Management of Technology Investment Risk with Real Options-Based Design: A case study of an innovative building technology

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Abstract
Implementation of innovative technologies is hindered by the perceived risks of technical failure or increased first cost. However, by designing a system to include real options within its architecture and by recognizing the value in operational flexibility, the project's value is structured to avoid downside risks yet benefit from upside opportunities. A real options based methodology for innovative engineering system design consists of identifying relevant uncertainties, designing options "in" the system, and modeling the performance of the options-based design subject to the uncertainties. The results guide decision makers on how much to spend on the design and construction of a flexible system. A case study of the market value of an innovative naturally ventilated building with embedded option to install mechanical cooling in the future demonstrates how the option "in" the system protects the asset from downside outcomes in market value yet allows it to benefit from upside opportunities.

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Acronyms

DCF   Discounted Cash Flow
HVAC Heating, Ventilation, and Air-Conditioning
MC   Mechanical Cooling
NV   Natural Ventilation
NVO   Natural Ventilation with Option

1   Introduction

Many otherwise superior, innovative technologies are not used in practice due to increased first costs and/or increased risk with insufficient return to warrant investment. In many cases it is simply the perception of these barriers that prohibits consideration of technological innovation. Renewable energy systems and energy efficient building design are two classes of technologies with first-cost and risk-related barriers (Davis, 2001; Wilson et al, 1998). Discounted cash flow (DCF) analysis, while an improvement on the building industry's common practice of first-cost based decision-making, generally uses expected values of input parameters. When the input parameters are, in reality, uncertain and when the performance of the system is a non-linear function of those uncertain variables, expected value based analysis does not capture the range of performance possibilities.

If, instead, the full distribution of operating performance were presented to investors, they could have a better understanding of the project's risk-reward profile. Furthermore, identification of the fundamental uncertain parameters that contribute to a system's range of outcomes provides engineers and architects with a tool to design the system with "options." An option-based design will have a different risk-reward profile than an inflexible system, and thus may be more attractive to investors. Options "in" technical systems provide managers with the ability to take an action in the future to steer the technology's performance towards opportunities while avoiding poor conditions. Options "in" systems are distinct from options "on" projects in that they require technical means of obtaining the option (de Neufville et al, 2005). This necessitates inclusion of designers (i.e. engineers or architects) in a real options design and valuation process.

A design and evaluation process for innovative technologies based on real options is proposed in this research. The methodology aims to design technical systems so as manage the risk profile of system performance, taking advantage of upside potential while mitigating downside risks. The framework guides the design process of options "in" technical systems. The valuation approach is based on DCF, a common technique used in practice, and Monte Carlo simulation. Decisions are built into the model to provide for exercise of the system's options when advantageous. Presenting the results as a probability distribution provides the designers and investors with a clear depiction of the shifts in value provided by the option. The methodology presented in this paper for managing risks and opportunities of innovative technologies is applicable to the very

initial design stage. It calls for the design and development team to work closely with the investors to share information on how uncertainties are addressed and, subsequently, how the value of the project benefits.

The research objective is presented in the next section. Then, a real options design methodology is introduced. The methodology is applied to a case study of an energy efficient building design that uses natural ventilation - an innovative cooling strategy. Because mechanical cooling (i.e. air-conditioning) is standard in office buildings, there is uncertainty in the future market value of the building due to its use of natural ventilation. The uncertainty is addressed with an option to install a standard mechanical cooling system. Background information on real options and flexibility in buildings is presented. Then, the model to evaluate the value of the building with and without the option is presented along with major results. The depth of risk-reward information contained in the full probability distribution of results is discussed. Finally, conclusions and suggestions for future work are given.

2   Research objective

The objective of this research is to develop a real options methodology for both a) design and b) valuation to address the uncertainties in using innovative technologies. Decision-makers who would use the methodology include designers as well as investors, and thus it must provide relevant information to both. The results provide comparative information on the value of the technology, and the system within which it is used, when designed with and without flexibility. The difference is the amount to be spent on design and construction of the flexible elements of the system. The research focuses on innovative technologies with an environmental benefit.

3   Real options methodology

A real options approach to engineering system design is presented in Fig. 1. The methodology is meant to augment the traditional design and development process by including uncertainty identification and design for flexibility. The process is conceptualized in five steps: identify uncertainties, define flexibility, design and real options analysis, compare results, and execute. The first step, identify uncertainties, guides the remainder of the process. By understanding the uncertainties that will affect the performance of the system, flexibility can be defined so as to a) reduce risk and b) take advantage of possible upside opportunities. The value of a system that employs innovative technologies is affected by both market and technical uncertainties, and specific model types are applicable to each.
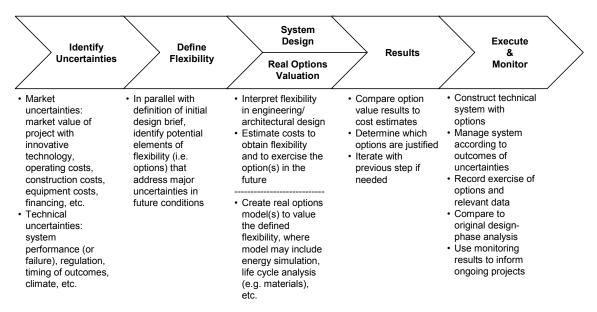
Identify Uncertainties	Define Flexibility	System Design / Real Options Valuation	Results	Execute & Monitor
• Market uncertainties: market value of project with innovative technology, operating costs, construction costs, equipment costs, financing, etc. • Technical uncertainties: system performance (or failure), regulation, timing of outcomes, climate, etc.	• In parallel with definition of initial design brief, identify potential elements of flexibility (i.e. options) that address major uncertainties in future conditions	• Interpret flexibility in engineering/ architectural design • Estimate costs to obtain flexibility and to exercise the option(s) in the future ---------------------------- • Create real options model(s) to value the defined flexibility, where model may include energy simulation, life cycle analysis (e.g. materials), etc.	• Compare option value results to cost estimates • Determine which options are justified • Iterate with previous step if needed	• Construct technical system with options • Manage system according to outcomes of uncertainties • Record exercise of options and relevant data • Compare to original design-phase analysis • Use monitoring results to inform ongoing projects

Figure 1. An approach to the design and valuation of flexibility in innovative technical systems.

3.1   Classification of uncertainties and risks

Table 1 lists relevant risks for innovative technologies and system designs, particularly for environmentally beneficial technologies such as "green" buildings and solar electric systems. Market risks for a product or service that use innovative technologies include greater variability in the future (sales or rental) value due to uncertainty in market acceptance of the innovative features. Uncertainty in energy prices represents another market risk for the value of a system dependent on energy consumption or sales. Technical risks, in the financial definition, are diversifiable and therefore addressable; however, first they must be understood and quantified. Technical risks applicable to innovative technology investment choices are consequences of uncertainties in "technological" performance, climate, future use, and future regulations. If these uncertainties evolve unfavorably, expenditures will be needed to correct the problem and bring the system to a productive state. Alternatively, the sub-standard system will not be able to obtain its full profit potential, all other things equal. Thus, both technical and market risks impact the financial value of an innovative technical system.

Table 1. Risks, uncertainties, and data sources for innovative technologies

Risk class	Uncertainties	Data source or means of quantification
Market	– Demand for product/service provided by system – Demand as a function of system's environmental features – Energy prices (e.g. electricity, gas)	– Historical data (if available) – Expert option – Simulation models of system performance
Technological	– Success/failure of new technology – Introduction of new, superior technology	– Expert opinion – Simulation models of system performance – Stochastic models
Climate (for systems whose performance depends on climate)	– Future ambient climate temperature and solar radiation – Global climate change and warming trends	– Stochastic climate models based on historical data and global climate change inputs – Simulation model of system subject to stochastic climate
Future use	– Capacity of system to respond to changes in service type or intensity – Rate of need for change	– Expert opinion – Historical data
Regulatory	– Introduction of new standards for existing facilities	– Expert information and opinion

Market risks, or the risk associated with the future value of the system, primarily arise from uncertainty in future demand for a system's characteristics. For buildings, the type of space (i.e. office, laboratory, retail, etc.) is the most common value determinant for a given geographical location (Bottom et al, 1999). However, as the recognition and awareness for green buildings increases, so might the value of buildings with green attributes.

Technological risk arises from uncertainty in the functionality of a component, which is partly determined by the system in which it is contained. Demonstration projects are one area of government-supported work in reducing the risk of using innovative technologies (Loftness, 2004). Another technological risk is that a superior technology will be introduced that competes with the system as originally designed. This risk may also affect the future worth of any options designed into a system.

Climate risks are especially applicable to the performance of environmentally beneficial innovative technologies. In buildings, innovative designs seek to take advantage of the natural climate to provide cooling, heat, light, and fresh air. The ambient climate partially determines a building's internal heating and cooling leads, and it directly determines the exterior air's cooling capacity. Concerns over greenhouse gas induced climate change are especially applicable to buildings and other engineering systems with lifetimes of twenty or more years.

Risk from uncertainty in future use or demand for a system are particularly suited for options-based design and assessment. Building functionality is highly affected by this exogenous uncertainty. Changes in use or demand happen somewhere along the continuum bounded by a high frequency with a low intensity of change to a low frequency but with a high intensity of change. (High frequency with high intensity of change is also possible but very uncommon). An example of the former is the desire to reconfigure office space to support formation of short-term working groups. An example of the latter is refurbishment of a building from laboratory to office space. Observable characteristics of change in building-use include changes in occupant density, types of office equipment, and a flow of construction materials. To address the risk of building obsolescence in the face of change, flexibility scenarios are needed in the initial design briefings.

The risk of future regulation is another risk applicable to today's engineering design decisions. Regulation may occur in the form of new physical (component) requirements, performance requirements, or economic changes that impact operating costs. Government intervention may also provide opportunities for installation of an innovative technology in the future that may not have existed at the time of initial design. Credits for installation and use of renewable energy systems or for buildings that perform to a certain extent better than standard energy codes are two examples. Thus, it may be valuable for today's design to include the flexibility to take advantage of regulatory opportunities or protect from penalties that may be imposed.

3.2   Models applicable to each risk class

Not all uncertainties present can be addressed by any single design structure. For guiding design and development of a real options model, it is useful to define two broad categories of flexibility: "macro," which describes changes that happen once or otherwise infrequently, and "operational," which may be described as adjustments in response to inputs that fluctuate on the time-scale of hours or days. The structure of any particular case may involve a combination of macro and operational components of flexibility. Cases involving more than one option will require "compound" option models if the subsequent option(s) depend on the outcomes of prior options. Financial type methodologies, which are useful for market risks, require reduction of uncertainty to one or two sources, such as rental price or price of energy.

Climate, technological, future use, and regulatory uncertainties require simulation-type real options models. To set up a simulation model for a real options analysis, it is necessary to define a "flexible" and an "inflexible," or baseline, case. The difference between the two is the option value. Simulation models can be created using physical, engineering models of the system(s) affected by the relevant uncertainties. For example, a model of building energy use is needed to determine the building's energy consumption characteristics under climate uncertainty. As another example, the structural loads acceptable to a particular design may be modeled under uncertainty for future use to determine costs associated with changing of building function that requires additional construction to existing foundations or structures.

4   Introduction of case study

An example of real options "in" building design is developed to demonstrate the ability of flexible design to achieve use of a beneficial technology while addressing its risks. The case study technology is natural ventilation (NV), which takes advantage of outdoor air to provide cooling for a building. In the era of air-conditioning, or mechanical cooling (MC), the risk that a naturally ventilated building will provide less than constant-comfort conditions inhibits its use (Raue et al, 2002). However, NV provides the potential benefits of improved indoor environmental quality and energy savings (Spindler et al, 2002; Brager and de Dear, 2000). This case study is based on a new office building designed for an owner-occupier who may want to sell the building in ten years. The initial owner is a company that has declared sustainability goals, and thus wants to include NV as one of the "green" features of the building. Initial screening studies indicate that the climate is suitable for NV to successfully meet the expected cooling loads of the building.

The uncertainty of concern is the NV building's future market value, or level of rent that it can command. The technical uncertainties of NV performance have a direct impact on the market value of a building. Commercial office buildings in the U.S. are divided into different classes to distinguish their physical and locational qualities, and therefore the levels of rent that the demand side of the market will pay (Geltner and Miller, 2001). Physical qualities assessed include energy costs and comfort conditions; thus MC is standard in the highest classifications (i.e. class A). However, recent research, motivated by the need to reduce building energy consumption, has brought much greater technical sophistication to the design and control of naturally ventilated buildings. Thus, NV is an innovative technology that could be used in lieu of MC in acceptable climates, such as the UK, Netherlands, and temperate climates in the U.S. (Spindler et al, 2002).

To address the uncertainty in future market value of a NV building, the building is designed with the option to install MC. Physically, this means the design accommodates future installation of chiller equipment, ducts, chilled water pipes, and a control system in coordination with any pre-existing heating systems. If, when it comes time to sell the building, the market views the building as inferior to buildings with MC, all other factors equivalent, the seller will receive a lower price. On the other hand, it may turn out that the NV building will be valued more than an otherwise equivalent MC building because of a proven track record of superior performance, including comfort, higher productivity, and energy savings. With the option, the building is positioned to benefit from this upside potential while also being protected from the downside outcome. This option also addresses uncertainty in future climate, particularly from the risk of overheating if the climate becomes much warmer than the assumptions used in the screening studies. Analysis of option value under climate uncertainty requires a heat transfer model to simulate the thermal performance of the building under stochastic climate, and thus is a separate, distinct analysis (see Greden and Glicksman, 2005).

The taxonomy of the option valued herein is defined as follows:

Uncertainty: The uncertainty that this option addresses is the office building's market value (i.e. level of rent) with NV relative to MC, all other characteristics equal. The NV market value is more uncertain due to the market's lack of familiarity with the technology. The risk of receiving a lower level of rent, or selling price, is hedged by the option.

Underlying assets: The two underlying assets are the price of a NV office building and the price of an otherwise equivalent MC office building. Randomized realizations of each price are assumed to be uncorrelated.

Option: The option is defined as the flexibility to install mechanical cooling in an otherwise naturally ventilated office building, thus obtaining a hybrid NV-MC building that will receive the market rate of rent for a MC building.

Exercise date: The date of exercise is 10 years from the present, which is the standard time frame for evaluating the future market value of a real estate asset. It is also the time at which the owner-occupier may want to sell the building.

Exercise costs: The exercise cost is the cost to install the mechanical cooling system and other features to create a hybrid NV-MC building.

Option value: Option value is determined by comparing the realization of NV building price to the realization of price for the otherwise equivalent MC building less the exercise costs. The option value provides a measure of how much to spend on the initial design and construction of the naturally ventilated building with option.

Before describing the model to value this option and presenting results, a brief review of real options as applied to real estate and flexibility in building design is provided.

4.1 Background

In the field of buildings and real estate, real options has primarily been applied to valuations of vacant land, development options, and construction costs (Geltner, 1989; Geltner et al, 1996; Patel and Paxson, 2001; Ellingham and Fawcett, 2002). These applications are characterized by options "on" projects, including options to expand, abandon or go ahead with the next phase subject to market uncertainties. Several authors have developed real options methodologies to value specific types of flexibility in the functionality of a building design (Kalligeros,2003; Greden and Glicksman, 2004). Others have developed methodologies to incorporate uncertainty into decision models; however, unlike real options, they do not include the flexibility to make decisions in the future, as uncertainties are resolved (Zmeureanu and Pasqualetto, 2000; Pace and Gilda, 1998).

Flexibility in buildings can be defined through the characteristics of a building that make it able, on the basis of its physical composition, to adapt or modify itself to changes.

Currently, intentional design for adaptability is relatively uncommon in architecture and building system engineering (Fernandez, 2002). Renovations are common, but generally at great expense due to structural, HVAC, and interior designs intended for a "static" set of initial specifications. However, evidence exists that designers are beginning to incorporate flexibility into architectural and HVAC system plans. One of the primary motivations is the need to facilitate less costly, quicker changeovers in space use (Joroff and Bell, 2001). Office building products such as movable walls, tiled carpet, and raised floors (which allow easy access to communications wiring) serve as evidence that the market is embracing change (Kats et al, 2003). Another motivation for flexible building systems, particularly for HVAC systems, is the need to manage highly variable cooling loads and fluctuating energy prices (ESM, 2003).

Real estate development and decisions to use innovative building technologies involve three sets of stakeholders: the development team (designer, developer, construction contractor), the tenant and/or owner, and the institutional investor (FCC, 1996). The barriers to environmental innovation in building design arise from concerns of each stakeholder individually as well as contractual relations among the parties. For the development team, competition creates pressure to keep first costs low. Financing tends to reward conservative practices (DOE, 2000). A developer is most likely to make an investment in technical innovation only if it will be visible to the consumer and, therefore, warrant asking for a higher price (OTA, 1992). Furthermore, uncertainty in how innovative building designs and technologies will facilitate adaptability or reuse is another barrier to their employment (FCC, 1996). The fragmented nature of the commercial buildings sector means that individual companies are seldom large enough to risk sizeable investments on their own or to capitalize on any resulting innovations. Improved communication between the parties is a necessary first step to reducing the various parties' perceived risks for building innovation. In addition, real options frameworks for designing a building with flexibility and recognizing the value of flexibility in evaluations will also help to advance building innovation.

4.2   Option valuation model

The option-based design to address the uncertainty in market price of the NV office building relative to a MC office building is evaluated using a DCF model and Monte Carlo simulation in a spreadsheet program. The exercise date decision rule is defined as choosing the greater of
a) the market value of the building as is, with natural ventilation (V_{NV}), and
b) the market value as a "standard" mechanically cooled building (V_{MC}) less the cost of installing the mechanical cooling system (X).
Market value V is defined as the present value of t years worth of lease payments at the prevailing annual market price of rent (per square foot or square meter) for each building:

$$V = P(1+a)^T(1-e^{-rt})r^{-1} \qquad\qquad (Eq.\ 1)$$

where P is the current annual market price of rent, a is the annual growth rate in rental prices, T is the exercise year (and first year in which rent payments would begin), r is the

discount rate, and *t* is the number of years of rent payments. The annual standard deviation of *P* (σ_P) is transformed to the annual standard deviation of *V* (σ_V) with the same continuously compounded annuity formula applied in Eq. 1:

$$\sigma_V = \sigma_P(1-e^{-rt})r^{-1} \qquad\qquad\qquad\qquad (Eq.\ 2)$$

In each trial of the Monte Carlo simulation, random draws of V_{MC} and V_{NV} are made subject to predefined lognormal probability distributions with standard deviations σ_{Vmc} and σ_{Vnv} respectively. The value of the option is determined by applying the following formula and discounting the result to the present time:

$$Decision\ rule = max\ [(V_{MC} - X) - V_{NV},\ 0\ ]\ e^{-rT} \qquad\qquad (Eq.\ 3)$$

If the first quantity is greater than zero, the option will be exercised and the building will become a hybrid NV-MC building. It will receive the market price for a MC building. However, if the value as a NV building is greater on the exercise date, the option will not be exercised. The building will remain naturally ventilated and receive the NV market price. This Monte Carlo simulation procedure is repeated 10,000 times to obtain a distribution of option value.

Several important assumptions are made:
- The value of the lease (defined by Eq. 1) solely describes the value of a building.
- Energy cost savings of the NV building are ignored, as are any other costs associated with future sale or subsequent lease of the two building types.
- Annual rent price *(P)* and, thus, future market value *(V)* of each building type are lognormally distributed random variables, described by a mean and standard deviation.
- The values of the two building types are uncorrelated.
- Both building types have the same current market price of rent.
- All of the uncertainty regarding the buildings' market prices is contained in the standard deviation of each.

To model the greater uncertainty in the value of the NV building relative to the MC building, a greater standard deviation is applied.

The base case input assumptions are given in Table 2. Both building types are assumed to start at the same current annual rental price ($25/SF) due to the tradeoff between constant comfort conditions in the MC building but better indoor environmental quality and expected energy savings in the NV building. Current annual rent of $25/SF translates to $193/SF for a ten-year lease beginning ten years from the current time, assuming an annual growth rate of 2 percent and a 10 percent discount rate using Eq. 1. Annual standard deviations in annual rent prices are 10 percent and 20 percent for the MC and NV buildings respectively, which equate to standard deviations of 63 percent

and 126 percent for the ten-year lease value using Eq. 2. The exercise cost is assumed to be a conservative $25/SF[1].

Table 2. Model inputs and calculated values.

Annual discount rate, r	10%	/year
Current MC building rent price, P_{MC}	25	$/SF
Annual lognormal std.dev., $\sigma_{P,MC}$.	10%	/year
Current NV building rent price, P_{NV}	25	$/SF
Annual lognormal std.dev., $\sigma_{P,NV}$.	20%	/year
Life of option, T	10	years
Strike price, X	25	$/SF
Length of lease, t	10	years
Annual growth rate in rents, a	2%	/year
Calculated values		
Annuity factor for lease	6.32	
Resulting current MC building value, V_{MC}	193	$/SF
Resulting std.dev., $\sigma_{V,MC}$.	63.2%	/year
Resulting current NV building value, V_{NV}	193	$/SF
Resulting std.dev., $\sigma_{V,NV}$.	126.4%	/year

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[1] RS Means Construction Cost Data 2005 provides a median value of $8.31/SF for new HVAC system construction.

4.3   Results

The results using the input assumptions in Table 2 are shown Fig.'s 2-4. Figure 2 shows the present value of the three building types:

        a) naturally ventilated with the option to install mechanical cooling (NVO)
        b) naturally ventilated alone (NV)
        c) mechanically cooled alone (MC)

The callout in Fig. 2 shows how the "option" building is able to take advantage of upside opportunities in greater market value. Likewise the shift of the probability distribution of "option" building value to the right of the NV building value curve at low probabilities shows how the option to install MC protects the seller from downside losses. This is also shown in the callout of Fig. 3, where the information is presented as cumulative probability distributions.
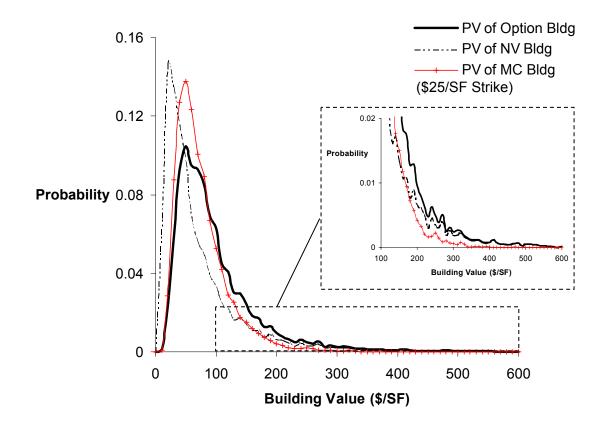

Figure 2. Probability distribution of the value of a naturally ventilated building with option as compared to the inflexible cases of either NV-only or MC-only. See Table 2 for input parameters.

Displaying the results as a cumulative probability distribution graph (Fig. 3) allows decision-makers to deduce the value of the option-based design for different levels of certainty. For example, reading from the 10 percent cumulative probability line in Fig. 3, it can be said that it is 90 percent certain that the option-based building is worth at least $32/SF. Also, with 90 percent certainty, the option-based building is worth more than either of the other two "static" cases of MC-only and NV-only. Table 3 provides the

expected (i.e. mean), lower (10 percent cumulative probability), and upper (90 percent cumulative probability) value of the three building types. The option-based building design is superior in all cases.
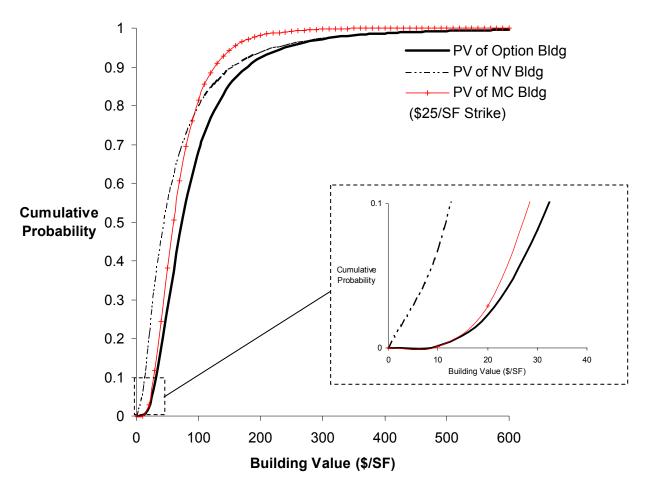

Figure 3. Cumulative probability distribution of the various building values. See Table 2 for input parameters.

Table 3. Building Value Results ($/SF)

	NV + Option Building	NV Bldg	MC Bldg
Expected value	$96	$71	$71
Lower limit value (10%)	$32	$12	$29
Upper limit value (90%)	$178	$155	$125

The value of the option given by Eq. 3 guides decision-makers on the amount to spend on design and construction features necessary to be able to install a MC system in the NV building. For the base case inputs of Table 2, which include a $25/SF exercise cost to install the MC system, the expected (present) value of the option is $25/SF. In this case, option value is not very sensitive to strike price. For example, reducing the strike price by 60 percent results in an increase of option value by only 12 percent. The assumed exercise cost of $25/SF is a conservatively high estimate. The results suggest that a "flexible" design that allows for installation of mechanical cooling at a cost of $25/SF ten-years from now should cost no more than $25/SF more than the base costs of the naturally ventilated building design. The assumption that current MC building and NV building market values are equivalent implies that the base costs of a NV building be equivalent to those of a MC building. If the base case assumptions are used with an exercise date of year 5, instead of year 10, the option value increases to $37/SF due to a shorter period of discounting. Thus, an exercise cost of $25/SF and exercise date of year 10 yield a conservative estimate for option value, if zero correlation is assumed. However, if V_{MC} and V_{NV} are correlated by positive 1.0, the base case mean option value decreases by 82 percent. If they are correlated by positive 0.5, option value decreases by 29 percent. Project investors may end up paying more for the option-based scenario overall, with expenditures to obtain flexibility and possible later expenditures to exercise the option. However, the ability to manage the distribution of the value of an option-based building (Fig. 2 and 3) ultimately rewards the investors relative to ownership of "static" real estate assets.
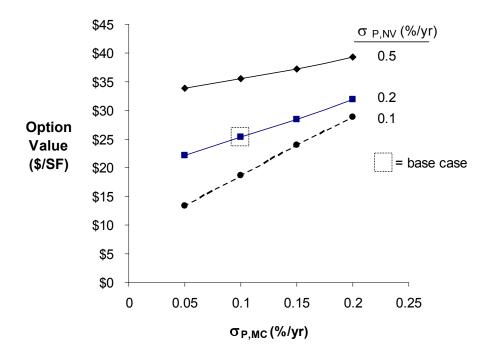

Figure 4. Sensitivity analysis of option value for various standard deviations of NV and MC annual rent prices. See Table 2 for other input parameters.

Option value is sensitive to the standard deviations in market price of both MC and NV buildings ($\sigma_{P,MC}$ and $\sigma_{P,NV}$). As illustrated in Fig. 4, if $\sigma_{P,NV}$ is changed from the base case of 20 percent to 50 percent, option value increases to \$33/SF, a 40 percent increase. If $\sigma_{P,NV}$ is reduced to 10 percent, or equivalent to $\sigma_{P,MC}$, the option value decreases to \$18/SF, or a 27 percent reduction. Figure 4 also shows that as $\sigma_{P,NV}$ increases, option value becomes less sensitive to $\sigma_{P,MC}$ (over the range of 5 to 20 percent). Publicly accessible data on historic rental prices of office buildings in a particular location would aid choice of standard deviation parameters for future applications of this model. Similarly, research on price differences between otherwise equivalent NV and MC buildings would serve this option value analysis.

5   Conclusion

A better understanding of the means to manage risk through flexible design will facilitate implementation of innovative technologies. The case study of an innovative naturally ventilated building designed with the option to install a mechanical air-conditioning system in the future demonstrates three advantages of flexible design. First, the building owners-investors are positioned to benefit if future market demand places a higher value on NV buildings relative to standard MC buildings. Second, if instead the NV building does not perform as expected, cannot meet the cooling and ventilation needs of future uses of the building, and/or the ambient climate becomes warmer, the owners will not suffer a reduction in selling or rental price relative to a MC building because mechanical cooling equipment can be readily installed per the flexible design. Third, independent of upside or downside realization of building value, the NV building with option is superior in terms of energy savings. These advantages can be generalized to carefully planned flexible designs for other innovative technologies.

To address both design and investment audiences, the use of a spreadsheet program with a DCF model and Monte Carlo simulation is an effective method of conducting a transparent, explorative analysis. A thoroughly thought out flexible design is an iterative process and requires teamwork among engineers, architects and real options analysts. Future research towards the goal of increased implementation of innovative, environmentally beneficial technologies is needed in the areas of contractual formats among parties, inclusion of a "real options" manager within a design team, and understanding of how liability might propagate throughout the various interested parties with an options approach to system design. Further research is also needed to optimize options based designs subject to uncertainty and evaluate other impacts of interest under uncertainty, such as life cycle materials usage and emissions.

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