

**CHAPTER 1****A New Paradigm?****INTRODUCTION**

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What are real options, how are companies using real options, what types of options exist, why are real options important, who uses real options, where are real options most appropriately used, and what are the experts saying about real options? This chapter attempts to demystify the concepts of real options and starts by reviewing the basics of real options as a new paradigm shift in the way of thinking about and evaluating projects. The chapter then reviews several business cases in different industries and situations involving pharmaceutical, oil and gas, manufacturing, IT infrastructure, venture capital, Internet start-ups, and e-business initiatives. The chapter then concludes with some industry “war stories” on using real options as well as a summary of what the experts are saying in journal publications and the popular press.

**A PARADIGM SHIFT**

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In the past, corporate investment decisions were cut-and-dried. Buy a new machine that is more efficient, make more products costing a certain amount, and if the benefits outweigh the costs, execute the investment. Hire a larger pool of sales associates, expand the current geographical area, and if the marginal increase in forecast sales revenues exceeds the additional salary and implementation costs, start hiring. Need a new manufacturing plant? Show that the construction costs can be recouped quickly and easily by the increase in revenues it will generate through new and improved products, and the initiative is approved.

However, real-life business conditions are a lot more complicated. Your firm decides to go with an e-commerce strategy, but multiple strategic paths exist. Which path do you choose? What are the options that you have? If you choose the wrong path, how do you get back on the right track? How do you

value and prioritize the paths that exist? You are a venture capital firm with multiple business plans to consider. How do you value a start-up firm with no proven track record? How do you structure a mutually beneficial investment deal? What is the optimal timing to a second or third round of financing?

Real options are useful not only in valuing a firm through its strategic business options but also as a strategic business tool in capital investment decisions. For instance, should a firm invest millions in a new e-commerce initiative? How does a firm choose among several seemingly cashless, costly, and unprofitable information technology infrastructure projects? Should a firm indulge its billions in a risky research and development initiative? The consequences of a wrong decision can be disastrous or even terminal for certain firms. In a traditional discounted cash flow (DCF) model, these questions cannot be answered with any certainty. In fact, some of the answers generated through the use of the traditional discounted cash flow model are flawed because the model assumes a static, one-time decision-making process while the real options approach takes into consideration the strategic managerial options certain projects create under uncertainty and management's flexibility in exercising or abandoning these options at different points in time, when the level of uncertainty has decreased or has become known over time.

The real options approach incorporates a learning model such that management makes better and more informed strategic decisions when some levels of uncertainty are resolved through the passage of time. The discounted cash flow analysis assumes a static investment decision, and assumes that strategic decisions are made initially with no recourse to choose other pathways or options in the future. To create a good analogy of real options, visualize it as a strategic road map of long and winding roads with multiple perilous turns and forks along the way. Imagine the intrinsic and extrinsic value of having such a strategic road map or global positioning system when navigating through unfamiliar territory, as well as having road signs at every turn to guide you in making the best and most informed driving decisions. This is the essence of real options.

*Business conditions are fraught with uncertainty and risks. These uncertainties hold with them valuable information. When uncertainty becomes resolved through the passage of time, actions, and events, managers can make the appropriate midcourse corrections through a change in business decisions and strategies. Real options incorporate this learning model, akin to having a strategic road map, while traditional analyses that neglect this managerial flexibility will grossly undervalue certain projects and strategies.*

The answer to evaluating such projects lies in real options analysis, which can be used in a variety of settings, including pharmaceutical drug development, oil and gas exploration and production, manufacturing, e-business, start-up valuation, venture capital investment, IT infrastructure, research and development, mergers and acquisitions, e-commerce and e-business, intellectual capital development, technology development, facility expansion, business project prioritization, enterprise-wide risk management, business unit capital budgeting, licenses, contracts, intangible asset valuation, and the like. The following section illustrates some business cases and how real options can assist in identifying and capturing additional strategic value for a firm.

### **EXPANSION AND COMPOUND OPTIONS: THE CASE OF THE OPERATING SYSTEM**

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You are the Chief Technology Officer of a large multinational corporation, and you know that your firm's operating systems are antiquated and require an upgrade, say to the new Microsoft Windows XP or Server 2003 series. You arrange a meeting with the CEO, letting him in on the situation. The CEO quips back immediately, saying that he'll support your initiative if you can prove to him that the monetary benefits outweigh the costs of implementation—a simple and logical request. You immediately arrange for a demonstration of the new operating system, and the highly technical experts from Microsoft provide you and your boss a marvelous presentation of the system's capabilities and value-added enhancements that took in excess of a few billion dollars and several years to develop. The system even fixes itself in times of dire circumstances and is overall more reliable and stable than its predecessors. You get more excited by the minute and have made up your mind to get the much-needed product upgrade. There is still one hurdle, the financial hurdle, to prove not only that the new system provides a better operating environment but also that the plan of action is financially sound. Granted, the more efficient and sophisticated system will make your boss's secretary a much happier person and hence more productive. Then again, so will an extra week's worth of vacation and a bigger bonus check, both of which are a lot cheaper and easier to implement. The new system will not help your sales force sell more products and generate higher revenues because the firm looks state-of-the-art only if a customer questions what version of Windows operating system you are using—hardly an issue that will arise during a sales call. Then again, when has using the latest software ever assisted in closing a deal, especially when you are a contract global-freight and logistics solutions provider?

You lose sleep over the next few days pondering the issue, and you finally decide to assemble a task force made up of some of your top IT personnel. The

six of you sit in a room considering the same issues and trying to brainstorm a few really good arguments. You link up the value-added propositions provided in the Microsoft technician's presentation and come up with a series of potential cost reduction drivers. Principally, the self-preservation and self-fixing functionality will mean less technical assistance and help-desk calls, freeing up resources and perhaps leading to the need for fewer IT people on staff. Your mind races through some quick figures, you feel your heart pounding faster, and you see a light at the end of the tunnel. Finally you will have your long-awaited operating system, and all your headaches will go away. Wait—not only does it reduce the help-desk time, but also it increases efficiency because employees will no longer have to call or hold for technical assistance.

Your team spends the next few days scouring through mountains of data on help-desk calls and issues—thank God for good record-keeping and relational databases. Looking for issues that could potentially become obsolete with the new system, you find that at least 20 percent of your help-desk calls could be eliminated by having the new system in place because it is more stable, is capable of self-fixing these critical issues, can troubleshoot internal hardware conflicts, and so forth. Besides, doesn't employee morale count? Satisfied with your analysis, you approach the CEO and show him your findings.

Impressed with your charts and analytical rigor in such a short time frame, he asks several quick questions and points out several key issues. The cost reduction in technical assistance is irrelevant because you need these people to install and configure the new system. The start-up cost and learning curve might be steep, and employees may initially have a tough time adjusting to the new operating environment—help-desk calls may actually increase in the near future, albeit slowing down in time. But the firm's mission has always been to cultivate its employees and not to fire them needlessly. Besides, there are five people on staff at the help desk, and a 20 percent reduction means one less full-time employee out of 5,000 in the entire firm—hardly a cost reduction strategy! As for the boss's secretary's productivity, you noticed two first-class air tickets to Maui on his desk, and you're pretty sure one of them is for her. Your mind races with alternate possibilities—including taking a trip to Hawaii with a high-powered digital-zoom camera but deciding against it on your way out. He notices your wandering eyes and tries to change the subject. You still have not sufficiently persuaded your boss on getting the new operating system, and you are up a tree and out on a limb. Thoughts of going shopping for a camera haunt you for the rest of the day.

Sound familiar? Firms wrestle with similar decisions daily, and vendors wrestling with how to make their products more marketable have to first address this financial and strategic issue. Imagine you're the sales director for

Microsoft, or any software and hardware vendor for that matter. How do you close a sale like this?

Performing a series of simple traditional analyses using a discounted cash flow methodology or economic justification based on traditional analyses will fail miserably, as we have seen above. The quantifiable financial benefits do not exceed the high implementation costs. How do you justify and correctly value such seemingly cashless and cash-flow draining projects? The answer lies in real options. Instead of being myopic and focusing on current savings, the implementation of large-scale servers or operating systems will generate future strategic options for the firm. That is, having the servers and system in place provides you a springboard to a second-, third-, or fourth-phase IT implementation. That is, having a powerful connected system gives you the technical feasibility to pursue online collaboration, global data access, videoconferencing, digital signatures, encryption security, remote installations, document recovery, and the like, which would be impossible to do without it.

*An expansion option provides management the right and ability to expand into different markets, products, and strategies or to expand its current operations under the right conditions. A chooser option implies that management has the flexibility to choose among several strategies, including the option to expand, abandon, switch, contract, and so forth. A sequential compound option means that the execution and value of future strategic options depend on previous options in sequence of execution.*

Hence, the value of upgrading to a new system provides the firm an *expansion option*, which is the right and ability, but not the obligation, to invest and pursue some of these value-added technologies. Some of these technologies such as security enhancements and global data access can be highly valuable to your global freight company's supply chain management. You may further delineate certain features into groups of options to execute at the same time—that is, create a series of *sequential compound options* where the success of one group of initiatives depends on the success of another in sequence, similar to a stage-gate investment process.

Notice that using an extrapolation of the traditional analytic approaches would be inappropriate here because all these implementation possibilities are simply options that a senior manager has, and not guaranteed execution by any means. When you view the whole strategic picture, value is created and identified where there wasn't any before, thereby making you able to clearly

justify financially your plans for the upgrade. You would be well on your way to getting your new operating system installed.

### **EXPANSION OPTIONS: THE CASE OF THE E-BUSINESS INITIATIVE**

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The e-business boom has been upon us for a few years now, and finally the investment bank you work for has decided to join the Internet age. You get a decree from the powers that be to come up with a solid e-commerce initiative. The CEO calls you into his office and spends an hour expounding on the wisdom of bringing the firm closer to the electronic Web. After hours of meetings, you are tasked with performing a feasibility analysis, choosing the right strategy, and valuing the wisdom of going e-commerce. Well, it sounds simple enough, or so you think.

The next two weeks are spent with boardroom meetings, conference calls with e-commerce consulting firms, and bottles of Alka-Seltzer. Being a newly endowed expert on the e-business strategies after spending two weeks in Tahiti on a supposedly world-renowned e-commerce crash course, you realize you really still know nothing. One thing is for certain: the Internet has revolutionized the way businesses are run. The traditional Sun Tzu business environment of “know thy enemy and know thyself and in a hundred battles you will be victorious” hadn’t met the Internet. The competitive playing field has been leveled, and your immediate competitors are no longer the biggest threat. The biggest threat is globalization, when new competitors halfway around the world crawl out of the woodwork and take half of your market share just because they have a fancy Web site capable of attracting, diverting, and retaining Web traffic, and capable of taking orders around the world, and you don’t. Perhaps the CEO’s right; it’s a do-or-die scenario. When a 12-year-old girl can transform her parents’ fledgling trinket store into an overnight success by going to the Internet, technology seems to be the biggest foe of all. You either ride the technological wave or are swept under.

Convinced of the necessity of e-commerce and the strong desire to keep your job, you come up with a strategic game plan. You look at the e-commerce options you have and try to ascertain the correct path to traverse, knowing very well that if you pick the wrong one, it may be ultimately disastrous, for you and your firm, in that particular order. In between updating your curriculum vitae, you decide to spend some time pondering the issues. You realize that there are a large number of options in going e-commerce, and you have decided on several potential pathways to consider as they are most appropriate to the firm’s core business.

Do we simply create a static Web site with nice graphics, text explaining what we do, and perhaps a nice little map showing where we are located and

the hours of availability, and get fired? Do we perhaps go a little further and provide traditional banking services on the Web? Perhaps a way for our customers to access their accounts, pay bills, trade stocks, apply for loans, and perhaps get some free stock advice or free giveaways and pop-up ads to divert traffic on the Web? Perhaps we can take it to the extreme and use state-of-the-art technology to enable items like digital television access, live continuous streaming technology, equity trading on personal digital assistants and cellular phones, interaction with and direct access to floor specialists and traders on the New York Stock Exchange for the larger clients, and all the while using servers in Enron-like offshore tax havens. The potentials are endless.

You suddenly feel queasy, and the inkling of impending doom. What about competition? Ameritrade and a dozen other online trading firms currently exist. Most major banks are already on the Web, and they provide the same services. What makes us so special? Then again, if we do not follow the other players, we may be left out in the cold. Perhaps there are some ways to differentiate our services. Perhaps some sort of geographical expansion; after all, the Internet is global, so why shouldn't we be? What about market penetration effects and strategies, country risk analysis, legislative and regulatory risks? What if the strategy is unsuccessful? What will happen then? Competitive effects are unpredictable. The threats of new entrants and low barriers to entry may elicit even more competitors than you currently have. Is the firm ready to play in the big leagues and fight with the virtual offshore banking services? Globalization—what an ugly word it is right about now. What about new technology: Do we keep spending every time something new comes out? What about market share, market penetration, positioning, and being first to market with a new and exciting product? What about future growth opportunities, e-traffic management, and portal security? The lists go on and on. Perhaps you should take a middle ground, striking an alliance with established investment banking firms with the applicable IT infrastructure already in place. Why build when you can buy? You reach for your Alka-Seltzer and realize you need something a lot stronger.

How do you prioritize these potential strategies, perform a financial and strategic feasibility analysis, and make the right decision? Will the firm survive if we go down the wrong path? If we find out we are on the wrong path, can we navigate our way back to the right one? What options can we create to enable this? Which of these strategies is optimal? Upon identifying what these strategies are, including all their downstream *expansion options*, you can then value each of these strategic pathways. The identification, valuation, prioritization, and selection of strategic projects are where real options analysis can provide great insights and value. Each project initiative should not be viewed in its current state. Instead, all downstream opportunities should be viewed and considered as well. Otherwise, wrong decisions may be made because only projects with immediate value will be chosen, while projects that

carry with them great future potential are abandoned simply because management is setting its sights on the short term.

### **EXPANSION AND SEQUENTIAL OPTIONS: THE CASE OF THE PHARMACEUTICAL R&D**

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Being the chief chemist of a small pharmaceutical firm that is thinking of developing a certain drug useful in gene therapy, you have the responsibility to determine the right biochemical compounds to create. Understanding very well that the future of the firm rests on pursuing and developing the right portfolio of drugs, you take your evaluation task rather seriously. Currently, the firm's management is uncertain whether to proceed with developing a group of compounds and is also uncertain regarding the drug development's financial feasibility. From historical data and personal experience, you understand that development "home runs" are few and far between. As a matter of fact, you realize that less than 5 percent of all compounds developed are superstars. However, if the right compounds are chosen, the firm will own several valuable patents and bolster its chances of receiving future rounds of funding. Armed with that future expectation, you evaluate each potential compound with care and patience.

For example, one of the compounds you are currently evaluating is called Creatosine. Management knows that Creatosine, when fully developed, can be taken orally, but has the potential to be directly injected into the bloodstream, which increases its effectiveness. As there is great uncertainty in the development of Creatosine, management decides to develop the oral version for now and wait for a period of several years before deciding on investing additional funds to develop the injectable version. Thus, management has created an *expansion option*—that is, the option but not the obligation to expand Creatosine into an injectable version at any time between now and several years. The firm thus creates no value in developing the injection version after that time period. By incorporating real options strategy, your firm has mitigated its risks in developing the drug into both an oral and injectable form at initiation. By waiting, scientific and market risks become resolved through the passage of time, and your firm can then decide whether to pursue the second injectable phase. This risk-hedging phenomenon is common in financial options and is applicable here for real options.

However, there are other drug compounds to analyze as well. You go through the list with a fine-tooth comb and realize that you must evaluate each drug by not only its biochemical efficacies, but also by its financial feasibility. Given the firm's current capital structure, you would need to not only value, prioritize, and select the right compounds, but also find the optimal portfolio mix of compounds, subject to budget, timing, and risk con-

straints. On top of that, you would have to value your firm as a whole in terms of a portfolio of strategic options. The firm's value lies not only in its forecast revenues less its costs subject to time valuation of money but also in all the current research and development initiatives under way, where a single home run will double or triple the firm's valuation. These so-called future *growth options*, which are essentially growth opportunities that the firm has, are highly valuable. These *growth options* are simply *expansion options* because your firm owns the right infrastructure, resources, and technology to pursue these future opportunities but not the obligation to do so unless both internal research and external market conditions are amenable.

Another approach you decide to use is to create a strategic development road map, knowing that every drug under development has to go through multiple phases. At each phase, depending on the research results, management can decide to continue its development to the next phase or abandon it assuming it doesn't meet certain prespecified criteria. That is, management has the *option to choose* whether a certain compound will continue to the next stage. Certain drugs in the initial phases go through a *sequential compound option*, where the success of the third phase, for example, depends on the success of the second phase, which in turn depends on the success of the first phase in the stage-gate drug development cycle. Valuing such sequences of options using a traditional approach of taking expected values with respect to the probabilities of success is highly dubious and incorrect. The valuation will be incorrect at best and highly misleading at worst, driving management to select the wrong mix of compounds at the wrong time.

### **EXPANSION AND SWITCHING OPTIONS: THE CASE OF THE OIL AND GAS EXPLORATION AND PRODUCTION**

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The oil and gas industry is fraught with strategic options problems because oil and gas exploration and production involves significant amounts of risk and uncertainty. For example, when drilling for oil, the reservoir properties, fluidic properties, trap size and geometry, porosity, seal containment, oil and gas in place, expulsion force, losses due to migration, development costs, and so forth are all unknowns. How then is a reservoir engineer going to recommend to management the value of a particular drill site? Let's explore some of the more frequent real options problems encountered in this industry.

Being a fresh M.B.A. graduate from a top finance program, you are hired by a second-tier independent oil and gas firm, and your first task is to value several primary and secondary reservoir recovery wells. You are called into your boss's office, and she requests you to do an independent financial analysis on a few production wells. You were given a stack of technical engineering

documents to review. After spending a fortnight scouring through several books on the fundamentals of the oil and gas industry, you finally have some basic understanding of the intricacies of what a secondary recovery well is. Needing desperately to impress your superiors, you decide to investigate a little further into some new analytics for solving these types of recovery-well problems.

Based on your incomplete understanding of the problem, you begin to explore all the possibilities and come to the conclusion that the best analytics to use may be the application of a Monte Carlo simulation and real options analysis. Instead of simply coming up with the value of the project, you decide to also identify where value can be added to the projects by incorporating strategic real optionality.

Suppose that the problem you are analyzing is a primary drilling site that has its own natural energy source, complete with its gas cap on one side and a water drive on the other. These energy sources maintain a high upward pressure on the oil reservoir to increase the ease of drilling and, therefore, the site's productivity. However, knowing that the level of energy may not be sustainable for a long time and its efficacy is unknown currently, you recognize that one of the strategies is to create an *expansion option* to drill a secondary recovery well near the primary site. Instead of drilling, you can use this well to inject water or gas into the ground, thereby increasing the upward pressure and keeping the reservoir productive. Building this secondary well is an option and not an obligation for the next few years.

The first recommendation seems to make sense given that the geological structure and reservoir size are difficult to estimate. Yet these are not the only important considerations. The price of oil in the market is also something that fluctuates dramatically and should be considered. Assuming that the price of oil is a major factor in management's decisions, your second recommendation includes separating the project into two stages. The first stage is to drill multiple wells in the primary reservoir, which will eventually maximize on its productivity. At that time a second phase can be implemented through smaller satellite reservoirs in the surrounding areas that are available for drilling but are separated from the primary reservoir by geological faults. This second stage is also an *expansion option* on the first; when the price of oil increases, the firm is then able to set up new rigs over the satellite reservoirs, drill, and complete these wells. Then, using the latest technology in subsurface robotics, the secondary wells can be tied back into the primary platform, thereby increasing and expanding the productivity of the primary well by some expansion factor. Obviously, although this is a strategic option that the firm has, the firm does not have the obligation to drill secondary wells unless the market price of oil is favorable enough. Using some basic intuition, you plug some numbers into your models and create the optimal oil price levels such that secondary drillings are profitable. However, given your brief

conversation with your boss and your highly uncertain career future, you decide to dig into the strategy a little more.

Perhaps the company already has several producing wells at the reservoir. If that is so, the analysis should be tweaked such that instead of being an *expansion option* by drilling more wells, the firm can retrofit these existing wells in strategic locations from producers into injectors, creating a *switching option*. Instead of drilling more wells, the company can use the existing wells to inject gas or water into the surrounding geological areas in the hopes that this will increase the energy source, forcing the oil to surface at a higher rate. Obviously, these secondary production wells should be switched into injectors when the recovery rate of the secondary wells is relatively low and the marginal benefits of the added productivity on primary wells far outstrip the retrofit costs. In addition, some of the deep-sea drilling platforms that are to be built in the near future can be made into *expansion options*, where slightly larger platforms are built at some additional cost (premium paid to create this option), such that if oil prices are optimally high, the flexible capacity inherent in this larger platform can be executed to boost production.

Finally, depending on the situation involved, you can also create a *sequential compound option* for the reservoir. That is, the firm can segregate its activities into different phases. Specifically, we can delineate the strategic option into four phases. Phases I to III are exploration wells, and Phase IV is a development well.

- Phase I: Start by performing seismic surveys to get information on the structures of subsurface reservoirs (the costs incurred include shooting the survey, processing data, mapping, etc.).
- Phase II: If anticlines and large structures are found, drill an exploration well; if not, then abandon now.
- Phase III: If the exploration well succeeds industrially or commercially (evaluated on factors such as cost, water depth, oil price, rock, reservoir, and fluid properties), drill more delineation or “step out” wells to define the reservoir.
- Phase IV: If the reservoir is productive enough, commit more money for full development (platform building, setting platform, drilling development wells).

*A switching option provides the right and ability but not the obligation to switch among different sets of business operating conditions, including different technologies, markets, or products.*

## **ABANDONMENT OPTIONS: THE CASE OF THE MANUFACTURER**

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You work for a midsized hardware manufacturing firm located in the heartland of America. Having recently attended a corporate finance seminar on real options, you set out to determine whether you can put some of your newfound knowledge to good use within the company. Currently, your firm purchases powerful laser-guided robotic fabrication tools that run into tens and even hundreds of millions of dollars each. These tools have to be specially ordered more than a year in advance, due to their unique and advanced specifications. They break down easily, and if any one of the three machines that your firm owns breaks down, it may be disastrous because part of the manufacturing division may have to be shut down temporarily for a period exceeding a year. So, is it always desirable to have at least one fabrication tool under order at all times, just as a precaution? A major problem arises when the newly ordered tool arrives, but the three remaining ones are fully functional and require no replacement. The firm has simply lost millions of dollars. In retrospect, certainly having a backup machine sitting idle that costs millions of dollars is not optimal. However, millions can also be lost if indeed a tool breaks down and a replacement is a year away. The question is, what do you do, and how can real options be used in this case, both as a strategic decision-making tool and as a valuation model?

Using traditional analysis, you come to a dead end, as the tool's breakdown has never been consistent and the ordered parts never arrive on schedule. Turning to real options, you decide to create a strategic option with the vendor. Instead of having to wait more than a year before a new machine arrives, while during that time not knowing when your existing machines will break down, you decide to create a mutually agreeable contract. Your firm decides to put up a certain amount of money and to enter into a contractual agreement whereby the vendor will put you on its preferred list. This cuts down delivery time from one year to two months. If your firm does not require the equipment, you will have to pay a penalty exit fee equivalent to a certain percentage of the machine's dollar value amount, within a specified period, on a ratcheted scale, with different exit penalties at different exit periods. In essence, you have created an *abandonment option* whereby your firm has the right not to purchase the equipment should circumstances force your hand, but hedging yourself to obtain the machine at a moment's notice should there be a need. The price of the option's premium is the contractual price paid for such an arrangement. The savings come in the form of not having to close down part of your plant and losing revenues. By incorporating real options insights into the problem, the firm saves millions and ends up with the optimal decision.

## **EXPANSION AND BARRIER OPTIONS: THE CASE OF THE LOST VENTURE CAPITALIST**

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You work in a venture capital firm and are in charge of the selection of strategic business plans and performing financial analysis on their respective feasibility and operational viability. The firm gets more than a thousand business plans a year, and your boss does not have the time to go through each of them in detail and relies on you to sniff out the ones with the maximum potential in the least amount of time. Besides, the winning plans do not wait for money. They often have money chasing after them. Having been in the field of venture capital funding for 10 years and having survived the bursting of the dot-com bubble, your judgment is highly valued in the firm, and you are more often than not comfortable with the decisions made. However, with the changing economic and competitive landscape, even seemingly bad ideas may turn into the next IPO success story. Given the opportunity of significant investment returns, the money lost on bad ideas is a necessary evil in not losing out on the next eBay or Yahoo! just because the CEO is not a brilliant business plan author. Your qualitative judgment may still be valid, but the question is what next? What do you do after you've selected your top 100 candidates? How do you efficiently allocate the firm's capital to minimize risk and maximize return? Picking the right firms the wrong way only gets you so far, especially when banking on start-ups hoping for new technological breakthroughs. A diversified portfolio of firms is always prudent, but a diversified portfolio of the right firms is much better. Prioritizing, ranking, and coming up with a solid financing structure for funding start-ups is tricky business, especially when traditional valuation methodologies do not work.

The new economy provides many challenges for the corporate decision maker. Market equity value of a firm now depends on expectations and anticipation of future opportunities in novel technologies rather than on a traditional bricks-and-mortar environment. This shift in the underlying fundamentals from tangible goods to technological innovation has created an issue in valuing the firm. Even the face of the intangibles created by technological innovation has changed. In most cases, a significant portion of a firm's value or its strategic investment options is derived from the firm's intangibles. Intangibles generally refer to elements in a business that augment the revenue-generating process but do not themselves have a physical or monetary appearance while still holding significant value to the firm. Intangibles may range from more traditional items like intellectual property, property rights, patents, branding, and trademarks to a new generation of so-called e-intangibles created in the new economy.

Examples of this new generation of e-intangibles include items like marketing intangibles, process and product technologies, trade dress, customer

loyalty, branding, proprietary software, speed, search engine efficiency, on-line data catalogs, server efficiency, traffic control and diversion, streaming technology, content, experience, collaborative filtering, universal-resource-locator-naming conventions, hubs, Web page hits, imprints, blogs, and community relationships. New entries in the e-commerce economy over the past few years include the financial sector (bank wires, online bill payments, online investing), health care sector (cross-border medical teaching), publication and retail auctions (e-pocket books, Web magazines, Web papers, eBay, Web-Van, Auto-Web). The new trend seems to continue, and new start-ups emerge in scores by the minute to include sophisticated and complex structures like online cross-border banking services, virtual offshore banks, cross-border medical diagnostic imaging, and online-server game playing. However, other less sophisticated e-business strategies have also been booming of late, including service-based Web sites, which provide a supposedly value-added service at no charge to consumers, such as online greeting cards and online e-invitations. Lower barriers to entry and significant threat of new entrants and substitution effects characterize these strategies.

Even using fairly well-known models like the discounted cash flow analysis is insufficient to value these types of firms. For instance, as a potential venture capitalist, how do you go about identifying the intangibles and intellectual property created when traditional financial theory is insufficient to justify or warrant such outrageous price-to-earnings multiples? Trying to get on the bandwagon in initial public offerings with large capital gains is always a good investment strategy, but randomly investing in start-ups with little to no fundamental justification of potential future profitability is a whole other issue. Perhaps there is a fundamental shift in the way the economy works today or is expected to work in the future as compared to the last decade. Whether there is indeed an irrational exuberance in the economy, or whether there is perhaps a shift in the fundamentals, we need a newer, more accurate, and sophisticated method of quantifying the value of such intangibles.

How do you identify, value, select, prioritize, justify, optimize, time, and manage large corporate investment decisions with high levels of uncertainty such that when a decision is made, the investment becomes irreversible? How do you value and select among several start-up firms to determine whether they are ideal venture candidates, and how do you create an optimal financing structure? These types of cashless return investments provide no immediate increase in revenues, and the savings are only marginal compared to their costs. How do you justify such outrageous market equity prices?

*A barrier option means that the execution and value of a strategic option depend on either breaching or not breaching an artificial barrier.*

There must be a better way to value these investment opportunities. Having read press releases by Motley Fool on Credit Suisse First Boston, and how the firm used real options to value stocks of different companies, you begin looking into the possibilities of applying real options yourself. The start-up firm has significant value even when its cash flow situation is hardly something to be desired because the firm has strategic *growth options*. That is, a particular start-up may have some technology that may seem untested today, but it has the *option to expand* into the marketplace quickly and effortlessly should the technology prove to be highly desirable in the near future. Obviously the firm has the right to also pursue other ancillary technologies but only if the market conditions are conducive. The venture firm can capitalize on this *option to expand* by hedging itself with multiple investments within a venture portfolio. The firm can also create strategic value through setting up contractual agreements with a *barrier option* (and *option to defer*) where for the promise of seed financing, the venture firm has the right of first refusal, but not the obligation, to invest in a second or third round should the start-up achieve certain management-set goals or barriers. The cost of this *barrier option* is seed financing, which is akin to the premium paid on a stock option. Should the option be in-the-money, the option will be executed through second- and third-round financing. By obtaining this strategic option, the venture firm has locked itself into a guaranteed favorable position should the start-up be highly successful, similar to the characteristics of a financial call option of unlimited upside potential. At the same time, the venture firm has hedged itself against missing the opportunity with limited downside proportional to the expenditure of a minimal amount of seed financing.

When venture capital firms value a group of companies, they should consider all the potential upsides available to these companies. These strategic options may very well prove valuable. A venture firm can also hedge itself through the use of barrier-type or deferment options. The venture firm should then go through a process of portfolio optimization analysis to decide what proportion of its funds should be disseminated to each of the chosen firms. This portfolio optimization analysis will maximize returns and minimize the risks borne by the venture firm on a portfolio level subject to budget or other constraints.

### **COMPOUND EXPANSION OPTIONS: THE CASE OF THE INTERNET START-UP**

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In contrast, one can look at the start-up entrepreneur. How do you obtain venture funding, and how do you position the firm such that it is more attractive to the potential investor? Your core competency is in developing software or Web-enabled vehicles on the Internet, not financial valuation. How

do you then structure the financing agreements such that your firm will be more attractive yet at the same time the agreements are not detrimental to your operations, strategic plans, or worse, your personal equity stake? What are your projected revenues and costs? How do you project these values when you haven't even started your business yet? Are you undervaluing your firm and its potential such that an unscrupulous venture firm will capitalize on your lack of sophistication and take a larger piece of the pie for itself? What are your strategic alternatives when you are up and running, and how do you know it's optimal for you to proceed with the next phase of your business plan?

All these questions can be answered and valued through a real options framework. Knowing what strategic options your firm has is significant because this value-added insight not only provides the firm an overall strategic road map but also increases its value. The real option that may exist in this case is something akin to a *compound expansion option*. For example, the firm can expand its product and service offerings by branching out into ancillary technologies or different applications, or expanding into different vertical markets. However, these expansions will most certainly occur in stages, and the progression from one stage to another depends heavily on the success of the previous stages.

## THE REAL OPTIONS SOLUTION

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Simply defined, real options is a systematic approach and integrated solution using financial theory, economic analysis, management science, decision sciences, statistics, and econometric modeling in applying options theory in valuing real physical assets, as opposed to financial assets, in a dynamic and uncertain business environment where business decisions are flexible in the context of strategic capital investment decision making, valuing investment opportunities, and project capital expenditures. Real options are crucial in:

- Identifying different corporate investment decision pathways or projects that management can navigate given the highly uncertain business conditions;
- Valuing each strategic decision pathway and what it represents in terms of financial viability and feasibility;
- Prioritizing these pathways or projects based on a series of qualitative and quantitative metrics;
- Optimizing the value of your strategic investment decisions by evaluating different decision paths under certain conditions or using a different sequence of pathways to lead to the optimal strategy;

*Real options are useful for identifying, understanding, valuing, prioritizing, selecting, timing, optimizing, and managing strategic business and capital allocation decisions.*

- Timing the effective execution of your investments and finding the optimal trigger values and cost or revenue drivers; and
- Managing existing or developing new optionalities and strategic decision pathways for future opportunities.

### ISSUES TO CONSIDER

Strategic options do have significant intrinsic value, but this value is only realized when management decides to execute the strategies. Real options theory assumes that management is logical and competent and that it acts in the best interests of the company and its shareholders through the maximization of wealth and minimization of risk of losses. For example, suppose a firm owns the rights to a piece of land that fluctuates dramatically in price. An analyst calculates the volatility of prices and recommends that management retain ownership for a specified time period, where within this period there is a good chance that the price of real estate will triple. Therefore, management owns a call option, an *option to wait* and defer sale for a particular time period. The value of the real estate is therefore higher than the value that is based on today's sale price. The difference is simply this option to wait. However, the value of the real estate will not command the higher value if prices do triple but management decides not to execute the option to sell. In that case, the price of real estate goes back to its original levels after the specified period and then management finally relinquishes its rights.

*Strategic optionality value can only be obtained if the option is executed; otherwise, all the options in the world are worthless.*

Was the analyst right or wrong? What was the true value of the piece of land? Should it have been valued at its explicit value on a deterministic basis where you know what the price of land is right now and, therefore, this is its value; or should it include some type of optionality where there is a good probability that the price of land could triple in value and, hence, the piece of land is truly worth more than it is now and should therefore be valued accordingly?

The latter is the real options view. The additional strategic optionality value can only be obtained if the option is executed; otherwise, all the options in the world are worthless. This idea of explicit versus implicit value becomes highly significant when management's compensation is tied directly to the actual performance of particular projects or strategies.

To further illustrate this point, suppose the price of the land in the market is currently \$10 million. Further, suppose that the market is highly liquid and volatile, and that the firm can easily sell it off at a moment's notice within the next five years, the same amount of time the firm owns the rights to the land. If there is a 50 percent chance the price will increase to \$15 million and a 50 percent chance it will decrease to \$5 million within this time period, is the property worth an expected value of \$10 million? If prices rise to \$15 million, management should be competent and rational enough to execute the option and sell that piece of land immediately to capture the additional \$5 million premium. However, if management acts inappropriately or decides to hold off selling in the hopes that prices will rise even further, the property value may eventually drop back down to \$5 million. Now, how much is this property really worth? What if there happens to be an *abandonment option*? Suppose there is a perfect counterparty to this transaction who decides to enter into a contractual agreement whereby for a contractual fee, the counterparty agrees to purchase the property for \$10 million within the next five years, regardless of the market price and executable at the whim of the firm that owns the property. Effectively, a safety net has been created whereby the minimum floor value of the property has been set at \$10 million (less the fee paid). That is, there is a limited downside but an unlimited upside, as the firm can always sell the property at market price if it exceeds the floor value. Hence, this strategic abandonment option has increased the value of the property significantly and hedged its downside risks. Logically, with this abandonment option in place, the value of the land with the option is definitely worth more than \$10 million after having such a safety net or downside insurance. The question is how much this insurance is worth and only real options analysis can answer this.

### **INDUSTRY LEADERS EMBRACING REAL OPTIONS**

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Industries using real options as a tool for strategic decision making started with oil and gas as well as mining companies, and later expanded into utilities, biotechnology, pharmaceuticals, and now into telecommunications, high-tech, and across all industries. Following are some examples of how real options have been or should be used in different industries.

**Automobile and Manufacturing Industry** In automobile manufacturing, General Motors (GM) applies real options to create *switching options* in producing its new series of autos. This is essentially the option to use a cheaper resource over a given period of time. GM holds excess raw materials and has multiple global vendors for similar materials with excess contractual obligations above what it projects as necessary. The excess contractual cost is outweighed by the significant savings of switching vendors when a certain raw material becomes too expensive in a particular region of the world. By spending the additional money in contracting with vendors as well as meeting their minimum purchase requirements, GM has essentially paid the premium on purchasing a *switching option*. This is important especially when the price of raw materials fluctuates significantly in different regions around the world. Having an option here provides the holder a hedging vehicle against pricing risks.

**Computer Industry** In the computer industry, HP-Compaq used to forecast sales of printers in foreign countries months in advance. It then configured, assembled, and shipped the highly specific printers to these countries. However, given that demand changes rapidly and forecast figures are seldom correct, the preconfigured printers usually suffer a higher inventory holding cost or the cost of technological obsolescence. HP-Compaq can create an *option to wait* and defer making any decisions too early through building assembly plants in these foreign countries. Parts can then be shipped and assembled in specific configurations when demand is known, possibly weeks in advance rather than months in advance. These parts can be shipped anywhere in the world and assembled in any configuration necessary, while excess parts are interchangeable across different countries. The premium paid on this option is building the assembly plants, and the upside potential is the savings from not making wrong demand forecasts.

**Airline Industry** In the airline industry, Boeing spends billions of dollars and several years to decide if a certain aircraft model should even be built. Should the wrong model be tested in this elaborate strategy, Boeing's competitors may gain a competitive advantage relatively quickly. Because so many technical, engineering, market, and financial uncertainties are involved in the decision-making process, Boeing can conceivably create an *option to choose* through parallel development of multiple plane designs simultaneously, knowing very well the increased cost of developing multiple designs simultaneously with the sole purpose of eliminating all but one in the near future. The added cost is the premium paid on the option. However, Boeing will be able to decide which models to abandon or continue when these uncertainties and risks become known over time. Eventually, all the models will be eliminated save one. This way, the company can hedge itself against making the wrong initial

decision and benefit from the knowledge gained through multiple parallel development initiatives.

**Oil and Gas Industry** In the oil and gas industry, companies spend millions of dollars to refurbish their refineries and add new technology to create an *option to switch* their mix of outputs among heating oil, diesel, and other petrochemicals as a final product, using real options as a means of making capital and investment decisions. This option allows the refinery to switch its final output to one that is more profitable based on prevailing market prices, to capture the demand and price cyclicalities in the market.

**Telecommunications Industry** In the telecommunications industry, in the past, companies like Sprint and AT&T installed more fiber-optic cable and other telecommunications infrastructure than other companies in order to create a *growth option* in the future by providing a secure and extensive network, and to create a high barrier to entry, providing a first-to-market advantage. Imagine having to justify to the board of directors the need to spend billions of dollars on infrastructure that will not be used for years to come. Without the use of real options, this would have been impossible to justify.

**Utilities Industry** In the utilities industry, firms have created an *option to execute* and an option to switch by installing cheap-to-build, inefficient energy generator peaker plants only to be used when electricity prices are high and to shut down when prices are low. The price of electricity tends to remain constant until it hits a certain capacity utilization trigger level, when prices shoot up significantly. Although this occurs infrequently, the possibility still exists, and by having a cheap standby plant, the firm has created the option to turn on the switch whenever it becomes necessary, to capture this upside price fluctuation.

**Real Estate Industry** In the real estate arena, leaving land undeveloped creates an option to develop at a later date at a more lucrative profit level. However, what is the optimal wait time and the optimal trigger price to maximize returns? In theory, one can wait for an infinite amount of time, and real options provide the solution for the optimal timing and price-trigger value.

**Pharmaceutical Research and Development Industry** In pharmaceutical research and development initiatives, real options can be used to justify the large investments in what seems to be cashless and unprofitable under the discounted cash flow method but actually creates *compound expansion options* in the future. Under the myopic lenses of a traditional discounted cash flow analysis, the high initial investment of, say, a billion dollars in research and development may return a highly uncertain projected few million dollars over the

next few years. Management will conclude under a net-present-value analysis that the project is not financially feasible. However, a cursory look at the industry indicates that research and development is performed everywhere. Hence, management must see an intrinsic strategic value in research and development. How is this intrinsic strategic value quantified? A real options approach would optimally time and spread the billion-dollar initial investment into a multiple-stage investment structure. At each stage, management has an *option to wait* and see what happens as well as the *option to abandon* or the *option to expand* into the subsequent stages. The ability to defer cost and proceed only if situations are permissible creates value for the investment.

**High-Tech and e-Business Industry** In e-business strategies, real options can be used to prioritize different e-commerce initiatives and to justify those large initial investments that have an uncertain future. Real options can be used in e-commerce to create incremental investment stages, *options to abandon*, and other future growth options, compared to a large one-time investment (invest a little now, wait and see before investing more).

**Mergers and Acquisition** In valuing a firm for acquisition, you should not only consider the revenues and cash flows generated from the firm's operations but also the strategic options that come with the firm. For instance, if the acquired firm does not operate up to expectations, an *abandonment option* can be executed where it can be sold for its intellectual property and other tangible assets. If the firm is highly successful, it can be spun off into other industries and verticals or new products and services can be eventually developed through the execution of an *expansion option*. In fact, in mergers and acquisition, several strategic options exist. For instance, a firm acquires other entities to enlarge its existing portfolio of products or geographic location, to obtain new technology (*expansion option*), or to divide the acquisition into many smaller pieces and sell them off as in the case of a corporate raider (*abandonment option*); or it merges to form a larger organization due to certain synergies and immediately lays off many of its employees (*contraction option*). If the seller does not value its real options, it may be leaving money on the negotiation table. If the buyer does not value these strategic options, it is undervaluing a potentially highly lucrative acquisition target.

All these cases where the high cost of implementation with no apparent payback in the near future seems foolish and incomprehensible in the traditional discounted cash flow sense are fully justified in the real options sense when taking into account the strategic options the practice creates for the future, the uncertainty of the future operating environment, and management's flexibility in making the right choices at the appropriate time.

## WHAT THE EXPERTS ARE SAYING

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The trend in the market is quickly approaching the acceptance of real options, as can be seen from the following sample publication excerpts.<sup>1</sup>

According to a *Harvard Business Review* article (December 2004):

*Companies that rely solely on discounted cash flow (DCF) analysis underestimate the value of their projects and may fail to invest enough in uncertain but highly promising opportunities. Far from being a replacement for DCF analysis, real options are an essential complement, and a project's total value should encompass both. DCF captures a base estimate of value; real options take into account the potential for big gains.*

According to another *Harvard Business Review* article (March 2004):

*The complexity of real options can be eased through the use of a binomial valuation model. Many of the problems with real options analysis stem from the use of the Black-Scholes-Merton model, which isn't suited to real options. Binomial models, by contrast, are simpler mathematically, and you can tinker with binomial model until it closely reflects the project you wish to value.*

According to an article in *Bloomberg Wealth Manager* (November 2001):

*Real options provide a powerful way of thinking and I can't think of any analytical framework that has been of more use to me in the past 15 years that I've been in this business.*

According to a *Wall Street Journal* article (February 2000):

*Investors who, after its IPO in 1997, valued only Amazon.com's prospects as a book business would have concluded that the stock was significantly overpriced and missed the subsequent extraordinary price appreciation. Though assessing the value of real options is challenging, without doing it an investor has no basis for deciding whether the current stock price incorporates a reasonable premium for real options or whether the shares are simply overvalued.*

*CFO Europe* (July/August 1999) cites the importance of real options in that:

*[A] lot of companies have been brainwashed into doing their valuations on a one-scenario discounted cash flow basis . . . and sometimes our recommendations are not what intuition would suggest, and that's where the real surprises come from—and with real options, you can tell exactly where they came from.*

According to a *Business Week* article (June 1999):

*The real options revolution in decision making is the next big thing to sell to clients and has the potential to be the next major business breakthrough. Doing this analysis has provided a lot of intuition you didn't have in the past . . . and as it takes hold, it's clear that a new generation of business analysts will be schooled in options thinking. Silicon Valley is fast embracing the concepts of real options analytics, in its tradition of fail fast so that other options may be sought after.*

In *Products Financiers* (April 1999):

*Real options are a new and advanced technique that handles uncertainty much better than traditional evaluation methods. Since many managers feel that uncertainty is the most serious issue they have to face, there is no doubt that this method will have a bright future as any industry faces uncertainty in its investment strategies.*

A *Harvard Business Review* article (September/October 1998) hits home:

*Unfortunately, the financial tool most widely relied on to estimate the value of a strategy is the discounted cash flow which assumes that we will follow a predetermined plan regardless of how events unfold. A better approach to valuation would incorporate both the uncertainty inherent in business and the active decision making required for a strategy to succeed. It would help executives to think strategically on their feet by capturing the value of doing just that—of managing actively rather than passively and real options can deliver that extra insight.*

This book provides a novel approach in applying real options to answering these issues and more. In particular, a real options framework is presented. It takes into account managerial flexibility in adapting to ever-changing strategic, corporate, economic, and financial environments over time as well as the fact that in the real business world, opportunities and uncertainty exist and are dynamic in nature. This book provides a real options process framework to identify, justify, time, prioritize, value, and manage corporate investment strategies under uncertainty in the context of applying real options.

The recommendations, strategies, and methodologies outlined in this book are not meant to replace traditional discounted cash flow analysis but to complement it when the situation and the need arise. The entire analysis could be done, or parts of it could be adapted to a more traditional approach. In essence, the process methodology outlined starts with traditional analyses and continues with value- and insight-adding analytics, including Monte Carlo simulation, real option analysis, and portfolio optimization. The real options

approach outlined is not the only viable alternative nor will it provide a set of infallible results. However, if utilized correctly with the traditional approaches, it may lead to a set of more robust, accurate, insightful, and plausible results. The insights generated through real options analytics provide significant value in understanding a project's true strategic value.

### **CRITICISMS, CAVEATS, AND MISUNDERSTANDINGS IN REAL OPTIONS**

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Before embarking on a real options analysis, analysts should be aware of several caveats. First, the following five requirements need to be satisfied before a real options analysis can be run:

- ***A financial model must exist.*** Real options analysis requires the use of an existing discounted cash flow model, as real options build on the existing tried-and-true approaches of current financial modeling techniques. If a model does not exist, it means that strategic decisions have already been made and no financial justifications are required, and hence, there is no need for financial modeling or real options analysis.
- ***Uncertainties must exist.*** Otherwise the option value is worthless. If everything is known for certain in advance, then a discounted cash flow model is sufficient. In fact, when volatility (a measure of risk and uncertainty) is zero, everything is certain, the real options value is zero, and the total strategic value of the project or asset reverts to the net present value in a discounted cash flow model.
- ***Uncertainties must affect decisions when the firm is actively managing the project and these uncertainties must affect the results of the financial model.*** These uncertainties will then become risks, and real options can be used to hedge the downside risk and take advantage of the upside uncertainties.
- ***Management must have strategic flexibility or options to make mid-course corrections when actively managing the projects.*** Otherwise, do not apply real options analysis when there are no options or management flexibility to value.
- ***Management must be smart enough and credible enough to execute the options when it becomes optimal to do so.*** Otherwise, all the options in the world are useless unless they are executed appropriately, at the right time, and under the right conditions.

There are also several criticisms against real options analysis. It is vital that the analyst understands what they are, and what the appropriate responses are, prior to applying real options.

- ***Real options analysis is merely an academic exercise and is not practical in actual business applications.*** Nothing is further from the truth. Although it was true in the past that real options analysis was merely academic, however, many corporations have begun to embrace and apply real options analysis. Also, its concepts are very pragmatic and with the use of the Real Options Valuation's Super Lattice Solver software, even very difficult problems can be easily solved, as will become evident later in this book. This book and software have helped bring the theoretical a lot closer to practice. Firms are using it and universities are teaching it. It is only a matter of time before real options analysis becomes part of normal financial analysis.
- ***Real options analysis is just another way to bump up and incorrectly increase the value of a project to get it justified.*** Again, nothing is further from the truth. If a project has significant strategic options but the analyst does not value them appropriately, he or she is leaving money on the table. In fact, the analyst will be incorrectly undervaluing the project or asset. Also, one of the requirements foregoing states that one should never run real options analysis unless strategic options and flexibility exist. If they do not exist, then the option value is zero, but if they do exist, neglecting their valuation will grossly and significantly underestimate the project or asset's value.
- ***Real options analysis ends up choosing the highest risk projects as the higher the volatility, the higher the option value.*** This criticism is also incorrect. The option value is zero if no options exist. However, if a project is highly risky and has high volatility, then real options analysis becomes more important. That is, if a project is strategic but is risky, then you better incorporate, create, integrate, or obtain strategic real options to reduce and hedge the downside risk and take advantage of the upside uncertainties. Therefore, this argument is actually heading in the wrong direction. It is not that real options will overinflate a project's value, but for risky projects, you should create or obtain real options to reduce the risk and increase the upside, thereby increasing the total strategic value of the project. Also, although an option value is always greater than or equal to zero (as will be seen in later chapters), sometimes the cost to obtain certain options may exceed its benefit, making the entire strategic value of the option negative, although the option value itself is always zero or positive.

So, it is incorrect to say that real options will always increase the value of a project or only risky projects are selected. People who make these criticisms do not truly understand how real options work. However, having said that, real options analysis is just another financial analysis tool, and the old axiom of "garbage in garbage out" still holds. But if care and due diligence are

exercised, the analytical process and results can provide highly valuable insights. In fact, this author believes that 50 percent (rounded, of course) of the challenge and value of real options analysis is simply *thinking about it*. Understanding that you have options, or obtaining options to hedge the risks and take advantage of the upside, and to think in terms of strategic options, is half the battle. Another 25 percent of the value comes from actually running the analysis and obtaining the results. The final 25 percent of the value comes from being able to explain it to management, to your clients, and to yourself, such that the results become *actionable intelligence* and not merely another set of numbers.

## SUMMARY

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Real options analysis simply defined is the application of financial options, decision sciences, corporate finance, and statistics to evaluate real or physical assets as opposed to financial assets. Industry analysts, experts, and academics all agree that real options provide significant insights to project evaluation that traditional types of analysis like the discounted cash flow approach cannot provide. Sometimes the simple task of thinking and framing the problem within a real options context is highly valuable. The simple types of real options discussed include expansion, abandonment, contraction, chooser, compound, barrier, growth, switching, and sequential compound options.

## CHAPTER 1 QUESTIONS

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1. What are some of the characteristics of a project or a firm that is best suited for a real options analysis?
2. Define the following:
  - a. Compound option
  - b. Barrier option
  - c. Expansion option
3. If management is not credible in acting appropriately through profit-maximizing behavior, are strategic real options still worth anything?