of ROA for investment analysis and decision-making.

The conclusions tie together the findings of the papers and the literature review.

1.4 Research methodology and data sources

The study utilizes a mixed method research strategy with both quantitative and qualitative data (Creswell, 2014). Case study research is used to collect data and to amount evidence to answer research questions (Eisenhardt, 1989; Yin, 1994). The aim of the dissertation is well supported by the case study approach because earlier research has identified case studies as an important source of new information on the topic. The case studies conducted in this dissertation address the research problem from current areas causing uncertainties in the traditional cash flow valuation of real estate investments, i.e. green building certificates, building flexibility, real estate portfolio management and public private partnerships. The cases were selected with theoretical sampling (Glaser and Strauss, 1967), which ensured that the cases are relevant to the research problem and can be used to draw inferences on the research questions. The case selection process developed during the research; the chosen cases for the dissertation aimed to represents several different actors on different levels in the real estate investment field in order to acquire a broader perspective of the method's potential.

The specific cases in the study are examined with quantitative and qualitative data. The main focus is on quantitative research but Papers III and V utilises quantitative data first and after that the qualitative data is collected and analysed. Table 1 presents the research method, research design and main data sources for each individual paper.

Table 1 Research methods, designs and main data sources used in the papers

Paper	Research method	Research design	Main data sources
I	Quantitative	Embedded multiple-case study	Property market reports Survey
II	Quantitative	Embedded multiple-case study	Property market reports Survey
III	Mixed	Embedded single case study	Investment case Government employee projections Workshop
IV	Quantitative	Embedded single case study	Real estate portfolio divestment case Housing statistics
V	Mixed	Embedded single case study	Investment case Municipality population growth projections Workshop

The research designs have been selected based on the nature of the research problems in each paper. According to Yin (1994), single case design is appropriate when testing a critical case with a well-formulated theory. In papers III, IV and V single case design is found appropriate to test the real options theory in different real-life conditions. Multiple-case study design is used in Papers I and II because the surveys from different participants are independent single-case studies. Finally, embedded design is employed because there are multiple unit of analysis.

The case studies are addressed with real-life data in real-life cases, which is well in line with the research aim of the dissertation (Eisenhardt, 1989). Papers I and II utilizes data from property market reports and spreadsheet surveys from industry professionals. Paper III analyses an investment case by exploiting governmental employee projections for real options valuation. The findings are assessed in a workshop. Paper IV uses housing statistics for examining a real estate portfolio divestment case. Paper V analyses an investment case by exploiting municipality population growth projections for real options valuation. The findings are analysed in a workshop.

It is worth mentioning that the applicability of real-life data for real options valuation has been recognized as a challenge in real options research

(Lander and Pinches, 1998; Oppenheimer, 2002). This dissertation utilises two real options valuation techniques: the well-known binomial option pricing method (BOPM) and the novel fuzzy pay-off method (FPOM).

Binomial option pricing method

BOPM was first proposed by Cox et al. (1979) as a simple discrete-time model for valuing options. It is widely used in different applications and can be considered together with Black-Scholes (1973) as the original option pricing methods. In the method, binomial trees project the evolution of an asset value over time. Figure 2 presents a binomial tree and how it is transformed into a probability distribution, which is used to calculate the option value.

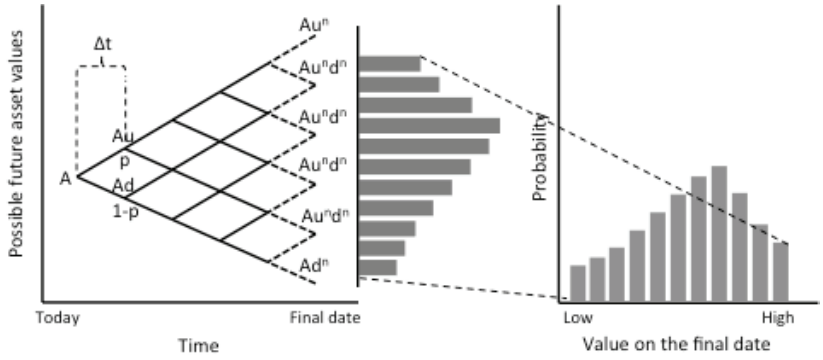

Figure 2 Binomial tree and projection of uncertainty (adapted from Amram and Kulatilaka, 1999)

In the figure can be seen how an asset value (A) is projected through time (t). After each time interval (Δt), the asset value has an upward (u) and a downward (d) value with probabilities of p and 1-p, respectively. The probabilities are calculated using volatility (σ) and risk-free rate (r_f). On the final date, the asset value has reached its maximum values with different probabilities, as presented on the right hand side of the figure. From these maximum values the option value is calculated by subtracting strike value, i.e. the value needed for exercising the option. The option value is risk-neutrally discounted to the present using the risk-free rate. The detailed equations and instructions for the method can be found in many books, such as Wilmott (2007) and Hull (2009).

In essence, the value of an option is calculated from the potential range that the underlying asset can have during its lifecycle. In BOPM, the range is determined by the volatility of the asset. In the financial industry, which is the original application of the method, the volatility can be easily determined because daily continuously updated historical data is available. In

the real estate industry, similar data is often not available due to the special characteristics of the industry, such as uniqueness, illiquidity, location bound and high transaction costs. This complicates the applicability of the method in real-life settings.

Fuzzy pay-off method

FPOM was originally developed on the basis of the so-called Datar-Mathews method, which calculates the option value from a pay-off distribution of net present values generated by Monte-Carlo simulations (Datar and Mathews 2004, 2007). Collan et al. (2009) realized that the probabilistic theory used in the Datar-Mathews method (and in other mainstream ROA methods) to treat for uncertainty could be replaced with fuzzy set theory (Zadeh, 1965). In the fuzzy set theory, different propositions (scenarios) have a degree of membership in a set, i.e. membership is 0 (complete non-membership), 1 (complete membership) or a value between 0 and 1 (an intermediate degree of membership).

This realization allowed simplification of the projection of uncertainty into three scenarios: minimum, best guess (i.e. the most likely scenario, which is normally drawn up in investment analysis) and maximum. These three scenarios are treated as triangular fuzzy numbers that form a triangular pay-off distribution where the best guess scenario has a complete membership, the minimum and maximum scenarios have complete non-membership, and other scenarios between have intermediate degrees of membership. This information is used to form a triangular pay-off distribution that is *"a graphical presentation of the range of possible future pay-offs the investment can take"* (Collan et al., 2009). Figure 2 presents an example of the triangular pay-off distribution. For a more detailed description of the method and mathematical formulas, see Collan et al. (2009) and Collan (2012).

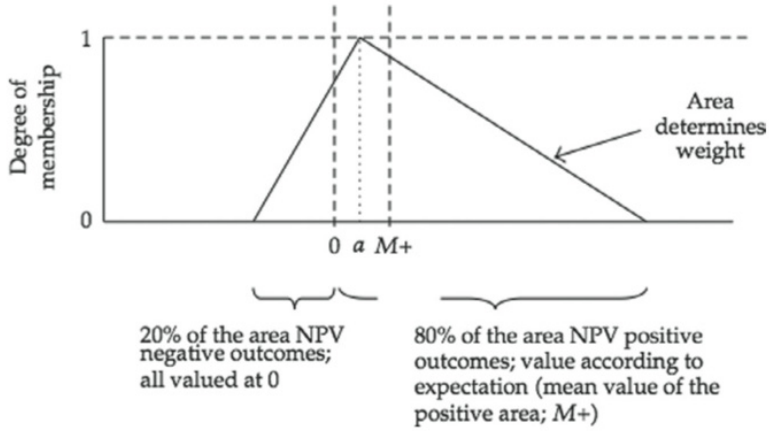

Figure 3 A triangular pay-off distribution, defined by three points describing the NPV of a prospective investment; percentages 20 and 80 are for illustration purposes only (Collan et al., 2009)

In FPOM, the projection of uncertainty can be done without determining the volatility for the asset. The uncertainty can be projected based on expert opinion and other relevant data available. In the real estate industry, this is often the only data available.

In principle, both of the presented methods use area for calculating the option value. In BOPM, the area is formed using a probabilistic approach based on a stochastic movement of an asset value through time. In FPOM, the area is formed using the fuzzy set theory to assign a degree of membership to present values of assets in different scenarios. FPOM can be considered as a more simplistic approach because it relies on deterministic values for the option valuation whereas BOPM is dependant of volatility as a key input parameter. In real estate, there is often insufficient data available for calculating the volatility. This is the advantage of FPOM because the method uses the data available in practice, which is the situation where all decision makers find them when making investment decisions.

2 Literature review

The literature review starts from an overview of real options literature (across all industries) and then moves to real estate industry specific literature. The summary of the review is presented in Table 2. The review process involved scanning references of well-known real options articles as well as using academic search engines (i.e. Scopus, Web of Science and Proquest) with keywords, such as *"real options"* and *"real estate"*. The author has tried to include important articles regarding history, motivation and criticism of real options in the identified general background topic. Real options research in the real estate industry was categorized based on the literature into five different topics: real estate market, land valuation, building flexibility, lease contracts and technology investment.

Table 2 Taxonomy of real options research in the real estate industry

Topic	**Authors**
General background (history, motivation, criticism)	Myers (1977, 1984), Kester (1984), McDonald and Siegel (1986), Trigeorgis and Mason (1987), Trigeorgis (1988, 1993), Pindyck (1991), Dixit (1992), Dixit and Pindyck (1995), Grenadier and Weiss (1997), Luehrman (1998), Lander and Pinches (1998), Amram and Kulatilaka (1999), Bowman and Moskowitz (2001), Miller and Park (2002), Oppenheimer (2002), De Neufville (2003), Adner and Levinthal (2004), Borison (2005), Copeland (2010), Geltner and de Neufville (2012)
Real estate market	Grenadier (1996), Lai et al. (2004, 2007), Wang and Zhou (2006), Bulan et al. (2009), Fu and Jennen (2009), Ott et al. (2012), Clapp et al. (2012, 2013, 2014), Chau and Wong (2014), Vimpari and Junnila (2014a)
Land valuation	Titman (1985), Williams (1991), Quigg (1993), Capozza and Sick (1994), Chiang et al. (2006), Cunningham (2006), Rocha et al. (2007), Grissom et al. (2010), Shen and Pretorius (2013)

Building flexibility	Gann and Barlow (1996), Trigeorgis (2005), Greden and Glicksman (2005), de Neufville et al. (2006), Guma et al. (2009), Fawcett (2011) and Fawcett et al. (2012), Dortland et al. (2012, 2014), Cardin et al. (2013a, 2013b), Vimpari et al. (2014a), Vimpari and Junnila (2014b)
Lease contracts	Grenadier (1995, 2005), Hendershott and Ward (2000), Ambrose et al. (2002), Sing and Tang (2004), Cho and Shilling (2007), Ashuri (2010)
Technology investment	Greden et al. (2005), Fleten et al. (2007), van der Maaten (2010), Ashuri and Kashani (2011), Verbruggen et al. (2011), Menassa (2011), Kumbaroglu and Madlener (2012), Hillebrand et al. (2014), Vimpari et al. (2014b)

2.1 General background

Myers (1977) introduced real options as *"opportunities to purchase real assets on possibly favourable terms."* Later on, Myers (1984) tried to explain the limitations of finance theory and strategic planning by proposing that the DCF *"may fail in strategic applications even if it's properly applied."* Role of options in capital investment decisions was further researched by pointing out growth options in capital budgeting (Kester, 1984) and value of waiting in investment decisions (McDonald and Siegel, 1986; Pindyck, 1991). Further, Trigeorgis and Mason (1987) and Trigeorgis (1988, 1993) researched the value of managerial and financial flexibility as well as role of options analysis in investment projects. Dixit (1992) and Dixit and Pindyck (1995) researched the role of options analysis in capturing the uncertainty in investment decisions by highlighting how options can improve the upside potential while at the same time limit downside losses. Option pricing was used to develop investment strategies for technological innovations (Grenadier and Weiss, 1997) and for business projects (Luehrman, 1998). Lander and Pinches (1998) and Oppenheimer (2002) both recognized the potential of real options investment analysis but indicated criticism of the method, especially in the complexity of the valuation. Amram and Kulatilaka (1999) compiled a profound review of real options in managing strategic investments. Bowman and Moskowitz (2001) studied the role of real options in strategic decision-making and concluded that options approach encourages managers to *"experimentation and the proactive exploration of uncertainty."* Miller and Park (2002) and de Neufville (2003) explored how real options can link market information with strategic engineering economic decisions. Adner and Levinthal (2004) added to the criti-

cism of real options that understanding the boundaries of the approach is essential in all path-dependent activity. Borison (2005) concluded a review of applicability, assumptions and mechanics of different real options valuation methods. Copeland (2010) discussed cases of real option applications and challenges that have to be overcome for a breakthrough of ROA as a practical method. Finally, Geltner and de Neufville (2012) have recently emphasized how compiling real options theory and 21st century digital data sources can result in *"better informed design and valuation, more efficient urban development laced with greater flexibility to avoid the worst down-side outcomes and to take advantage of the best up-side opportunities, saving vital resources of capital, land, raw materials, and energy."*

2.2 Real estate market

Real option research in real estate industry is used to explain real estate market phenomena, such as market behaviour, development cycles, role of competition, and risk in development decisions. Grenadier (1996) used game-theoretic option exercise strategies to explain investment decisions, particularly to explain why some markets have bursts of development activities and others smooth development activities. Lai et al. (2004) used real options to analyse the price uncertainty of new developments for modelling presale strategy of developers. The findings explain developers' risk management activities as well as barriers to enter a development market. Lai et al. (2007) continued the research to explain developers' behaviour with rents and occupancy levels in different market types. Wang and Zhou (2006) claim that their real options model can explain many development activities observed in the market, such as causal relationship of development option holding and exercising. Bulan et al. (2009) used real options in analysing correlation of volatility and investment under competitive situations. The estimates suggest that increases in both idiosyncratic and systematic risk lead developers to delay investments. Fu and Jennen (2009) argue that real options are capable of predicting new office construction, especially role of volatility in hurdle rents and construction delays. Ott et al. (2012) used a real options framework to explain the rationale of phasing and building for inventory in large-scale residential development. Clapp et al. (2012, 2013) explained how option to redevelop residential real estate explains value changes in different housing markets and cycles. Furthermore, Clapp et al. (2014) analysed what drives the exercise timing of an expansion option in shopping centres. Chau and Wong (2014) identify a negative impact that urban renewal has on nearby properties redevelopment option values. The impact is found to be negative depending age and location of nearby buildings. Paper IV of this dissertation is placed on this

category because it explains the special characteristics of residential real estate market by identifying the value of waiting in a residential real estate portfolio divestment case.

2.3 Land valuation

Land valuation is one of the original applications of real options in the real estate industry. Titman (1985) argued that option pricing is needed if uncertainty about future real estate values is high. The option to select the type and size of building raises the value of the vacant land and has important role in decision-making. Williams (1991) followed by arguing that the stochastic evolution of operating revenues and construction cost should be acknowledged in development decisions. Quigg (1993) argued that the current land valuation models should account for the option to wait because it has a value in decision-making. Capozza and Sick (1994) explained the value and risk structure of land markets where urban land is priced using CAPM and agricultural land with real options because it can be converted into urban land where the value of conversion increases with urban growth rate. Chiang et al. (2006) used option pricing to identify similar embedded options inside vacant land, arguing that NPV cannot capture the value of options available within project developments, such as defer, abandon, expand, contract and switch. Cunningham (2006) identified the presence of real options in vacant land prices and suggested that real options should be included in capital investment analysis. Rocha et al. (2007) demonstrated how real options could improve investment analysis in real estate development cases by identifying optimal strategy and timing for sequential investing. Grissom et al. (2010) used option-pricing theory together with portfolio analytics to assess single and mixed-use of the same land. The option value is important because a development process includes different options of which values depend on land use and growth. Shen and Pretorius (2013) argued that more practical factors should be incorporated into real option theory, including institutional arrangements, direct interactions and financial constrains. The study points out how these factors affect the land value and development timing.

2.4 Building flexibility

Building flexibility can be identified as one of the key themes of the topic. Gann and Barlow (1996) discussed criteria in building design that needs to be evaluated when converting offices into apartments. They conclude that most buildings are rarely designed for future requirements and the owners should seek for mixed-use options. Trigeorgis (2005) laid a foundation for

modular decision-making. It was suggested that complex real options problems should be simplified with modular building blocks. Greden and Glicksman (2005) conducted a study for valuing flexible space with real options. A binomial real options model for addressing the problem of calculating how much flexible space is justified economically was developed. De Neufville (2006) presented how ROA provides the decision-maker with information for planning an investment a parking garage investment in stages when demand is uncertain. Guma et al. (2009) studied vertical phasing as a corporate real estate strategy. Several case studies identified that option to raise a building can highly improve real estate investment project's lifecycle performance. Fawcett (2011) and Fawcett et al. (2012) discussed the importance of real options in designing buildings; it was proposed that options-based decision-making is a continuum for LCC and LCA calculation methods. Dortland et al. (2012, 2014) used qualitative methods to discuss flexibility in healthcare investments; scenario planning and ROA were found as effective tools to increase the management of understanding the importance of flexibility. Cardin et al. (2013a) developed a framework for optimizing the phasing of a development project. The method is used for recognizing flexibility that enhances value of a real estate project. Furthermore, Cardin et al. (2013b) evaluated methods for identifying flexibility to engineering systems design. Prompting mechanisms and explicit training was found to increase the flexibility in a case study of real estate development. Papers II and III of this dissertation may be located in in this literature category. Paper II demonstrates that option pricing could be used for valuing green building certificates because their value is dependent on a contingent claim in a future event. The certificate provides the flexibility to adapt into future market conditions. Paper III used a fuzzy pay-off method for real options valuation to valuate flexibility in a retrofit office case study. It is pointed out that flexibility is not valuable in all parts of the building and decisions should be made accordingly.

2.5 Lease contracts

Several studies have identified ROA as a method for valuing options within commercial lease contracts. Grenadier (1995, 2005) produced a model for valuing equilibrium lease term structures for different kind of contracts, such as leases with options to renew or cancel and with insurances. The model accounts for economic uncertainty (supply/demand) and competitive interaction to improve the understanding of the current spot lease prices. Hendershott and Ward (2000) incorporated option-like features, such as overage rent and expense stops into valuation of shopping centre leases.

The benefit is that different economic conditions are acknowledged through drift rate and volatility. Ambrose et al. (2002) presented a stochastic pricing model for upward-only adjusting leases. The model is used to explain why initial rents should be significantly lower in upward-only leases compared to fully adjustable leases. Sing and Tang (2004) addressed investor's leasing risk with a binomial option model; a default option is analysed by addressing the costs from both lessor's and lessee's side in a case of lease renegotiation. The model increases the investor's understanding in embedded cancellation and default options in lease contracts. Cho and Shilling (2007) used ROA for valuing shopping centre leases by delivering further evidence why the user-cost of capital does not hold in uncertain environments by claiming that it does not include the risk premium related to tenant risks. It was found that *"positive value of the tenant's default option is roughly equal to the negative value of the overage or percentage rents in present value terms."* Ashuri (2010) used ROA to valuate the worth of flexibility in a corporate lease. The model incorporated uncertainty in the rental market as well as uncertainty in workspace demand.

2.6 Technology investment

ROA has been proposed as a method for controlling technology investment risks, mostly related to energy investments. Greden et al. (2005) used option-based design to justify the costs of a switch option between natural and mechanical ventilation, where the market value effect of the chosen technology is uncertain. Fleten et al. (2007) discussed the option to postpone a decentralized renewable energy solution where the stochastic electricity price is the main variable for the option value. It is found that the optimal investment strategy is to invest in different capacities at different price ranges high above the traditional NPV break-even point. Van der Maaten (2010) used binomial option pricing to value the timing of a solar power investment in residential real estate. ROA was suggested as a method for guiding governmental renewable energy incentives. Ashuri and Kashani (2011) discussed the same topic by proposing a real options theory based investment framework for identifying the optimal timing of solar panel investments. The model incorporates elements, which are missed in the standard NPV analysis. Verbruggen et al. (2011) argued that irrevocability and dynamic sequential analysis of future events have to be accounted when making correct decisions about energy investments in buildings. Menassa (2011) developed a framework for guiding sustainable retrofit investments. The framework combines option pricing and CAPM in order to provide simple estimates for the decision-maker in developing optimal in-

vestment strategies. Kumbaroglu and Madlener (2012) studied energy retrofit investments by using traditional static decision-making (NPV) and dynamic decision-making (ROA) in an office building case. It was found that energy price uncertainty significantly affects profitability of retrofit investments and that option to wait in envelope retrofits is not valuable if energy price increases remain moderate and smooth. Hillebrand et al. (2014) furthered the comparison of Kumbaroglu and Madlener (2012) by highlighting a wait and learn option when making a retrofit investment decision. It is highlighted that multi-criteria evaluation is needed when finding an optimal retrofit solution. Paper V is positioned in this category as it discusses construction methods as well as energy source investments.

2.7 Literature summary

The examined research on real options has demonstrated why understanding real options are important for the real estate and construction industry. There is already well-defined real estate market phenomena that can be explained through real options, and thus provide valuable insight into strategic decision-making in the industry. Similarly, real options in specific application domains of land valuation and building flexibility are important to understand when making long-term decisions in fast-changing markets. Understanding option values embedded in lease contracts have a growing importance when average leases are becoming shorter. Finally, the option value of renewable and conserved energy may be one of the major applications of the method in climate conscious future.

Even though the potential of the method is claimed to be extremely valuable, most of the real options analyses have been tested so far in hypothetical settings. Accordingly, many studies have concluded that more real life cases are needed. Therefore, it seems that adoption of ROA as an investment analysis and decision-making tool in practice is very slow.

3 Summaries of the papers

This chapter presents a summary of the papers. The summaries briefly highlight purpose, research methodology, findings and contribution of each paper. The full papers are appended to the dissertation.

3.1 Paper I: Value influencing mechanism of green certificates in the discounted cash flow valuation

The first paper serves as a foundation to the research problem of the dissertation. The paper helped to focus the research questions by discussing DCF valuation and uncertainty in a sustainability investment context. Sustainability in the real estate and construction sector has received heaps of attention during the past few years. This attention has lead to a wide range of different sustainability measurement systems for companies and actual building properties. These and other more legislative measures have put pressure on different stakeholders to participate in sustainable development. However, at the same time there is a strategic pull to sustainability due to real environmental, social and economical benefits that can be gained from investments in sustainable solutions.

Growing amounts of research (Eichholtz et al., 2008; Fuerst and McAllister, 2008, 2009a, 2009b; Pivo and Fisher, 2009; Reichardt et al., 2012; Chegut et al., 2012) have examined the economical benefits of green properties and building certificates, especially on how they affect cash flow parameters: rents, maintenance costs, vacancy rates and yields. Most of the earlier research has been either surveys with different stakeholders in the sector or regression analysis based on large datasets of certified and non-certified properties in the most mature markets with certificates, such as the US and the UK. Even though many of the research results indicate a positive relationship between certified buildings and the cash flow parameters, it remains unclear what the actual value influencing mechanisms are and how the green certificate should be incorporated into property valuation.

This paper sheds light on the value influencing mechanism of green certificates in the DCF valuation. A traditional DCF model for property valuation

was constructed in spreadsheet programme and sent to different stakeholders (i.e., property valuers, investors and developers) for valuing an office property in metropolitan Finland. The participants were asked to valuate the office property first without a certificate and then with a premium (LEED Platinum) certificate. Table 3 summarises the responses received.

Table 3 Summary of the differences in the DCF parameters between non-certified and certified properties

Parameter	Scenario	Valuers Mean	Investors Mean	Developers Mean	All Mean	All Median	All Min	All Max
Rent (€/sqm/m)	Max	0.25	0.33	0.67	**0.44**	0.25	0.00	1.00
	Normal	0.25	0.00	1.50	**0.63**	0.25	0.00	3.00
	Min	0.25	0.00	2.33	**0.94**	0.25	0.00	5.50
Vacancy Rate (%-unit)	Max	-0.36 %	-1.82 %	-1.64 %	**-1.39 %**	-1.05 %	-4.09 %	0.00 %
	Normal	-0.36 %	-2.24 %	1.26 %	**-0.46 %**	-0.36 %	-4.91 %	5.91 %
	Min	-0.32 %	-2.73 %	5.09 %	**0.81 %**	-0.32 %	-4.91 %	17.27 %
Maintenance Costs (€/sqm/m)	Max	-0.18	-0.23	-0.07	**-0.16**	-0.15	-0.50	0.00
	Normal	-0.25	-0.23	0.00	**-0.15**	-0.10	-0.50	0.00
	Min	-0.26	-0.23	-0.10	**-0.19**	-0.23	-0.50	0.00
Repair and Replacement Costs (€/sqm/m)	Max	-0.03	0.00	0.00	**-0.01**	0.00	-0.05	0.00
	Normal	-0.03	0.00	0.00	**-0.01**	0.00	-0.05	0.00
	Min	-0.02	0.00	0.00	**-0.01**	0.00	-0.05	0.00
Yield (%-unit)	Max	-0.13 %	-0.28 %	-0.18 %	**-0.21 %**	-0.13 %	-0.75 %	0.00 %
	Normal	-0.13 %	-0.28 %	-0.30 %	**-0.25 %**	-0.13 %	-0.75 %	0.00 %
	Min	-0.12 %	-0.28 %	-0.08 %	**-0.17 %**	-0.10 %	-0.75 %	0.00 %
Property Value (€)	Max	718 864	1 521 985	1 069 806	**1 151 638**	961 278	273 333	2 754 902
	Normal	689 445	1 276 170	987 143	**1 021 104**	826 605	189 808	2 797 270
	Min	587 572	1 288 779	112 530	**672 384**	637 605	-967 891	2 954 587

Based on the earlier research, it was hypothesized that the participants will increase rent and decrease vacancy rate, maintenance costs, operating expenses (i.e., maintenance costs and repair and replacement costs), and yield that would eventually result in higher property values. It was found that property values were increased in every case except one out of 24 scenarios. This indicated that certified properties indeed have higher property values than non-certified properties. However, it was hard to pinpoint exact parameters for the increased property value with the exception of yield that was adjusted downward by seven out of eight participants. This could be interpreted that most of the participants consider certified properties less risky than non-certified properties. Similarly, seven out of eight participants responded that the certificate does not have an effect in the parameter of Repair and Replacement Costs.

The main result of higher property values were expected even though it was surprising that the results were so consistent with each other: all of the participants valued certified properties higher. Additionally, based on the interviews with industry professionals, it was expected that different participants would weight different DCF input parameters differently. However, it was unexpected that yield was decreased in almost all of the responses, because yield often has the highest impact on property value. On the other

hand, earlier research indicates that certified buildings are less risky, and since yield measures risk, adjusting it is an easy way for incorporating the impact of a certificate into the property valuation. In addition, since yield is the most subjective of the parameters, it might be the logical parameter for including the green certificate.

Finally, the results seem to suggest (based on analytical not a statistical generalization) that a green certificate increases on average the property value with 9.0 % in the DCF valuation model. The finding is in line with the earlier theoretical studies presented in the literature review. All of respondents adjusted the DCF parameters to have a positive effect in the property value. The standard deviation of the positive effect was high, so there was not a clear consensus of the size of the positive impact between the respondents. It is notice worthy that the above deduction is based on the highest available LEED certificate, and thus cannot be generalized to all green certificates. Additionally, the scope of the research was Finnish office property market. The findings are based on a rather small sample size, partly because of the small number of property valuers, investors, and developers in the Finnish real estate and construction sector, and partly because a strong hypothesis could be constructed based on earlier literature and the study was sort of "critical case" design. Finally, the DCF is known for its weaknesses in producing reliable results, if the input parameters are not well founded.

3.2 Paper II: Valuing green building certificates as real options

The second paper is a follow-up to Paper I, which raised the question is DCF the best method for analysing the value of a green building certificate. The data gathered in the first paper could be used in real options valuation as well. Thus, the second paper evaluates whether ROA could supplement the dominant DCF valuation in valuing green building certificates, which during the past decade has become the mark of sustainability in the industry.

The paper addresses the research questions from a sustainability investment perspective. Investments into sustainability are recognized as one of the key future topics in the real estate industry (Roper and Bear, 2006). However, investments in sustainability seem to have been delayed partly because justifying the investments with the traditional investment analysis methods is difficult because of uncertainty in the value creation of a sustainability investment. On the other hand, ROA has been used for justifying investments that traditional investments analysis methods fail to justify (Trigeorgis, 1990; Kemna, 1993; Grenadier and Weiss, 1997; de Neufville et al., 2006). The paper discusses whether green certificates could be valued

as real options by identifying the option characteristics of green certificates, see Table 4.

Table 4 Real option characteristics of green certificates

Option characteristics of green certificates	**When to use (real) option valuation**
The scope of potential future value of green certificates is very wide. All the way from a new industry standard (building without the certificate does not sell) to nothing (new low-carbon legislation makes green certificate obsolete)	*"When there is a contingent investment decision. No other approach can correctly value this type of opportunity."* (Amram and Kulatilaka, 1999)
It seems that the uncertainty of the value of a green certificate has probably delayed investments in green buildings and certificates.	*"When uncertainty is large enough that it is sensible to wait for more information, avoiding regret for irreversible investments."* (Amram and Kulatilaka, 1999)
The value of a green certificate includes growth options, e.g., if in the future, green certified buildings are transacted with a value premium.	*"When the values seems to be captured in possibilities for future growth options rather than current cash flow."* (Amram and Kulatilaka, 1999)
The green certificate provides flexibility to the holder, e.g., better positioning in the market, depending on the position of green certificates in the future.	*"When uncertainty is large enough to make flexibility a consideration. Only the real options approach can correctly value investments in flexibility."* (Amram and Kulatilaka, 1999)
At the moment, the value of a green certificate has not been proven in practice; thus, it is an unique asset without true comparables.	*Uniqueness or presence of comparables (Damodaran, 2002)*
Market value for green certificates has not been determined; therefore, the value of a green certificate should be based on fundamental analysis rather than reference to its market value.	*Market neutrality, determining intrinsic value (Damodaran, 2002)*

Markets are not efficient in valuing the flexibility that a green certificate may provide in the future.	*Beliefs about markets (Damodaran, 2002)*

The main finding of the paper is that green certificates have several characteristics that makes it well found to value them as real options and that ROA can be used for the valuation. The paper also explains how option pricing theory and DCF deal with uncertainty and suggests that the shortcomings of DCF could be addressed with ROA.

The applicability of ROA for valuing green certificates is also demonstrated using the fuzzy pay-off method (Collan, 2009). The method is applied into green certificate data gathered from eight professional industry organizations (two valuers, three investors, and three developers). The eight different responses are analysed as individual cases and cross-case conclusions are drawn. The results show that the green certificate (LEED Platinum) can be valued using ROA in every case, and that the mean value gain from the estimated LEED Platinum certificate upgrading of an office building is €985,000 (or 8.8% of the mean property value) for all of the cases. The authors of the paper are not aware of other studies where green building certificates are valued using option pricing models.

The main deduction from the empirical findings is that by examining the certificate as a real option, the uncertainty of the value gain from a certificate can be addressed with real-life data. It is argued that analysing the impact of a certificate in multiple scenarios is better than trying to include everything in a single valuation. The real option value in the case comes from the flexibility to adapt into future market conditions where the role of green certificates is uncertain.

The generalization of the paper's results is examined from two perspectives. The theoretical framework of the option characteristics of green certificates is based on the paper's authors' interpretation and is thus subject to external evaluation. However, the characteristics are widely noted and fit into the uncertainty issues between DCF and ROA. The main reason for the empirical study is to demonstrate the use of ROA in valuing green certificates. Thus the empirical result of the value premium (8.8%) should not be directly generalized to other office buildings, especially in different settings and market areas. However, the results could be used as guidance for the development of ROA in valuing green certificates.

3.3 Paper III: Valuing flexibility in a retrofit investment

The third paper addresses the research questions from a flexibility investment perspective. Maximizing occupancy rates and profitability re-

quires design flexibility, which can be provided by introducing new technologies and planning methods, such as mobile walls and open building design. However, while estimating the costs of these investments is relatively straightforward, measuring the economical value of the flexibility investments in premises is not due to the uncertainty of the potential future cash flows. In this paper, the economical value of flexibility is examined in a real life investment case using ROA. The value is evaluated from two perspectives: the value gain to a corporation and the value gain to a corporate real estate (CRE) unit (Senate) of the corporation.

The purpose of this paper is to research how ROA can be used for valuing flexibility in a real retrofit investment case, to present a research process for valuing the flexibility in a retrofit investment case and to evaluate the empirical usability of ROA results compared with traditional DCF valuation results. First, the results supports the idea that ROA is able to produce numerical and comprehensive data for valuing flexibility in a real retrofit investment case. In the case study, it is indicated quantitatively that the whole building should not be made flexible because the flexibility is economically feasible only in certain sections of the building. The present value of the pay-off from flexibility ranged from a negative €58/sqm to a positive €130/sqm, depending on the tenant and space, see Table 5.

Table 5 Pay-off of flexibility per tenant (discounted to present using 7.0 per cent discount rate)

Tenant	Initial investment cost	Option value CRE unit (Senate)	Pay-off CRE unit (Senate)	Option value corporation	Pay-off corporation
Tenant 1	−€65/sqm	€81/sqm	*€16/sqm*	€97/sqm	*€32/sqm*
Tenant 5	−€65/sqm	€81/sqm	*€16/sqm*	€161/sqm	*€96/sqm*
Tenant 6	−€65/sqm	€13/sqm	−€52/sqm	€173/sqm	*€108/sqm*
Tenant 7	−€65/sqm	€16/sqm	−€49/sqm	€128/sqm	*€63/sqm*
Tenant 8	−€65/sqm	€70/sqm	*€5/sqm*	€195/sqm	*€130/sqm*
Tenant 9	−€65/sqm	€7/sqm	−€58/sqm	€7/sqm	−€58/sqm
Tenant 10	−€65/sqm	€8/sqm	−€57/sqm	€8/sqm	−€57/sqm

Second, a seven-step research process is developed for valuing the flexibility. The research process provides guidelines for the systematic valuation of flexibility in a real estate context where the tenant's space requirements are uncertain. Third, ROA results are found to deliver more comprehensible data for decision-making than the results from DCF valuation only. The main difference is the projection of uncertainty in ROA where ranges of vacant space are assessed in minimum, best guess and maximum scenarios. These numerical projections provide an indication of the extent and the actual location of the benefits achievable with flexibility. Finally, the process provides information for comparing the pay-off and the risks of flexi-

bility, justifying investments into flexibility and, eventually, avoiding unprofitable investments into flexibility.

In the paper, the results were assessed in a workshop with the CRE unit's investment experts who perceived ROA as a valuable approach to systematically sharing and analysing investment decision-making information inside the company. The main advantage of the method compared to DCF valuation was found as handling of uncertainty, i.e. individual tenant risks were assessed more carefully and systematically by acknowledging several sources of information. Also, projection of the three scenarios into the building layout provided Senate with a comprehensible result that showed the potential vacancy for each tenant. The comprised scenarios also provide practical benefit: it is easier to include several opinions from different experts into the analysis; this allows for the easier follow-through of proposals within an organisation. Overall, it was concluded that ROA provided Senate with better decision-making material regarding retrofit investments. The analysis pointed out where flexibility is economically justifiable and where it is not, i.e. which options are worth investing in and which are not.

The findings of the paper were found to be in line with the earlier research (Greden and Glicksman, 2005; de Neufville, 2006) suggesting that ROA is a suitable method for valuing flexibility in real estate projects. The major difference in the findings of the paper compared to earlier research was the used solution technique for ROA. The applicability of the fuzzy pay-off method into a practical investment case was found straightforward because the assignment of probabilities into different uncertainty scenarios was unnecessary.

The main contribution of the paper is to demonstrate the use of ROA in a real life investment case. Real options literature, especially in the real estate and construction sector, has requested for new applications of ROA in practical settings. This paper adds to the request with an example of evaluating flexibility in a retrofit investment case. The empirical analysis produced in this paper can be used for guidance and as motivation for finding further applications of real options in the industry. Additionally, within the field of CRE, the paper adds to the value creation and distribution between a corporation and a CRE unit.

3.4 Paper IV: Value of waiting - option pricing as a tool for residential real estate fund divestment management

The fourth paper addresses the research questions from a residential real estate fund divestment perspective. The paper discusses two insufficiently examined topics: portfolio divestment strategies and residential real estate valuation.

The purpose of the paper is to use option pricing for quantifying the option to wait in a residential real estate fund divestment case. It is argued that embedded options in a divestment decision should be acknowledged and that option pricing can supplement the current mainstream investment analysis methods in producing better decision-making material for the decision-maker.

The paper founds that standard industry valuation practices miss the value of active fund management that should be included when planning a fund divestment strategy. Option pricing provides a risk-neutral quantified value whether an apartment building portfolio should be divested in a single transaction or in multiple transactions over time. In the paper's case study, an option value of 6.6 % was found for a residential real estate portfolio, Figure 4 demonstrates the option pricing of an individual apartment.

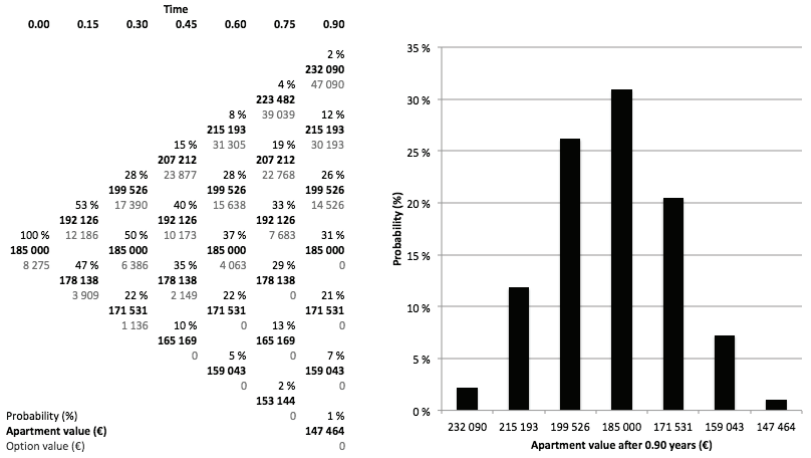

Figure 4 Option pricing of a two-bedroom apartment.

The application of option pricing questions whether apartment building valuation should include the opportunity value as an embedded option. It is proposed that management should acknowledge this value in decision-making.

The paper underlines that the option value premium was not unexpected because in practice it is expensive and takes time to build a large real estate portfolio. It is unknown why this value is not recognized, especially when apartments are viewed as the most riskless real estate class with a great potential for value appreciation. The approach proposed in the paper risk-neutrally calculates the value appreciation from the range of the potential values, which provides the decision-maker a deeper understanding of the implications regarding the chosen line of action.

The paper's findings suggest that the case study fund should be liquidated by selling the apartments individually. However, since the values of options are tied to the risk (volatility) of different apartment buildings, optimal exit strategy is the one that maximizes risk-return levels and meets the fund's targets. For example, does the fund want to return the liquidated assets to investors as soon as possible (individual apartments from all apartment buildings are put on market at the same time), does the fund want to maximize both rental income and potential apartment value increase during the sales process (first apartment buildings with longer total sales time are sold), does the fund want to maximize potential apartment value increase during the sales process (riskier apartment buildings are held longer during the sales process), does the fund want to maximize rental income but to minimize apartment value risk (riskier apartment buildings are sold first). These decisions can be examined with equations of modern portfolio theory by following sales times and volatilities of different apartment buildings and updating the risk-return levels of different apartment buildings.

3.5 Paper V: Risk management with real options in public private partnerships

The fifth paper addresses the research questions from a public private partnership (PPP) perspective with specific characteristics of flexible contract and long contract period. PPPs have secured a position as an alternative to direct investment in construction projects in the municipal sector. The construction costs of PPP projects are often justified by stating that the quality of construction is better and the overall lifecycle costs are optimized according to the client's needs. Recently a need for flexibility in PPP contracts has emerged. In some cases the client demand for services may vary during the concession period. This generates a need to make flexible contracts between the client and the provider. Providers in PPP projects have an increasing need to identify and manage uncertainty and risks related to contract flexibility. In order to do this effectively, the economic feasibility of risk management actions must be evaluated.

The purpose of this paper is to use ROA for evaluating risk management actions in a Finnish healthcare project. A large Finnish healthcare facility PPP project is used as a case in the paper. The key performance metrics used are high building occupancy and rental yield.

Three main sources of uncertainty are identified related to the flexible contract and long contract period. Accordingly, the risk management actions for coping with the uncertainties were proposed and examined with the developed ROA procedure. The provider stated to have received several benefits from ROA such as decision-making information directly applicable

to investment decision and guidelines for developing briefing and design management documents; thus, potentially improving project profitability in later life-cycle stages.

The actual monetary values provided by ROA were 680 000 € for flexibility designed in parking structure compared to the original design. The proposed physical flexibility for coping with the uncertainty in final space demand was found to have a value of 460 000 €. The building integrated onsite energy source production for addressing the uncertainty in raising energy costs was found to have an option value of 440 000 €.

The theoretical implication of the paper is that ROA can reveal opportunities and risks inside a PPP project that might remain unnoticed with the traditional investment analysis methods. The identification of separate investments as options can be used for managing risk and value inside a PPP project.

4 Conclusions and discussion

4.1 Summary of the results

The aim of this dissertation was to examine the opportunities that real options analysis opens in real estate investment analysis and decision-making as well as determine real option values in topical issues affecting the real estate industry. The accordingly set research questions were addressed by reviewing past literature and by conducting relevant case studies.

The literature review organized real estate related real options literature into major application domains, and stated benefits of ROA in investment decision-making. The literature revealed that ROA could provide valuable insight into strategic decision-making, enhance understanding in land valuation and building flexibility analysis, highlight the importance of embedded options in lease contracts and help justifying investments in renewable energy solutions. However, most of the studies were conducted in hypothetical settings and many pointed out that real life cases are needed for validating the findings.

The conducted case studies addressed the research questions from different application levels: conceptual (Paper I and II), property (Paper III and V) and portfolio (Paper IV). The case studies used available real-life data on real investment opportunities as well as discussed the findings with industry professionals. In this a way, the findings of the case studies answer the need for real-life cases on the topic. The scope of the dissertation is limited to real estate investment field, even though the method could be applied to several other fields in the built environment.

Papers I and II discussed how ROA can supplement DCF in uncertainty assessment by identifying option characteristics of green building certificates. It was found that contemporary real option valuation methods are appropriate for assessing the value uncertainty of green building certificates. The findings suggest that investment analysis of a building certificate could benefit from expanding the analysis to include the effect of different market conditions.

Paper III found that ROA can provide justification where flexibility in premises is economically sensible. The approach was found to assess uncer-

tainty more efficiently than DCF by taking into account several sources of information regarding the tenant risk. This generated more accurate, numerical decision-making information for allocating limited funds in an investment case.

Paper IV found that option pricing can provide risk-neutral quantified value whether an apartment building portfolio should be divested in a single transaction or in multiple transactions over time. The paper argues that standard industry valuation practices miss the value of active fund management that should be included when planning a fund divestment strategy.

Paper V pointed out that ROA can reveal opportunities and risks inside a PPP project that might remain unnoticed with the traditional investment analysis methods. The identification of separate investments as options can be used for managing risk and value inside a PPP project.

The findings of the dissertation demonstrate that the current valuation practices miss value elements that are important in real estate investment analysis and decision-making, and that ROA can help identify and value these elements. The findings provide new viewpoints for analysing real estate investments, especially presenting how ROA can supplement the DCF valuation in conventional investment cases. Furthermore, the feedback from practitioners in the Papers III and V suggests that ROA provides new information for decision-making by allocating resources more efficiently. The dissertation finds that ROA can enhance real estate investment analysis and decision-making and proposes that:

i. ROA should be used in real estate investment analysis and management because it can identify value elements missed by standard valuation practices
ii. lifecycle performance of real estate assets can be enhanced with real options
iii. ROA can produce results that can encourage investments necessary for long-term success in the real estate industry

4.2 Contribution of the research

The contribution of this dissertation can be assessed by first looking into the parts individually and then as a whole.

The literature review organizes the literature of real options research in the real estate industry, which is of value for both researchers and practitioners. The review is of use for both newcomers and professionals in the topic of real options because it introduces key articles over the real options theory as well as application domains in the real estate industry.

Paper I is the first known study to empirically open the value influencing mechanisms of green building certificates presented in earlier theoretical

studies. The findings of the study identify issues in investment analysis methods that should be examined further.

Paper II is the first study to argue that option-pricing theory can be used for valuing green building certificates. The identification of the option characteristics of green building certificates and demonstration of ROA in an empirical case questions whether the current mainstream investment analysis approaches are the most suitable methods for valuing sustainability related investments.

Paper III adds to the request for new applications of ROA in practical settings with an example of evaluating flexibility in a real retrofit investment case. The empirical analysis produced in this paper was perceived valuable by the case study investor and can be used as a guidance and motivation for further applications of real options in the industry.

Paper IV is the first of its kind to propose that value of waiting to divest is an important element when planning a real estate fund divestment. The approach proposed in this study risk-neutrally calculates the value appreciation from the range of the potential values. This provides the decision-maker a deeper understanding of the implications regarding the chosen line of action.

Paper V illustrates that real options have practical applications in managing risks in PPP projects. In fact, the provider of the project has already reported to receive benefits from the analysis. For example, the output of the analysis presented in this study was used as an investment analysis document in the actual investment decision-making process by the provider's board of directors. Later on the building briefing process and design team selection were partly based on the results from the analysis.

As a whole, this dissertation contributes to the body of knowledge in real estate investment field by introducing what ROA can bring into investment analysis and decision-making. The categorisation of previous research and building upon it new applications form a coherent whole of the method's potential in the real estate industry. The results enhance real estate investment analysis and decision-making by highlighting the role of uncertainty through different application levels. It points out that option analysis can reveal new information and lines of actions, which can supplement or replace results of traditional DCF analysis. This is important for directing limited resources in long-term investments into right positions. The results presented in the papers enhance lifecycle performance of real estate investments from different viewpoints, and serves as a guidance for professionals in similar decisions but as well as a starting point for developing new applications. The dissertation also discusses the practical adaptability of real options valuation techniques through different cases. At least the

methods used in the dissertation, FPOM and BOPM seems to be relatively easy to use and understand. The amount of information they need can produce approximation of results that can enhance investment analysis and decision-making. At the very least, the approach can help practitioners to identify new relevant information that can help reduce risk in real estate investments and guide limited resources into real sources of added value.

4.3 Evaluation of the research

Each paper contains its own discussion regarding the quality of research. This section evaluates the research quality of the dissertation as a whole. Yin (1994) presents four tests relevant to evaluate the quality of case study research: construct validity, internal validity, external validity and reliability.

Construct validity evaluates whether correct operational measures are used for the studied concepts (Yin, 1994). Yin suggests three tactics for increasing construct validity: multiple sources of evidence, chain of evidence and reviewing case study reports by key informants. This dissertation has examined the research problem using multiple case studies and the findings from multiple sources of evidence have supported the argument of the dissertation. Data have been collected from multiple sources and the case studies have quantitatively formed a chain of evidence between the questions, data and conclusions. Finally, the findings have been benchmarked against previous research and in some cases with key informants.

Internal validity examines the relationship between conditions in causal and explanatory research (Yin, 1994). The quantitative research approach using documented real options valuation techniques enhances internal validity because the case studies numerically produce relationship between starting parameters and results.

External validity measures the generalization of the results (Yin, 1994). The findings of this dissertation are analytically generalizable because the research processes and results can be used to test the real options theory and valuation techniques in general. The case studies use real-life data, which can be replicated in similar settings to test the generalization.

Reliability measures the repeatability of the research procedures and results (Yin, 1994). Yin suggests that two main ways for increasing reliability are clear documentation and making as many steps as possible during the research process. This dissertation mainly uses quantitative approach for research, which is carried out in practice with well-documented ROA methods and presenting openly the starting data, intermediate results and final results. A good example is the division of the first study into two papers (I and II). This allowed the presentation of the data and analysis of both in-

termediate and final results in substantial detail. Additionally, the papers discuss in detail the steps taken in the calculations. Together the effect of these ensures high reliability.

4.4 Future research

The research topic of this dissertation could be pursued further in several ways. Firstly, more case studies are needed for demonstrating the potential of ROA in real-life settings. Secondly, this process could be hastened by developing an easy-to-use manual containing real options theory and past applications as well as real option valuation techniques in a spreadsheet format for lowering the threshold for practical adaption. Since the manual in practice would greatly benefit from real-life cases, the manual should be updated as the cases are identified and conducted. Thus, an open source platform could help the process and practical adoption of the method.

The content of this dissertation could serve as a basis for the manual, even though much more research has to be conducted. The literature part would benefit from selected detailed case descriptions from past research in each identified applications domains as well as linking the cases into decision-making processes of real estate investors. The used real options valuation techniques could be complemented by adding other methods, such as Monte Carlo Simulation and providing guidelines with decision-rules when to use each method as well as describing the advantages and disadvantages of each method in different real-life settings. The accuracy of the results between the valuation techniques should be discussed because often pinpoint accuracy is unnecessary in practical decision-making. The real options literature seems to have lacked this discussion, as there are many examples where a perfect "rational" real options approach has not grown in number due to over-complexity and under-transparency to the markets. This is why the potential of more simplistic methods, such as FPOM, should be discussed more. Historically, the real estate industry has started with more simplistic analysis methods before moving into more complicated methods, e.g. direct capitalization before DCF valuation.

There are several interesting topics for further research in general and for specific application fields. In general, as ROA is a method that connects financial and engineering analysis, it is necessary to rethink whether current decision-making material producers, which seem to be mainly (financial) analysts using DCF, incorporate enough real estate substance *(i.e. technical attributes, environmental and areal qualities and future rental opportunities)* information in the analysis. This is something that should be studied further together with practitioners and real estate education because building attributes are the real source for added value, e.g. a green

certificate does not reduce lifecycle costs of a building *per se*. Additionally, building attributes will likely have a larger role in the future due to the megatrends affecting the industry. This could be clarified further by discussing the linkage between flexibility and sustainability: flexibility extends the useful life of buildings and this has both economical and environmental implications. A good starting point for this kind of research could be to increase the understanding of the current decision-making processes in the real estate industry and to identify how real options could enhance these processes.

Interesting topics for case studies can be identified in several specific application fields. Energy efficiency surveys and investments have the potential to have a significant impact on real estate maintenance costs, which should be transformed into higher real estate values in appraisal. The uncertainty in the true decreasing maintenance cost effect could be assessed with ROA. Building information modelling (BIM) can be used for marking real options in building technical data and layouts. This is an interesting topic for concretely communicating the purpose and eventually value of real options to different stakeholders. Since real options can be used for transforming risk profile of investments, the potential that real options opens up in real estate financing is an interesting topic for further research. Finally, it would be interesting to examine that could more flexible buildings reduce the supply inelasticity of real estate markets.

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The understanding of real options analysis (ROA) has been claimed by academics to be extremely valuable for the real estate industry; yet adoption of the method in practice has been very slow. The aim of this dissertation is to examine opportunities that ROA opens in real estate investment analysis and decision-making as well as to demonstrate the actual real option value in some topical areas of real estate investment. The findings of the dissertation demonstrate that the current valuation practices miss value elements that are important in real estate investment analysis and decision-making, and that ROA can help identify and value these elements. The findings provide new viewpoints for analysing real estate investments, especially presenting how ROA can supplement the dominant discounted cash flow valuation in conventional investment cases.

Aalto-DD 204/2014

ISBN 978-952-60-6007-1 (printed)
ISBN 978-952-60-6008-8 (pdf)
ISSN-L 1799-4934
ISSN 1799-4934 (printed)
ISSN 1799-4942 (pdf)

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