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Published in:
BUILDING RESEARCH AND INFORMATION

DOI:
10.1080/09613218.2016.1098055

Published: 18/05/2016

Document Version
Publisher's PDF, also known as Version of record

Please cite the original version:
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To cite this article: Jussi Vimpari & Seppo Junnila (2016) Theory of valuing building life-cycle investments, Building Research & Information, 44:4, 345-357, DOI: 10.1080/09613218.2016.1098055

To link to this article: http://dx.doi.org/10.1080/09613218.2016.1098055

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Published online: 30 Oct 2015.

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RESEARCH PAPER

Theory of valuing building life-cycle investments

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The physical adaptability of buildings is very important in today’s fast-changing business environment. The actors who invest in long-term adaptability are positioned better to the changes during the life cycle of a building. This conceptual paper argues that the current dominating real estate (property) investment analysis theories do not accommodate enough building design-related information (i.e. physical asset characteristics), which results in long-term loss of competitiveness and unsustainable use of built environment resources. It is demonstrated that physical asset characteristics can create valuable real options that should be acknowledged in real estate investment analysis and management. The real estate investment literature has not so far been able to produce a widely accepted financial model for justifying life-cycle investments. A theory is proposed here that can be used to value life-cycle investments in buildings. This new theory combines of real options valuation, investment analysis and building component life-cycle design. These themes are used to formulate a conceptual framework for valuing life-cycle investments. The framework is intuitive and transparent, and it can be easily added to current spreadsheet investment analysis tools.

Keywords: adaptability, buildings, investment analysis, life cycle, physical asset characteristics, real estate, real options, value creation

Introduction

The traditional long-term predictability of real estate (property) investments is decreasing due to current industry revolution with megatrends, such as digitalization and globalization. The influence can already been seen in shortened average lease lengths (IPD, 2014). To meet the requirements of the fast-changing operating environment, the buildings have to be adaptable into the multiple possible future scenarios. This phenomenon increases the significance of active real estate management and adaptable building design. Both are closely tied together as many of the opportunities in active real estate management are constrained by the physical asset characteristics (PACs) of real estate investments, which are in turn determined in design processes. In this paper, PACs are defined as limitations and opportunities that the physical attributes of buildings’ impose on assets’ economically best use. In other words, PACs express the extent in which the real estate manager has to operate during the life cycle of a building investment.

Geltner (2003) noted that successful operational property investment management depends on operational expense management, capital improvement expenditure management, leasing strategy and marketing. These four factors are closely linked to PACs. The first two factors can be categorized as cost-related factors as they have a direct link to building related costs, e.g. capital expenditures and maintenance costs are dependent on building design and used materials and components. The last two factors can be categorized as income-related factors and are indirectly linked to PACs as potential tenant mix and renting possibilities depends on the physical constrains of the rentable space, e.g. whether the building can be transformed from a single- to a multi-tenant building. In real estate investment analysis, which is mainly done with discounted cash flow (DCF) valuation method (KTI & IPD, 2012; Shapiro, Mackmin, & Sams, 2013), these factors are used as input parameters for predicting cash flows into the future. These cash flows are then discounted to the present value using an appropriate discount rate. The discount rate effect ensures that less weight is given to cash flows further in the future. Many authors, such as Hayes and Garvin (1982) and Myers (1984), have noted that the
use of DCF results in short-sighted decision-making. In the real estate sector, the short sightedness of DCF is especially problematic because buildings are constructed for life cycles of 50+ years and initial design plays a key role on how the buildings can be used in different market conditions.

This paper argues that current practices in real estate investment analysis do not feature enough building design related information (PACs), which in turn results into long-term loss of competitiveness and unsustainable use of built environment resources. The paper demonstrates that PACs can create valuable options that should be acknowledged in real estate investment analysis and management. Both life cycle performance and real options have separately already been recognized as very important factors in long-term value creation; however, the real estate investment literature has not yet been able to present conceptual framework for justifying life-cycle investments. This paper attempts to present a theory of judging building life-cycle investments. The theory draws from real options valuation, investment analysis and building life-cycle design theories. These themes are used to formulate a conceptual framework for valuing life-cycle investments. The paper also discusses the implications of this theory to the real estate / property industry.

The paper is organized as follows. The next section describes current focus of real estate / property investment analysis and discusses the role of PACs in it. The following section discusses how real options analysis (ROA) can enhance competitiveness. Then the conceptual framework is presented, and some simple numerical examples are provided. Finally, discussion ends the paper.

**Current focus of real estate investment analysis**

The nature of real estate investment has changed considerably during the past two decades as the industry has shifted towards global capital markets. This shift has increased the professionalism in the industry as research methods and quantitative approaches have been adopted from the financial industry. The understanding of global economic cycles in the context of capitalization rates, occupancy levels and debt availability have increased investors’ understanding of risks associated in real estate investment. As real estate investment education and research have increased focus on the global perspective and its implications, the development of property level investment analysis tools seem to have lagged behind. For example, several well recognized real estate investment textbooks (Baum & Harzell, 2012; Brown & Matysiak, 2000; Brueggeman & Fisher, 2010; Geltner & Miller, 2001) highlight the importance of property fundamentals but the main focus seems to be in real estate finance and investment and portfolio strategy. The property-level analysis chapters are mainly built around the (market) information needed for DCF analysis. Again, this focus is understandable since the market parameters eventually command the returns of an investment. What has not received that much attention is the PACs that constrain how the property can position itself in different market conditions. To be more precise, it appears that PACs do not have a large role in property analysis as they are mainly assessed through their negative effect on rent and on capital expenditures that is not as a source of value creation, *per se*.

This is also seen in real estate investment research. It appears that major real estate investment journals have not discussed the role of PACs in real estate investment analysis. In fact, there are only a handful of articles somewhat related to this topic. Ho, Newell, and Walker (2005) argue that property quality attributes, such as column layout and subdivisibility, space efficiency, heating, ventilation and air-conditioning (HVAC) control and capacity, and passenger lifts performance have a positive influence in central business district (CBD) office rents. Nase, Berry, and Adair (2013) argued that interior, exterior and urban-scale design could increase real estate values. Additionally, there are many articles, such as Wiley, Benefield, and Johnson (2010) and Fuerst, Wyatt, and van de Wetering (2013), that discuss the implications of energy efficiency investments and certificates on real estate values. All these articles focus on how PACs can impact DCF parameters (*e.g.* rents and maintenance costs) rather than on the opportunities that PACs create for new value creation (*in the face of uncertainty*).

One reason for the absence of PACs in real estate investment analysis may lie in the history of real estate investment appraisal, which was originally developed to compare the performance of properties to other investment classes. DCF has its origins in corporate valuation; hence, the valuation has been developed on the basis of financial information used to forecast cash flows. In both corporate and property context, cash flow forecasting involves difficulties, but in property context the PACs adds a unique aspect to the process: the cash flow forecasting horizon is much shorter than the actual life cycle of the investment. For example, the average holding period for institutional investors in the UK was approximately 13 years during the 1990s (Collett, Lizieri, & Ward, 2003), whereas a building’s first life cycle is often considered at least 50 years (Duffy & Henney, 1989). A recent study (Huuhka & Lahdenivu, 2014) has recorded the actual life cycle of buildings being around 50 years (44–64 years). This gap...
has likely widened during the past two decades as property markets have globalized and the popularity of real estate funds has increased to favour shorter holding periods.

This mismatch is problematic because shorter investment horizons encourage for short-term decision-making, which can lead to major difficulties in the long-term. For example, a manager with objectives to maximize returns may aim to increase the income-related parameters and decrease the cost-related parameters. Since often the income-related parameters are tied to market conditions, the cost-related parameters are the only source for additional profits in the short-term. This investment behaviour has also been noted in research. Arge (2005, p. 216) found that short-term owners, such as developers, invest less into long-term adaptability because the extra investment may be hard to justify in the transactions. On the contrary, long-term owners, such as owner-occupiers, invested more into adaptability.

This is an interesting observation because construction literature argues that the cost of adding adaptability into PACs is only marginal. Slaughter (2001, p. 216) analysed 48 commercial renovation projects and found that interaction between building systems (i.e. structure, enclosure, services and interior finish):

strongly influenced the building’s adaptability, and that the structural and exterior enclosure systems, as well as the services and interior finish, should be designed with respect to anticipated changes.

The study found out that different design strategies that increase the adaptability often requires only, on average, 2% extra investments into initial construction costs.

Traditionally, investments into adaptability might have been deemed unnecessary because buildings have been constructed for a specific purpose. However, since average lease lengths have decreased, real estate investors find themselves more often in situations where active real estate management, constrained by PACs, is needed to be competitive. Figure 1 demonstrates why acknowledging PACs in successful real estate investment analysis and management is now more important than previously. Here, three different historical average lease lengths in the UK, 13.0 years in 1990, 7.6 years in 2000 and 4.7 years in 2010 (BPF-IPD, 2012; McAllister, 2001), are used to calculate the number lease break points during building’s first life cycle of 50 years.

Lease break points can cause both costs and benefits to the building owner. McAllister (2001) lists these costs as marketing and legal fees for finding a new tenant, potential loss of rental income due to void and/or other tenant incentives as well as changes in management costs. Additionally, possible refurbishment costs can incur to the owner. The owner can benefit from the break point if the net rental stream can be increased. A passive investor may view these break points only as cost-related factors whereas an active investor can view them also as income-related factors, as opportunities to create new value with active real estate management. Since both cost and income-related factors are constrained by PACs, it is surprising that their role in real estate investment research have not increased together with decrease of lease lengths.

A growing amount of real estate research has recognized the potential that ROA can bring into real estate investment analysis. The research has highlighted the superiority of ROA to DCF in addressing uncertainty because option pricing sees uncertainty as a source of value rather than the opposite.
Real options analysis as a competitive edge

Myers (1977, p. 163) originally defined real options as ‘opportunities to purchase real assets on possibly favourable terms’. The paper pointed out that growth opportunities in firms’ investment strategies are real options and should be valued together with other tangible assets. Furthermore, Myers (1984) argued that DCF could fail in strategic applications because it cannot value properly time-series links between investments, i.e. options that are generated by initial investments. This was further emphasized by Dixit and Pindyck (1995, p. 107):

- sometimes an investment that appears uneconomic when viewed in isolation may, in fact, create options that enable the company to undertake other investments should market conditions turn favorable.

The paper explains that the possibility of a positive value is valuable because new information can change the distribution in asymmetric way. Ultimately, real options are about creating flexibility, which is essential to be competitive in an uncertain world.

Real options literature has highlighted the importance of recognizing option value in maintaining competitiveness and developing business strategies. Baldwin (1987, p. 61) noted:

- given the increase in variability in both product and financial markets worldwide, companies that recognize option values and build a degree of flexibility into their investments are likely to be at a significant advantage in the future, relative to companies that fail to take account of options in the design and evaluation of capital projects.

Luehrman (1998) highlighted that as we gather new information along the way of an investment, we must have the tools for adapting into new situations. The paper notes that options mindset turns managers towards more active management of uncertainty rather than passive management. Copeland and Keenan (1998) argued how real options can help to focus the strategic scope for management in uncertain business environments where cash flows are volatile. More recently, Copeland (2010) further discussed the importance of real options in handling irregular cash flows but also noted that problems in practical adoption of ROA. These problems are mainly related to the complexity of the valuation methods and to the fact that the method is not known in practice (Lander & Pinches, 1998; Oppenheimer, 2002). Nevertheless, applications of ROA have been recognized in the real estate field. Vimpani (2014) recognized five major application fields where ROA could enhance real estate investment analysis and decision-making: real estate market, land valuation, building flexibility, lease contracts and technology investments. This paper could be categorized in the building flexibility topic, which is briefly discussed in the following.

De Neufville, Scholtes, and Wang (2006) presented an example where the option to raise a parking garage can reduce the risk of an investment but maintain the upside potential. Verbruggen, al Marchohi, and Jansens (2011) discuss how optionality in building attributes changes economical performance of buildings in the long-term. The paper finds that initial extra costs in to the attributes are likely worth the investment. Menassa (2011) follows in the same field by developing an options based framework for guiding sustainable retrofit investments. The paper uses different strategic options, such as staging, deferring and switching options to demonstrate what is their role in value creation in a building retrofit investment.

The main advantage of ROA is, as de Neufville (2003, p. 4) says, it:

- leads analysts to adopt a substantially different perspective on how to design systems for uncertainty; and systematically recognizes that broad classes of projects are much more valuable than they have appeared to be, and thus will tilt investments toward these activities.

Option pricing has received some attention in the real estate investment literature as many textbooks (Baum & Harzell, 2012; Brueggeman & Fisher, 2010; Geltner & Miller, 2001) and articles (Copeland, 2010; Geltner & de Neufville, 2012) have mentioned their potential for real estate analysis. Yet adoption of the method in practice seems to have been very slow (Vimpani, 2014).

ROA can be defined as a process that connects financial and engineering analysis in order to identify and value embedded options related to physical investments (de Neufville, 2003). The aim of the process is to enhance life-cycle performance of a real asset, i.e. how an asset performs in various market conditions throughout its life cycle. This process can be communicated in six steps:

1. Identify uncertainties
2. Define real options for managing the identified uncertainties
3. Analyse which of the defined real options are included in the current PACs
4. Calculate costs for adding the absent real options
5. Value the real options and implement the options that are more valuable than the costs
• Exercise the real options (i.e. utilize the technical opportunities designed into the PACs) if uncertainty realizes

The aim of the process is to create real options with initial investments into PACs. The importance of these kinds of investments is discussed by Gann and Barlow (1996) who present the economical adaptability of PACs in an environment where offices are converted into residential buildings due to changed market conditions. In their example, they note that depth of building, internal layout, building structures in terms of service ducts, glazing and walling systems, HVAC systems, acoustics, and fire safety regulations can either turn conversions obsolete or at least have significant reductions to profitability. The work of Gann and Barlow (1996) demonstrates in detail how initial technical solutions can affect profitability of physical conversions. In the construction literature, costs of different technical solutions are assessed with methods, such as life-cycle costing (LCC) that compare initial and running costs throughout the building’s life cycle. These methods have also received criticism for the discount rate approach to uncertainty.

To develop them further, Ellingham and Fawcett (2006) proposed that not all decisions should be made in year zero because better information is often available later on during a project. In the spirit of option pricing theory, they introduced a concept of life-cycle options to describe decisions that can be taken in the future with better information. In essence, the goal is to identify and value options related to design of buildings in order to position the buildings against future uncertainties. For example, the value of an option to switch ground floor office space into retail use and vice versa depends on the market demand for office and retail space as well as the costs of conversion. The costs are tied to PACs, such as whether the ground floor slabs and ceiling heights can suit future retail use or whether the plan layout and mechanical services can ensure that the retail premises operate independently of upper floor offices. In order to purposefully value these kinds of options, one must be able to transparently communicate the value creation mechanism of the options, which seem to have been too complex for wide practical adoption.

Conceptual framework for valuing life-cycle investments

This conceptual framework aims to overcome the complexity of option pricing by developing it on the basis of a novel real options valuation method, the fuzzy pay-off method (FPOM) (Collan, Fuller, & Mezei, 2009). In the development is also acknowledged simplicity of LCC as well as some of the barriers recognized in practical adoption of LCC. For example, Cole and Sterner (2000) recognized motivation, contextual issues, methodological problems and reliable data as factors limiting general acceptance. Furthermore, Gluch and Baumann (2004) highlighted that LCC fails to handle irreversible decision-making in the long-term and that LCC cannot handle uncertainty from a decision-maker’s perspective. The framework credits the FPOM, DCF and LCC theories and it aims to provide the first standard for valuing life-cycle investments by connecting the analysis of life-cycle performance into investment decision-making. Additionally, it can be easily constructed in spreadsheet and added into the dominant DCF methods as a complementary approach.

Logic of option pricing

In option pricing, option value is calculated from a distribution of possible outcomes for the underlying asset during the maturity of the option. In original option pricing methods, such as binomial option pricing or Monte Carlo simulation, the distribution is projected using a stochastic variable based on geometrian Brownian motion. This results into a detailed distribution of possible outcomes of random movements. When there is limited information available for the parameters needed in projecting a normalized distribution, these methods are hard to use. This is often the case in real estate, where good quality information is scarce as property transactions are discrete and information asymmetry remains between stakeholders. This information asymmetry is even emphasized when the building’s value (physical construction) increases proportionally compared with the underlying land value (Wong, Yiu, & Chau, 2012).

Collan et al. (2009) realized that the probabilistic theory for modelling uncertainty could be replaced with fuzzy set theory developed by 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 (intermediate membership). This allows simplification of the projection of uncertainty into only 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. These scenarios are 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). Therefore, in FPOM, the option value is calculated using the triangular distribution. In essence, FPOM requires only three net present value (NPV) scenarios to be drawn up for option pricing. This simplifies the calculation but...
maintains the logic of option pricing. It should be acknowledged that all of these three scenarios may be subjective through personal opinions and expertise. When applying this deterministic method, it is of importance that all three scenarios are done carefully to include all necessary information available. Figure 2 presents the logic of FPOM.

Once the triangular distribution is formed using the three NPVs, the real option values can be calculated. Collan (2012, p. 32) defines the real option value as:

\[
\text{ROV} = \frac{\int_{0}^{\infty} A(x)dx}{\int_{-\infty}^{\infty} A(x)dx} \cdot E(A_+),
\]

where \( \int_{0}^{\infty} A(x)dx \) is the positive area of the pay-off distribution; \( \int_{-\infty}^{\infty} A(x)dx \) is the whole area of the pay-off distribution; and \( E(A_+) \) is the possibilistic mean of the positive side of the pay-off distribution. Collan (2012) has observed that the possibilistic mean of the positive side of the pay-off distribution can be calculated in four different ways, depending on the shape of the triangular pay-off distribution:

- When the whole pay-off distribution is above zero; when \( 0 < (a - \alpha) \), then \( E(A_+) = a + ((\beta - \alpha)/6) \).
- When the pay-off distribution is partly above zero, so that zero is between the minimum possible NPV and the best estimate NPV; when \( (a - \alpha) < 0 < a \), then \( E(A_+) = a + ((\beta - \alpha)/6) + ((\alpha - a)^3/6a^2) \).
- When the pay-off distribution is partly above zero, so that zero is equal to the best estimate NPV or between the best estimate NPV and the maximum possible NPV; when \( a \) is below zero, but \( a + \beta \) is above zero \( (a < 0 < a + \beta) \), then \( E(A_+) = ((a + \beta)^3/6\beta^2) \).
- When the whole pay-off distribution is below zero, then \( E(A_+) = 0 \).

Method for the framework

In order to create the required triangular distribution for a life-cycle investment, the method for creating the three NPV scenarios has to be defined. This method relies on just two key variables: PAC’s life-cycle length and investor’s hurdle rate. The PAC’s life-cycle length defines the maturity of the real option, which is the most important part of option value creation since building components can have very long average life cycles, such as 50+ years for building structures, 20–50 years for building services, 20–30 years for building envelope and 10–15 years for internal layout. The investor’s hurdle rate transforms the life-cycle length into economic value and acknowledges the risk–return preferences of different kinds of investments. Figure 3 illustrates this methodology.

![Figure 2](image-url)  
**Figure 2** A triangular pay-off distribution, defined by three points describing the net present value (NPV) of a prospective investment; 20% and 80% are for illustration purposes only.  
*Source: Collan et al. (2009)*
In the framework, life-cycle investment valuation requires determining the life cycles \( n_{\text{min}}, n_{\text{best}} \) and \( n_{\text{max}} \) and calculating the related net present values (NPV\(_{\text{min}}\), NPV\(_{\text{best}}\) and NPV\(_{\text{max}}\)) for the three scenarios. Additionally, the standard life cycle \( n_{\text{stan}} \) of the PAC is needed. This is often the same as the best-guess life cycle because in investment analysis it is common that the main scenario is based on ‘standard’ expectations. Still, there are no reasons why the two could not differ. The minimum and maximum life cycle is determined with information at hand. The ISO-15686 standards provide a good starting point for developing general life-cycle lengths for different PACs. The standards use functional resistance, design level, labour quality, indoors and outdoors environment, usage conditions and maintenance level to measure the life-cycle length. In addition, the standards have defined boundary coefficients of 0.6 and 1.5 for the minimum and maximum life cycles, respectively. This paper suggests that these coefficients are used to define the standard minimum and maximum life cycles, which can be then altered if better information becomes available.

Once the life cycles have been determined, equations for calculating the actual NPVs are needed. In the following are proposed equations, where \( X \) is cost of the PAC investment; \( r \) is investor’s hurdle rate; and \( n \) is life-cycle lengths for the different scenarios. The NPVs represent the amount that is lost or gained due to the length of the life cycle: if the life cycle lasts only \( n_{\text{min}} \) years, then NPV\(_{\text{min}}\) is lost because the PAC has to be replaced \( n_{\text{stan}} - n_{\text{min}} \) years earlier compared with the standard life cycle. On the other hand, if the life cycle lasts \( n_{\text{max}} \) years, NPV\(_{\text{max}}\) is gained for the opposite reasons. Therefore, if the PAC reinvestment has to be made early, the \( X \) cannot be invested elsewhere with the hurdle rate and it is lost because the PAC does not produce any profits, per se.\(^5\) The higher the hurdle rate, the higher the amount lost/gained and vice versa:

\[
\begin{align*}
\text{NPV}_{\text{max}} &= -X + \frac{\sum_{n=1}^{n_{\text{max}}} X \times (1 + r)^{n-1} \times r}{(1 + r)^{n_{\text{max}} - n_{\text{min}}}} \\
&= -X + \sum_{n=1}^{n_{\text{max}}} X \times \frac{r}{1 + r} \times \frac{X}{(1 + r)^{n_{\text{max}} - n_{\text{min}}}} \\
&= -X + (n_{\text{max}} - n_{\text{stan}}) \times \frac{X \times r}{1 + r} + \frac{X}{(1 + r)^{n_{\text{max}} - n_{\text{min}}}}
\end{align*}
\]

Figure 3   Conceptual framework for valuing life-cycle investments
Similarly using the same deductions for the best and min scenarios:

\[
\begin{align*}
\text{NPV}_{\text{best}} &= \begin{cases} 
-X + (n_{\text{best}} - n_{\text{stan}}) \times \frac{X \times r}{1 + r} & \text{if } n_{\text{best}} > n_{\text{stan}} \\
\frac{X}{(1 + r)^{n_{\text{best}} - n_{\text{stan}}}} & \text{if } n_{\text{best}} = n_{\text{stan}} \\
-X + (n_{\text{stan}} - n_{\text{best}}) \times \frac{X \times r}{1 + r} + \frac{X}{(1 + r)^{n_{\text{stan}} - n_{\text{best}}}} & \text{if } n_{\text{best}} < n_{\text{stan}}
\end{cases}
\end{align*}
\]

\[
\text{NPV}_{\text{min}} = -\left[-X + (n_{\text{stan}} - n_{\text{min}}) \times \frac{X \times r}{1 + r} + \frac{X}{(1 + r)^{n_{\text{stan}} - n_{\text{min}}}}\right]
\]

Once the three NPVs have been calculated, the triangular distribution can be formed and the option value is calculated using FPOM. The triangular distribution captures the range of uncertainty of the life-cycle investment and the option value measures the value of the life-cycle investment.

**Theoretical evaluation of the framework**

The proposed NPV functions encourages for examining solutions with longer life-cycle lengths. However, the true contribution is to connect the life cycle into investor’s preferences in a way that the long-term value creation effect is not discounted away. The hurdle rate in the function does this. On the contrary to the normal discount effect, the function values higher investments with higher hurdle rates. This transforms the logic of traditional investment analysis and LCC because the function creates value when uncertainty is high (and discount rates are high). This follows the logic of option pricing theory.

The framework connects well to the traditional real estate investment decision-making, where different investments are ranked with their risk-return characteristics. For example, a building may command a lower hurdle rate than an identical building in another location, because the expected change in future income may differ between the assets due to demand uncertainty. In traditional investment analysis, the larger hurdle rate would underestimate important long-term investments into adaptability because their long-term effect is discounted away. This is irrational because these investments are of higher value where demand uncertainty is higher. The options based framework works in the opposite way as higher uncertainty raises the value of these investments. To sum up, the framework follows the traditional risk–return preferences of real estate markets but specifically creates value there where uncertainty is high and life-cycle investments are needed.

Some discussion regarding the inputs of hurdle rate (r) and life-cycle lengths (n) is required. The framework suggests that the hurdle rate is independent of the three scenarios. There are two main reasons for this. Firstly, in real estate investments the hurdle rate (commonly referred as yield or cap rate) should reflect the risks inherent in the demand of the specific property, i.e. the hurdle rate is market driven and therefore is not dependent on the life cycle of an individual building component. Secondly, the aim of the framework is to focus on how new value can be created through PACs rather than trying to focus on changing market given parameters. Therefore, defining the life-cycle lengths is the key driver of the model.

The framework suggests starting with the ISO standards because they are based on research and thus serves as a good starting point. It is emphasized that the purpose of this framework is to give a new tool for approaching the problems presented in this paper. The outcomes of the framework are only as good as the inputs are, which is the case with all other tools as well. Naturally defining these life-cycle lengths need to be developed further as we want to develop the quality of the outcome. A heuristic process can be used for adjusting the life-cycle lengths. Additionally, if empirical data is available it can help in quantifying the correct life-cycle lengths for different type of property investments.

**Example case with the framework**

The conceptual framework is applied into a hypothetical case of a single tenant office building investment. In the case, ROA has revealed that there is uncertainty regarding demand of the office premises in the current form. After reviewing categories of PACs, the investor has identified that the adaptability of the building structures is poor if demand changes. The structures have the investment costs of €20 million and the standard life cycle of 50 years. Additionally, the initial lease agreement is 10 years (i.e. there is uncertainty regarding the best use of the premises after 10 years). The investor’s hurdle rate for this kind of an investment is 10.0%. The investor applies the framework to the building structures in order to quantify the economic value of adaptability.

The investor wants to compare three cases of adaptability. In case A, the building structures have been designed that they are fully adaptable into multi-tenancy office use or into residential use. In case B, the structures are not adaptable into other uses than single tenancy. In case C, the structures are partly adaptable that is they can be exploited also in the use of multi-tenancy (but not residential). Figure 4 presents the
triangular distribution for these three cases of adaptability.

When interpreting the distributions, it is important to understand how the life-cycle lengths have been determined. In case A, the ISO coefficients of 0.6 and 1.5 are applied to the standard life cycle of 50 years, i.e. case A essentially represents a distribution where the building structures can be normally used throughout its life cycle in all types of use. When the framework’s equations are applied to these life cycles using the investor’s numbers above, the NPVs for different scenarios can be calculated. Cases B and C produce different distributions because the building structures are not fully adaptable. In both cases’ minimum scenarios is assumed that the structures can be only exploited for the first lease agreement of 10 years, thus leading to high losses in income if the worst occurs. It is highlighted that it is a very unlikely scenario but the triangular distribution appropriately assigns the correct weight on it. More important is the best-guess scenario because it has the highest weight (complete membership) in the distribution, which also determines how much weight is given to the values close to the minimum and maximum scenarios. In case B, the building structures has been designed according to the first tenant’s use and no extra investments into adaptability has been made. It is assumed that for this solution the best-guess scenario is 25 years (half of the standard life cycle). In case C, investments into part adaptability have been made, which moves the best-guess scenario to 50 years.

The above distributions can be used for valuating the real options that are created with adaptability. Using Collan’s equations to the numbers in Figure 4, the option values are €2.7 million (13.3% of initial investment), €0.2 million (1.0%) and €1.5 million (7.7%) for cases A, B and C, respectively. These option values represent the value of the adaptability. Case A option value is high because there is a large possibility that the structures lasts longer than the average life cycle. This value can also be interpreted as the maximum level of extra investments into adaptability as full adaptability would transform the distribution to this in all types of use, i.e. the structures can be used throughout their technical life cycle. Case B option value is very small because there is only a small possibility that the structures last longer than

Figure 4 Triangular distributions of a physical asset characteristic’s (PAC) life-cycle length and lost/gained income in three different cases.
50 years (the distribution’s weight is in the far left). Case C option value is somewhere between because it does not offer full adaptability, i.e. there is a possibility that the structures will only last 10 years but the best-guess estimate is still 50 years.

As Slaughter (2001) found out, most of the adaptability strategies require only an extra investment ranging from 1% to 3% of the initial construction costs. Therefore, as the option values are much higher for part and full adaptability, it would be sensible to make extra investments into adaptability, depending on the amount of uncertainty regarding the investment. Sensitivity analysis reveals how the option value changes when the parameters of the framework are altered. For example, if the standard life cycle in case A is 20 years, then the option value is 3.0% of the initial investment – much closer to the findings of Slaughter (2001). Moreover, a change in the investment environment can have an effect on the hurdle rate. For example, a hurdle rate of 7.0% would result into an option value of 8.1% in case A. This decrease in risk explains why adaptability is worth more in the changed investment environment.

It is noted that when analyzing the adaptability strategies, the interrelation of PACs must be taken into consideration, which can complicate the analysis. However, the so-called Open Building approach to building design have increased the understanding how different building components have to be adaptable through time and how their interrelation can be separated (Kendall, 1999). This research topic has pointed out both in academia and practice that adaptability can be added through clever design.

Nevertheless, when the values of all real options are summed up, it can make a significant impact on the investment analysis compared with the traditional DCF analysis, which would not value them properly because it cannot valuate time series link between projects (Myers, 1984). On the other hand, option pricing has been designed for pricing contingent claims like these. Finally, it is worth mentioning that the above example only focuses on the cost-related factors. Adaptability of PACs can also have major benefits to the income-related factors as well. Most importantly, changing the best use of adaptable premises is often much faster than non-adaptable premises, which can result into major decrease to void months in rent generation.

Discussion and conclusions

Copeland (2010, p. 24) ended his article with the following:

The next decade will reveal that real options has almost completely replaced discounted cash flows as the paradigm of choice by top management decision-makers, or that it will suffer a lingering indifference that subjects it to the sidelines. The intuition behind real options is the value of flexibility – a point that almost everyone can agree is fundamental. But the number crunching is perceived by many to be complex and therefore requires standardization, most likely in the form of a versatile, transparent, and user-friendly software routine.

So far, little progress has been made in practical adaption. It seems that options in lease agreements are the closest for practical adaption as simple options are implemented into contracts in regular basis. However, it appears that they are not valued properly with option pricing methods even though their valuation can be rather simple as authors, such as Hendershott and Ward (2000), Ambrose, Hendershott, and Klosek (2002) and Cho and Shilling (2007) have proven. It is important to understand options embedded into contract as short leases could be the status quo in the near future. Moreover, it could be even more important to understand options related to PACs as their maturities are much longer compared with lease options.

The importance of this can be emphasized with actions of large cities, such as London where the local government introduced a three-year temporary regulation that allows change of use from offices to residential without planning permission. Similar regulations have been allowed in other major cities as well (Langston, Wong, Hui, & Shen, 2008). It seems that the increasing demand volatility together with sustainable development agendas drive public authorities to encourage for reusing the existing building stock more efficiently.

To identify and understand efficiently the economic value of these kinds of life-cycle options, it is necessary to understand PACs. Larger investors often have in-house personnel with construction background and smaller investors can use external advisors in this area, but as the value of the options are tied to market conditions covered by the financial team, their success depends on their ability to efficiently identify them. Practical examples of this kind of success can be found by looking at projects undertaken by opportunistic investors, which are able to identify potential of physical development in distressed properties. It can be a major competitive edge for the investor to be able to look at these options both in existing properties and in new developments. The costs that can be saved from avoiding unnecessary investments can be a significant part of the investment’s success. Furthermore, in a resource intelligent investment environment, investors should try to bring technical life cycle and economic life cycle as close as together as possible (e.g. it is unnecessary to invest into
technical quality if the quality will not be fully exploited due to economical factors).

The built environment is known to be in a key role in the fight against climate change. It is very important that the existing stock can be used as long and as efficiently as possible, and that the new developments are done in a way that maximizes life-cycle performance. The current real estate valuation methods do not encourage for this. Justifying long-term value instead of discounting it can encourage investors to fasten their investments into PACs that create long-term, sustainable value in the real estate industry.

There is a growing demand for the long-term approaches in different industries. Recently, McKinsey & Co. together with Canada Pension Plan Investment Board (2013) examined this topic by conducting a survey for more than 1000 board members and executives. The report found that 86% of the respondents believed that using a longer time horizon to make business decisions would positively affect corporate performance in a number of ways, including strengthening financial returns and increasing innovation.

The report also pointed to four steps for how large investors could fast-forward the long-term approach. One of them focused on strategies creating long-term value and another on metrics that can be used for justifying the long-term investments. This paper has presented these two steps in the real estate context: PACs role in long-term value creation and the conceptual framework as a metric for measuring the value of PACs.

Pioneers in the industry already know how to identify options created with PACs. However, it would raise the level of professionalism in the industry if more stakeholders would know how to look for them. It might be unrealistic to expect that the real estate investment professionals would also be experts in construction techniques but some knowledge with the right tools can efficiently help the investment professionals to demand more from those who have a stronger background in construction. In the same way, the real estate investment professionals now know how to look for key issues in the city plans even though they are not experts in planning.

Finally, it is known that practical adoption of option pricing has been criticized for issues, such as that the models are not known in practice, the models’ assumptions are often violated and the mathematical complexity of the method is not transparent to understand. However, it should be recognized that from the applied perspective it is not necessary to calculate exact values, as it is more important to focus on right strategies to implement or initial decisions to be made. The accuracy of the results between the valuation techniques should be discussed because often pinpoint accuracy is unnecessary in practice. 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 examined 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 analysis.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

**References**


Endnotes

1The physical attributes of buildings can be divided into fixed and movable category. The fixed category includes components, such as heating, ventilation, sewage, air-conditioning, electricity, structures, windows, facades, roofs, balconies, and fixed devices and systems. The movable category includes components, such as surfaces of walls, roofs and floors, fittings, partitioning walls and doors.

2It seems there is little empirical work done on the actual holding periods of different types of investors, but it is likely that the holding periods have decreased even for institutional investors. Other types of investors, such as real estate funds, have been reported typical holding periods of six to 10 years (e.g. Baum & Harzell, 2012).

3The 1990 average lease length is from McAllister (2001) and the author acknowledges that this length might have been measured differently than the one in BPF-IPD (2012). However, it is commonly agreed that the lease lengths have been much higher in the 1990s; thus, for the purposes of Figure 1, the potential difference in measurements is not seen as a problem.

4In principle, both types of methods use area for calculating the option value. In the original methods, 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 the original methods are dependent 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 methods use the data available in practice, which is the situation where all decision-makers find them when making investment decisions.

5The physical parts of the building do not generate any income on themselves. They rather produce the whole (the rentable building) that generates income.

6See note 1.

7Consider an extended NPV calculation where (often subjective) probabilities are assigned to the scenarios: 0.3 for maximum, 0.5 for best guess and 0.2 for minimum; resulting in probability weighted NPVs of 3.9, -14.6 and -2.2 million for cases A, B and C, respectively. These would either over- or undervalue the options that could result either into poor decision-making or neglecting the values altogether.

8This is the authors’ interpretation based on literature as well as interviews and talks with both practitioners and academics in the Nordics and the UK.

9This is another important application of option pricing as land valuation (and the uncertainty of land uses) is one of the original real option applications; see Titman (1985) and Williams (1991) for more information.