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**PLANNING TECHNOLOGY INVESTMENTS FOR HIGH PAYOFFS:
A RATIONAL EXPECTATIONS APPROACH TO GAUGING POTENTIAL
AND REALIZED VALUE IN A CHANGING ENVIRONMENT**

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ABSTRACT

The importance of distinguishing between potential and realized value for IT investments has been recognized by senior managers and IS researchers since some time in the 1980s, when it became apparent that not all IT investments were likely to achieve equivalent levels of return on investment. This chapter explores a new perspective with respect to potential and realized value, specifically noting the importance that rational expectations of IT strategic planners and investment managers play in conditioning decision-making by senior managers. The key insights that we offer are as follows: (1) Since organizational, operational and market contexts will tend to vary around different kinds of IT investments, it is only natural that such heterogeneity in outcomes should be reflected in the heterogeneous expectations of the managers who make the investments; (2) With this in mind, it should also be apparent that understanding heterogeneity in both potential and realized value should be a matter of arriving at an appropriate set of expectations, based on the acquisition of relevant updated information over time that will permit adaptive learning to occur on the part of senior managers; (3) No matter what the process is that enables managers to update their expectations (and achieve rational expectations in the process about their IT investments), the planning process that leads to new estimates of the payoffs from specific IT investments should be tuned for encouraging the tracking of a trajectory of values for potential value. This view is analogous to what an investor would do in tracking the value of stocks held in an investment portfolio, which are subject to value changes based on a variety of forces that are likely to affect the future cash flows of the firm and the present value of its growth opportunities. We develop this IT investment planning perspective in terms of the underlying theory and offer a number of new conceptual and methodological ideas that will enable managers to think their IT investment processes through with a more effective understanding of the rational expectations that are likely to be inherent in them.

Keywords: Adaptive learning, business value, investment evaluation, IT investments, planning perspective, potential value, rational expectations theory, realized value.

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INTRODUCTION

Senior managers have long recognized the important distinction between the potential value of their IT investments and the realized value that is actually observed to accrue in the context of firm operations in different industries. Since the 1990s, IS researchers have incorporated the notion into formal models and analyses. Davern and Kauffman [2000, p. 122] argued that “it is diagnostic, both *ex ante* and *ex post*, to compare the potential value of an IT project and its realized value. Furthermore, analyzing the potential value of an IT investment, in addition to related expenditures, is useful both for researchers developing theories of IT value creation and for practitioners who must evaluate IT projects and strategies.”

Potential and Realized Value Assessments Are Necessary in Managing Technology Investments

We have observed the necessity for making these kinds of assessments in many different contexts where technology investments are impacted over time by a variety of forces that are endogenous and exogenous to the firm. Senior managers are hard-pressed to find the time to fully surface all of the relevant information, suffer from bounded rationality, and sometimes fail to place enough emphasis on the value of information. Some of the most immediately obvious forces can be identified in settings such as commercial banking, air travel services, Internet-based selling and e-commerce infrastructure services.

In commercial banking, for example, in the 1980s Clemons and McFarlan [1986] and Banker and Kauffman [1988] asked whether telecommunication investments for electronic banking networks were a “hook up or lose out” value proposition. They wondered whether e-banking had the capability to enable firms to create unique competitive advantage and, on that basis, appropriate value from the marketplace. Similar arguments were made by Duliba et al. [2001] in the context of airline reservation systems in support of airline competition for higher market shares at the city-pair route level, and higher load factors, well-controlled operating costs and greater profits at the aggregate national level. More recently, we have seen growth towards increasing transparency in products and prices of airline firms and the related reservation-making travel intermediaries [Granados et al. 2006]. The potential value of the underlying technologies that support the industry’s operations seems tremendous. However, to some extent the technologies also have eroded the capacity of airline firms to control price competition and lock in their own profitability [Granados et al. 2007].

A similar conclusion can be reached for firms involved in financial markets, especially the stock market and the market for fixed income securities [Bloomfield and O’Hara 1999, Granados et al. 2005, Granados et al. 2006]. With greater market transparency, we have seen changes in the capabilities that investors have to acquire knowledge of market prices and be more effective in trading and investing, as was predicted earlier in the 1990s [Hasbrouck 1995]. (For additional materials that may be useful for expanding on some of the themes discussed in this chapter for undergraduate, MBA and executive teaching, the interested reader should see the following: Benaroch and Kauffman [1999, 2000], Benaroch et al. [2007],

Clemons [1991, 2007], Clemons and Gu [2003], Devaraj and Kohli [2000, 2002, 2003], Han et al. [2004], Kauffman and Wang [2002], and Saloner and Spence [2002].)

The Value of IT Investments in the Marketplace

The same can be said in the contexts of Internet-based selling and e-commerce infrastructure services provision. Although there are quite a few great examples of outstanding profitability in a “blue ocean” marketplace [Kim and Mauborgne 2005] involving transformed business opportunities for nearly uncontested entry in network technology-based entrepreneurship (e.g., Amazon, Travelocity, Google, Digital River, Akamai, YouTube, etc.), not everything has come out like knowledgeable industry analysts expected [Burnham 1999]. Recall such names as Mobshop and Mercata in group-buying on the Internet [Kauffman and Wang 2001, 2002], Priceline and Expedia in air travel and hospitality services reservation-making [Granados et al. 2005], I2 and Ariba in Internet-based procurement services [Day et al. 2003] and many others that have since failed or strategically morphed their business models to be only shadows of their earlier forms when they entered the market as entrepreneurial ventures [Kauffman et al. 2006]. It is clear from these examples that the potential value of these firms’ IT investments was “defeated” by a variety of forces: the inappropriateness of the Internet channel for transaction-making in a product or service, the lack of competitive immediacy for some Internet-based sellers in the presence of everyday discounters like Wal-Mart and BestBuy, and the “deep pockets” and latent competitive capabilities of long-time industry players (the coalition of airlines behind Orbitz.com, or the capacity of Sotheby’s and Christie’s to bring their prowess in collectibles auctions to the Internet). Today, companies such as Amazon and Travelocity are faced with formidable and capable competitors, proving that the technological innovations that drove their development and initial valuations are not long-term barriers to entry for other firms. As a result, we observed—as we should have expected—the migration and movement in the value of their underlying technology-based competencies for the marketplace [Kauffman and Li 2005].

Evaluation and Planning Need to be Aligned with Effective IT Strategy for Changing Environments

These observations motivate us to work toward aligning planning perspectives for IT investments with the realities of a changing environment that inflict severe pressures on the operations and organizational capabilities that different kinds of IT investments create. This is true for traditional firms that invest in IT to support their operations, as well as e-commerce firms that are exploring the latest technologies for data mining and recommender systems, to other firms that use technology to transform the marketplace that exists around them [Burnham 1999]. In all these instances, one thing is certain: the technological and competitive business world will not be static. Instead, the changes and the perceived impacts on the organizations that are affected should evolve over time—exhibiting *volatility* in their *variance* and *returns*, from the point of view of finance professionals and IT value researchers.

In one of the most well-referenced articles in the IS literature that deals with changes in value depending on different estimates of the variance of the expected costs and payoffs, Dos Santos [1991] offered the first meaningful recognition and illustration of the role of the volatility of costs and revenues in identifying the differential payoffs of IT. Implicit in his view, as many of us have come to understand today, is that cost and benefits flows are stochastic in time with respect to IT investments. As a result, based on observations as time passes, one should be able to track the trajectory of the costs and the benefits, and determine whether they match the forecast levels of volatility when the investment decision was made initially, or if they perhaps fall outside the confidence interval of the original forecast. More recently, Schwartz and Zozaya-Gorostiza [2003] and Kauffman and Li [2005] have formalized the assessment of the volatility of IT value and its fundamental drivers by using stochastic analysis in the context of real options models related to prospective IT investments. Although the modeling treatments in each are somewhat different than what Dos Santos used (i.e., the asset-for-asset exchange model of Margrabe [1978]), the strategic intuition hardly improves on Dos Santos' [1991] early conceptualization.

IT Investment Value Volatility Requires New Perspectives in Senior Management Decision-Making

As of 2007, it is fair to say that the spate of research that Dos Santos' [1991] work spawned in the IS field, supported by the many works in financial economics [Dixit and Pindyck 1994] and strategy [Kogut and Kulatilaka 1994, Kulatilaka and Venkatraman 2001] that appeared, has now reached a point of relative maturity. Real options methods have been proposed for use in both conceptual (e.g., [Fichman et al. 2005]) and modeling terms (e.g., [McGrath and MacMillan 2000, Taudes 1998]), as well as embedded in other game-theoretic models [Dai et al. 2007, Zhu and Weyant 2003], applied [Benaroch 2001, Benaroch and Kauffman 1999, 2000] and evaluated [Gustafson and Luft 2002, Taudes et al. 2000]. Nevertheless, Sougstad and Bardhan [2007] and Kauffman and Sougstad [2007] suggest that there is ample room for innovation in the development of trajectory metrics that enable an analyst to gauge the impacts of changing risk over time. Their modeling insights suggest that it is possible to establish value trajectories and risk bounds in a portfolio of IT assets that can be evaluated based on preset probabilities that a given cost or revenue flow stays within a given limit.

The volatility of IT value requires senior managers to update their expectations of the payoffs, and to think of their portfolio of IT investments as a set of market assets, even though they will never be traded or priced by others outside the firm [Au and Kauffman 2001, 2003, 2005]. Indeed, this is our core insight: senior managers within the firm ought to be sensitive to the impacts of a variety of market forces which act on their IT investments that have already been made (i.e., the returns to their sunk costs), as well as on those that are under review, and whose estimates for potential value can be flexibly updated to match new information as it is acquired.

In this general context, we find the rationale for developing a planning perspective that considers potential value and realized value more explicitly, to provide MBA students, technology planners and senior executives with stronger tools and a more effective roadmap for translating their expectations into meaningful assessments of the changing value of their planned and implemented IT investments. We are especially interested in laying out some key concepts that will guide their thinking. One key concept involves the *drift or migration of potential value over time*, in terms of pre-investment potential value, when the details of the investment are not well understood, and in terms of post-investment potential value, when the payoff outcome can be affected by various factors [Dos Santos 1991, Kauffman and Li 2005, Schwartz and Zozaya-Gorostiza 2003]. They include: the commitments of senior managers, the success of the implementation effort, the vagaries of the marketplace and interfirm competition, emerging technologies that substitute for or entirely replace the functionality of prior technologies, and changing patterns of business and consumer use of the technologies.

New Concepts Are Needed to Create the Basis for More Effective Managerial Understanding

We will discuss such concepts as the *role of market consensus*, the development of *rational expectations* among senior managers for IT payoffs, the *potential value trajectory*, and the related modeling ideas to provide a quantitative basis to pull these concepts together into a useful tool set. At the present, most technology strategists understand the basis for making effective high-level assessments of the forces that impinge on the business value of IT. We have seen this in the work of Clemons and his coauthors and some others. Some examples include: the *move-to-the-middle theory* [Clemons et al. 1993]; the role of *functionality risk* in strategic systems design and *chunkification strategies* in determining the value outcomes of decomposable large-scale IT investments [Aron et al. 2005, Clemons 2007]; the impacts of *information exploitation* [Clemons and Hitt 2004, Han et al. 2004], and most recently, the effects of *informational asymmetries* in the context of the technological transformation of electronic markets [Clemons 2007].

The dual roles risk and return are increasingly well understood in IS research. In addition to Clemons et al.'s [1993] move-to-the-middle revelations, today we know much more about the volatility-driven risks from the underlying investments in IT that firms make which give rise to digital options [Amram and Kutilaka 1999, Benaroch et al. 2006, Dewan et al. 2004, Hunter et al. 2004, Kauffman and Mohtadi 2004, Sambamurthy et al. 2003]. We also have a much better understanding of the time-varying risk-return relationship relative to the volatility of IT investments in a portfolio analysis context [Bardhan et al. 2004, Cummings 2002, Hoffman 2003, Jeffery and Leliveld 2004, Kauffman and Sougstad 2007, Luehrman 1998].

Josefek and Kauffman [1997] and Clemons and Gu [2003] have also pointed out the difficulties and risks that strategic IT investments pose. Time and expectations of value become critical in an anticipated

or potential sense, and also in terms of the accrual and realization of value. Wait too long—so the usual story often goes—and the opportunities to appropriate value vanish with the result that your best people leave seeking opportunities elsewhere. Move too soon, and you may not get it right; in spite of the satisfaction that comes with organizational learning. Enter late and join the competitive fray, but also face the risk of possibly losing the opportunity to capture value, as your key competitor achieves near-monopoly market power relative to the technology innovation (e.g., Apple with iPods, and Skype with VoIP in the past several years) [Kauffman and Wu 2006]. Timing, then, is critical; yet equally critical is balancing the speed of action with the risks that a firm faces before all of the competitive facts of the technology, the market, as well as the consumer and firm behavior relative to the IT investment become known [Clemons and Gu 2003].

Why Rational Expectations Shape Managerial Decisions about IT Investment Value

Rational expectations about the range of possible outcomes from an IT investment on the part of senior managers become especially important in such strategic managerial contexts. The term, *rational expectations*, was coined by the economist, John Muth, more than 45 years ago [Muth 1961]. Since Muth's early musings on rational expectations, other researchers in economics and finance have developed these ideas much further, creating a strong theoretical basis for a generation of foundational thinking that has influenced the development of macroeconomic policy, the management of campaigns for political candidates, and even the conduct of military operations. Some examples include Frydman [1982], Sargent [1993], and Sargent and Wallace [1976].

Muth argued that agents in an economy form their expectations of relevant future outcomes (e.g., price levels or interest rates) on the basis of the “true” structural model of the economy in which they make their decisions. He also viewed the agents' expectations as being the same as the predictions of the relevant economic theory: what they think will be the best-informed interpretation of what is likely to occur in the future. A similarly compelling idea was put forth by Nerlove [1958], who posited that agents learn over time, and that the extent to which they learn adds flexibility to their expectations about potential outcomes that rational expectations alone would not predict under the same circumstances. These ideas have many applications in real life, including the formation of consumer expectations of gas prices for their cars, mortgage interest rates related to their house purchases, the likelihood of finding a well-paying job, and so on. The perspective reflects the feedback loops that tie the expectations of one agent to the expectations of another (and another and another, etc.).

Lohmann [2000] aptly characterizes this perspective in the title of an article on common knowledge and information cascades: “I know you know he or she knows we know you know they know.” We tie this into Nerlove's view of adaptive expectations, since a change in any agent's perspective in this is likely to affect the sentiments of the others. Pop psychologist R. D. Laing expressed these concepts ex-

ceptionally well outside the context of economic theory, in his poetic descriptions of psychological rational expectations in human relationships in his “new age” psychology book called *Knots* [Laing 1970].

Nobel laureate in economics, Herbert Simon [1957], further enriched this dialogue on the theory of agent decision-making in contexts where information sharing is possible. He argued that all managers are subject to bounded rationality, and as a result, no matter how much information a senior manager or policy-maker is able to acquire, there will still be issues related to the person’s inability to process all of it, or to comprehend what it means, such that boundedly-rational decision making necessarily will be fraught with discrepancies and characterized by disagreements among agents that can only be resolved as they compare what they know over time.

Research Questions

With these observations on this extraordinary body of theoretical knowledge in mind, we will explore the following research questions in this chapter:

- How can we leverage the theories of rational expectations, adaptive learning and bounded rationality to create a new theoretical synthesis that will inform senior management perspectives on the potential and realized value of IT investments?
- To what extent do rational expectations and adaptive learning provide a basis for describing and analyzing the expected value trajectories of new technology investments over time?
- How should the insights from the theory inform decision-making related to strategic planning for technology adoption, investment and business value outcomes? How do market perceptions and information sharing among agents tie in? What is likely to come out, as a result, for private intrafirm and heterogeneous interfirm assessments of value?
- How do these newly-available theoretical perspectives provide a basis to think creatively about methodological innovations to support rational expectations-based evaluations in IT strategic planning and investment evaluation? What new and valuable ideas flow from this relative to some of the classical problems in the IT value literature, especially related to IT investment decisions under uncertainty (e.g., standards, network externalities, optionality, adoption rate, market saturation, etc.).

Plan of the Chapter

The remainder of this chapter is structured in six sections. The next section explores some of the current and basic thinking that we have brought to our research on IT planning and evaluation for investments. It examines the role of incomplete information, uncertainty and risk in this area, and further develops our views on potential value and realized value. We also discuss information sharing and the role of “cheap talk” in the formation of estimates for technology value. The third section provides additional background on the rational expectations and adaptive learning perspectives, and attempts to identify fac-

tors that will affect rational expectations in technology investment decision contexts. It also considers how rational expectations support a somewhat different conceptualization of the role of risk and uncertainty in decision-making, and uses these insights as a basis for the formulation of a conceptual model for planning in IT investments. The fourth section further develops our arguments about rational expectations-based technology investment decision-making, and explores the process that leads to a market-wide consensus for investments, something that is especially relevant for technologies subject to network effects. The penultimate section extends the discussion, by providing some new concepts and suggestions for analysis tools that will aid IT investment managers to improve their decision-making practices. Our conclusion section offers a discussion of the contributions and limitations of our work, as well as encouragement to our readers to try to put these new ideas to work, and influence best practices in industry for IT investment planning and assessment.

WHY EFFECTIVE TECHNOLOGY INVESTMENTS ARE CHALLENGING TO MAKE

We next consider the impetus for the planning perspectives that we offer in greater detail, by focusing on the role of incomplete information and the extent to which it impedes decision-making for IT investments by creating uncertainty about the payoffs that are likely to occur. We first discuss the sources of uncertainty and risk in technology investment decision-making, including technology, consumers, organization and management, IT investment performance, stakeholder considerations, standards, market competition, and financial issues. These risks impact IT investment decision-makers' sense of the relationship between potential and realized value. To change their perception, it is helpful to obtain additional information to diminish uncertainty so that there is greater clarity about the payoffs associated with an investment. The observations that we make in this section provide a foundation for our subsequent consideration of why rational expectations theory is useful in characterizing the technology investment decision-making behavior we have observed in our field study research, and why an appropriate planning approach for IT investments needs to incorporate some consideration of information sharing for uncertainty reduction.

Sources of Uncertainty and Risk

Incomplete information constitutes one of the more difficult issues for senior managers who are charged with IT investment decision-making. At one level, the firm ought to be risk-neutral in terms of its evaluation of IT assets, since it will make many decisions over time and many technologies that hold considerable promise (as well as unknown risks) will not be considered. There are a number of reasons that we can point to for why senior managers who are involved in technology investment decisions feel they have incomplete information. The same reasons also explain why the information that they have changes over time, complicating their understanding of the value of their investment decisions.

Technology. One issue is *technology and innovation uncertainties*, which are probably the first source that most people would consider beyond their control and, sometimes, even beyond their ability to effectively predict what developments are to come. Benaroch [2001] refers to these as *technology investment risks*. Technology vendors have different and often unknown capabilities to deliver on their promises and value propositions. They are significantly affected by competition in the market, their ability to hold on to key staff, the emergence of new technologies that substitute for what they offer, and their own profitability outcomes. The performance of Digital Equipment Corporation in the 1980s and early 1990s comes to mind, for example. After a period when the firm was a league-leader in mid-tier mini-computer solutions, the market shifted to higher-end PC-based servers and other solutions in which DEC had no real competitive advantage. Technology and innovation uncertainties often give rise to *functionality risks*, as prior technology investments may no longer be able to serve current needs and functionality requirements.

Consumers. The success and payoffs that come from technology projects are also typically influenced by *consumer acceptance in the marketplace*, which give rise to *market acceptance risks*. Senior managers are rarely able to perfectly predict the speed and degree of consumer acceptance, and so it often occurs that the growth of the user installed base cannot be accurately forecasted. A goal that is set out is often to achieve “critical mass” in the marketplace, such that there is some certainty going forward that a particular technology or software application will continue to be demanded. For example, we have seen this with Apple PCs relative to Microsoft Windows-compliant PCs over the years; Apple has always managed to maintain its viability in installed base, although there was rarely a time when there was no uncertainty about Apple’s future prospects and its market share was small. Other technological innovations, on the other hand, have not lived up to the high hype of market expectations, including the e-money plays on the Internet, Beenz and Flooz, IBM’s OS/2, Steve Job’s Next computers and e-books [Haskin 2007].

Organization and Management. A third issue is the *stability of organizational structure* and the extent of *commitment of senior managers* of the firm. In the first instance, there are many events that may lead an organization to change its structure and governance. At the extreme end is a merger or an acquisition, resulting in full reconsideration of the likely value flows and expected costs of a large-scale IT investment. When this occurs, it is normally necessary for the management team to reappraise its commitment. On the other end of the spectrum is the importance that senior managers in a strategy-stable, structure-stable organization can make by acting as project “champions” and promoters of the adoption and usage of new systems and technology investments. When things don’t go right, it usually becomes apparent that technology investment projects are subject to ongoing *organizational risks*.

IT Investment Performance. A fourth issue is the performance of IT investments in support of business processes. In some instances, the value flows from implementing IT in support of business process

are relatively immediate. In other cases, there may be a considerable lag time that occurs before value is produced. This period of diminished value flows is called the *value latency period*, which has been extensively explored by a number of different IS researchers, including Deveraj and Kohli [2000], Goh and Kauffman [2005], and Kauffman and Wu [2006]. The current thinking suggests that very large-scale IT investments typically take a longer period of time to pay off – up to several years – and they are subject to many sources of *value latency risk*. In other cases, the barriers to achieving value are more associated with *implementation risks*, for example, not providing enough resources for training, leaving behind application bugs and usability problems, or failing to get all of the elements of the systems analysis correct.

Stakeholders. A fifth issue is the degree of the relevant stakeholders' support for higher payoffs from an IT investment. Different stakeholders create different kinds of uncertainties and risks. For example, in procurement-related settings, the success of an IT implementation often is based on what Devaraj and Kohli [2003] have called the "missing link:" the degree of usage that occurs by stakeholders to the deployed systems. Similar arguments apply regarding usage of systems that support trade services in international banking, where systems integration capabilities make it possible to achieve highly productive transactional support between trade services banking business partners. The stakeholders can be of numerous kinds, including external stakeholders like buyers and suppliers, and other industry and technology partners, as well as internal business partners, like financial and accounting managers, or product design and development, and manufacturing operations. In all of these cases, IT implementations are subject to a variety of *relational risks* that come up in principal-agent relationships.

Standards. Another concern that results in uncertainty is what happens over time with respect to technology standards and technology-led network externalities in the marketplace. There is much research that suggests the key difficulty that a manager faces is to figure out whether and when a particular technology will become a standard in the marketplace. In the absence of certainty about future outcomes, the best they will be able to do is to make informed predictions, probably based on common knowledge and shared expectations across the marketplace. For example, we have seen this with Bluetooth, the Wi-Fi family of 802.11 standards, WiMax, and more recently with RFID chips and readers. We have also recently had experience with electronic bill payment and presentment (EBPP) systems and technologies, where it has required the broad consensus of a number of different stakeholders before standard solutions gain the confidence of the marketplace [Au and Kauffman 2003]. The primary risks that managers face that relate to uncertainty include the *adoption timing risk* of being too early or late and incurring higher costs as a result, and the *lock-in risk* of being stranded with the wrong choice of standard as the market's sentiments shift to a different standard.

Competition. When new IT investments support products and services whose performance is determined in the marketplace, competitive factors give rise to significant uncertainties and *competitive risks*.

The firm's investments are subject to *strategic entry risk* by major competitors in general, as well as the *preemption risk* of earlier entry by a competitor when the firm has its own entry in the works for a technology product or service area. Kauffman and Wu [2006] have recently studied such developments for large-scale IT investments in mass storage email services by competitors, Google and Yahoo!, where the competition has seemed like a timing game in near-duopoly form. Other examples of this include the race to bring photo-sensors to market on digital single lens reflex (D-SLR) cameras that are larger and larger – from 4 megapixels to 8 megapixels to 10.2 megapixels for image capture now [Stensvold, 2007], and in the near future up to 13.5 and 16.7 megapixels, according to *Digital Photographer* magazine [2007a, 2007b]. Additional uncertainties arise with technology-based products that are associated with different technology generations, an *obsolescence risk*.

Financial Issues. All IT investments that are planned to occur over multiple periods (e.g., quarters or years) are subject to uncertainties that relate to the availability of scarce financial capital in the firm, and being able to consistently obtain the funding commitments from the CFO's office. These *funding risks* often shape the decisions that senior managers make about how to plan and structure IT investments, so as to do as much as possible to ensure that they will be viable on a continuing basis. As a result of funding risks, and some of the other issues that we have discussed above, managers often think in terms of the real options that are embedded in their technology investments, including the option to defer investment, reduce scale, increase scale, shift the emphasis development, or abandon a project entirely [Benaroch 2001, Benaroch et al. 2007].

Table 1 summarizes and describes the different sources of risk and uncertainty.

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These additional observations that we have made, and their relationships to different kinds of risks that arise further prompt us to explore how to specifically incorporate the consideration of incomplete information into managerial thinking related to IT investment planning. This is why information sharing and exchange among senior IS managers can play an important role in diminishing their uncertainty by enabling them to find a basis for a shared understanding of developments related to the variety of uncertainties and risks that they face.

Potential Versus Realized Value of Investments

The IT value conversion process [Kauffman and Weill 1989] is impacted by firm-specific, market-related factors and other factors that we have discussed which are dynamic in nature [Benaroch 2001]. Stochasticity in these factors causes greater variability in the value trajectory of IT investments and leads to higher risks in the investment. Information about the key risks is important for managers to assess and predict the possible inaccuracies in their estimation of potential and realized value. Incomplete information leads to greater uncertainty and exacerbates the risk profile of the IT investment. Potential value and

realized value of an IT investment are constantly changing due to risk exposure of the IT investment and this dynamic process. (See Figure 1 for a theoretical illustration.) The potential value for a given (fixed) level of IT investment is represented by the dotted curve that measures the upper bound of output produced. The realized value is represented by the solid curve at or below the potential value curve. This figure shows that shifts in both the potential value and realized value can occur due to changes in the risk exposures experienced by the IT investment.

INSERT FIGURE 1 ABOUT HERE

Since the potential value of IT investments is constantly updated by changes in the underlying risk factors, the curve representing the estimation of potential value should shift whenever new information is introduced into the estimation function. The shift of this potential value curve is likely to be substantial in the early phases of IT system investment, where high variability and unpredictability of project progress prevails. As time passes, the movement of potential value will become more stable usually, and come closer to its final position as realized value. The realization of IT value occurs predominantly after the implementation and is not instantaneous due to value latency involving possible factors such as learning discontinuities, organizational inertia and user resistance. We do not expect actual realized value to match estimated potential value in all instances; instead, what will be of interest to managers are the reasons for why they do not end up matching one another.

The value trajectory shifts throughout the lifecycle of an IT investment. This calls for greater understanding and objective assessment of the phenomenon. Accepting that the value flow process is dynamic allows managers to arrive at current and informed decisions about the IT investment and implementation process. Managers should estimate the ever-changing potential value over time by basing it on updated expectations of the IT investment payoff, enabling them to better realize the value through additional effort in making value-related treatments such as complementary investments, training and revised deployments.

Information Sharing for the Reduction of Uncertainty

As managers face the risks outlined above that arise from incomplete information, they will seek ways to engage in information sharing and information gathering to minimize this risk. For example, a manager considering a technology investment may seek to reduce uncertainty by gaining a better understanding of what other relevant parties are likely to do in the future. This includes understanding the plans of vendors who may change their support for the technology, competitors who may choose to adopt a different technology, partners who may have different timing expectations of adoption, or senior management who may or may not be supportive in the future. Second, managers may seek information from others to gain a better understanding of the technology and its capabilities in terms of the future viability of a given technology, the evolutionary track of its functionality over time, the likelihood benefits will be

realized in a reasonable amount of time, or what factors must be in place to shorten the latency period to realize benefits sooner. Finally, managers considering technology investments may try to gather information to gain a better understanding of what others believe the future state of the world might be, such as what other seemingly unrelated projects may be on the planning horizon that may drain resources, the possibility of a merger or acquisition that may impact the decision, or the overall future economic climate that may necessitate scaling back investments in the new technology. Such information sharing and information gathering are ways of diminishing incomplete information thereby minimizing unnecessary risks and controlling for uncertainty about the future.

Farrell and Rabin [1996] point out three ways that information sharing may occur between parties that might inform decision making. First, it is well known in economics that various forms of *economic institutions* can convey information to managers, such as competitive markets that adjust prices based on supply and demand. Second, on a smaller scale *signaling* may occur between parties based on their actions or announcements that can convey information about intended future actions [Spence 1973, 1974]. The third way, as proposed by Farrell and Rabin [1996], is through informal communication they call cheap talk. *Cheap talk* is represented by costless, non-binding, and non-verifiable messages between parties that may occur in a variety of settings such as through e-mails, telephone conversations, discussions at industry conferences, hallway chat at technology conventions, or even discussions on the golf course. Although this type of communication may be easy to dismiss as meaningless, research has shown that parties often have an incentive to provide truthful information in such situations lest they come to be regarded as untrustworthy in the future or find themselves inadvertently committed to unmanageable situations later [Kim 1996]. As managers come into contact with others they engage in information sharing and information gathering that they can use to update their expectations of future events regarding the possible actions of others, the potential of the technology, and future states of the environment. Along with more formal mechanisms such as economic institutions and signaling, we can see that cheap talk is a valuable way of sharing information to inform technology investment decision making.

THE RATIONAL EXPECTATIONS PERSPECTIVE: DEVELOPMENT

We next provide background on the rational expectations and adaptive learning theory, and identify factors that will affect rational expectations in technology investment decision contexts, on the basis of our earlier discussion of why technology investments are challenging to make, and involve decision-making uncertainty. We discuss how the rational expectations theory supports perceptions of variation over time in the value trajectory of IT investments. We then use these insights as a basis for the formulation of a conceptual model for planning in IT investments. In contrast to the more general observations that we offered in the previous section on why IT investment decision-making is complex, here we de-

velop a more focused theoretical perspective on why the decision-making process is in harmony with adaptive learning about the likely payoffs on the part of managers. Our discussion culminates in a proposal for IT investment planning which takes into account rational expectations, factors affecting the perceived risks and managerial uncertainty, which bring together elements of the prior section with those of the present section of this chapter.

Rational Expectations and Adaptive Learning

Muth's [1961] rational expectations hypothesis (REH) basically states that economic agents form their expectations based on the "true" structural model of the economy in which their decisions are made. In our case, economic agents are the managers that make IT investment/adoption decisions. The REH claims that managers' subjective expectations of economic variables are the same as the mathematical conditional expectation of those variables. It considers subjective expectations on average as equal to the variables' true values, and this is a central tenet of the theory. The theory is relevant in the IT planning context because it assumes that managers act rationally in circumstances of economic uncertainty and make efficient use of all available information and their understanding of the model governing the market. Muth [1961] further maintained that from a purely theoretical perspective, there are good reasons for assuming rationality. One of them is because it is a principle that is applicable to all dynamic problems which fit the descriptions of IT planning.

The REH is based on two key assumptions: (1) economic agents form their expectations based on a given set of information and will fully utilize all of the information available; and (2) economic agents somehow know the stochastic process that generates the rational expectations equilibrium (REE) condition. The second assumption is what makes the REH unique. However, this assumption often is considered too strong since it requires economic agents to have full knowledge of the structure of the relevant models and their parameter values. Simon [1957] argues that economic agents have bounded rationality since they have limited cognitive resources and capabilities that often make it hard for them to process all available information and come up with the correct decision quickly. Another challenge is all that information may not be available to the managers, at least not initially. Considering these limitations, Sargent [1993] suggested an alternative notion, *adaptive learning*, in which agents are assumed to be willing and able to update their expectations about relevant parameter values on the basis of newly-received information. Consequently, in order for the rational expectations theory to work, the managers should be allowed some time to obtain and process all available information. Table 2 includes definitions for the primary terms and concepts that are drawn from rational expectations theory.

INSERT TABLE 2 ABOUT HERE

In IT investment/adoption planning, the rational expectations adaptive learning theory can be used to explain the phenomenon of drift or migration of potential value over time described in the previous sec-

tion. The fluctuation is due to the fact that boundedly-rational managers may not be able to determine the true potential value of a new technology right away although they will be able to do so over time. These managers must continue to collect new information about the technology from all available sources and update their expectations about the technology's potential value accordingly. The REH and adaptive learning perspectives can help us foresee the process through which some of the "wait and see" issues will be worked out as the capabilities of a new technology expand. In fact, we expect managers to be rational expectations planners, taking advantage of new information as it comes from the variety of players that have entered the market with hopes to profit from it. Consequently, they will continue to follow the development of the new technology and only make a full commitment to adopt when the time is right.

A critical component in the rational expectations-based perspective of IT investment/adoption planning is the alignment of expectations. The rational expectations adaptive learning theory suggests that managers observe the environment and try to align their expectations with those of the other managers before making an IT investment/adoption decision. The alignment is done through the exchange of information among managers. It should occur intra-organizationally (among CEO, CIO, and other managers within the same organization), as well as inter-organizationally (among managers from different companies). The alignment is necessary to confirm each manager's own expectations about the potential value of the technology being considered. Any new developments may alter each manager's expectations and result in a new level of alignment.

The alignment process may take some time during which we can expect no major decision to be made. This may explain the current adoption status of Blu-ray and HD-DVD, two competing high-capacity optical disc storage technologies backed by various computer and consumer electronics manufacturers. Blu-ray is Sony's standard and backed by Dell, Hewlett-Packard, Hitachi, LG Electronics, Matsushita Electric Industrial (Panasonic), Mitsubishi Electric, Philips Electronics, Pioneer Electronics, Samsung Electronics, Sharp, TDK, and Thomson Multimedia. On the other hand, HD-DVD is supported by Toshiba, NEC, Sanyo, Memory-Tech, and Microsoft (which is also supporting HD-DVD in its next version of Windows).

Although it got an early start and had powerful backers, Blu-ray was not able to quickly win the market. In fact, it later found itself having to compete with HD-DVD, which was introduced to the market about three years later in 2006. During the first three years on the market, boundedly-rational managers were not able to reach the equilibrium point of adoption because new information about the new technology (i.e., Blu-ray) kept coming in, causing the managers to repeatedly adjust their expectations about the potential value of the technology. This was made worse by the fact that there were a lot of rumors about the potentially competing technology, HD-DVD. Although Blu-ray offered more capacity, HD-DVD was cheaper due to the fact that it carries the same basic structure as the current DVD, making converting ex-

isting manufacturing lines into HD-DVD lines simpler and more cost-effective. Consequently, it took more time for managers to decide on any particular technology. This explains why some major studios, such as Paramount Pictures, DreamWorks, Warner Bros., and New Line Cinemas, have been essentially neutral in the battle of the two technologies. If it is any indication, recent sales figures show that Blu-ray discs have outsold HD-DVD discs during the first quarter of 2007 by a 70-30 margin, according to market research conducted by *Home Media Magazine* [McGoughey 2007], indicative of an upcoming technological winner.

Factors Affecting Rational Expectations in Technology Investment Decisions

There are different kinds of factors that are likely to be influential in affecting the development of technology value in light of their impacts on the formation of rational expectations. The IT investment/adoption scenario that we described above assumes similar levels of risk-averseness among managers. The assumption may not always hold, however, since managers may take actions under different degrees of uncertainties. For example, managers of a firm may decide to invest in an emerging technology early to secure the first-mover advantage. Although Shapiro and Varian [1999] maintain that first-mover advantage can be powerful and long-lasting for firms that can establish an installed base before the competition arrives, the advantage can be short-lived or even fail to materialize if early entrants are unable to maintain their dominance. This implies higher degrees of uncertainties and risks. The impact of risk aversion and perceived reliability of information is analyzed by Chatterjee and Eliashberg [1990]. They find that lower risk aversion and greater perceived reliability of information imply earlier expected adoption. Another reason for adopting early is because a firm has a vested interest in the technology. In the Blu-ray vs. HD-DVD case, some major movie studios such as Columbia Pictures and MGM, have long decided to adopt Blu-ray simply because these companies are owned by Sony Corp., the company that created and now sells the technology.

Another factor that may affect the formation of rational expectations is the degree of information sharing among managers. Without a full-degree of information sharing, some managers will be unaware of the plans of the other managers. This, of course, will inhibit the formation of rational expectations due to the fact that when it is very costly to share information, it will be very costly for managers to reach a shared understanding of the potential value of a technology. Consequently, the rational expectations adaptive learning theory will work best when information sharing is costless or nearly costless such as with cheap talk. When information transmission costs become somewhat larger, it may be in the interest of some managers (or firms) to subsidize the diffusion of relevant information.

Self-fulfilling expectations can also interfere with the formation of rational expectations. Merton [1957] maintains that a *self-fulfilling prophecy* is a phenomenon that occurs when “a false definition of the situation evoking a new behavior ... makes the original false conception come true. This specious

validity of the self-fulfilling prophecy perpetuates a reign of error.” Once an expectation is set, even if it is not accurate, people will tend to act in ways consistent with that expectation. Any new and emerging technology goes through a phase of over-enthusiasm or hype, and unrealistic projections due to a flurry of well-publicized activities by technology vendors and supporters. During this phase, it is possible that some managers may prematurely reach a consensus on the potential value of the technology and make technology investment decisions based on the consensus. Thus, it is very important for the managers to be aware of this initial phase so as not to fall into the trap of a false sense of security thinking they have done the best possible job in the technology potential value assessment. Managers should be able to gauge these factors during a technology investment planning process to the extent that they can filter this “noise” that can potentially distort the real potential value.

Rational Expectations, Risks and Uncertainties: A Model for Planning

In decision-making under uncertainty, managers begin with certain expectations about future events and modify these expectations as new information and insights are gained from interactions and information sharing with other relevant parties. The rational expectations and adaptive learning theory implicitly maintain that managers will be able to minimize the gap between potential value and realized value if they recognize the dynamic nature of the various factors and underlying risks that together determine the value of the technology. Managers who acknowledge that there is great uncertainty associated with any new technology will allow themselves enough time to assess the potential value of the technology. Through multi-lateral interactions with the other stakeholders, cheap talk, and other market-based information sharing mechanisms (e.g., industry and technology conferences), each manager will repeatedly update their predictions about the potential value of the technology until they reach a consensus with respect to potential value, which should be a better prediction of the realized value.

What is needed is a means for understanding how these expectations translate into specific decisions and actions. It should explain several issues related to decision making and investment decisions under uncertainty. For example, to what extent can we assume that the manager’s expectations about the future accurately reflect the best guess about future events? How does the manager formally update these expectations as new information is gathered? How might different managers arrive at decisions to adopt the same technology that ultimately resembles clustered adoption by the marketplace? These and other issues are formally dealt with in the theories of rational expectations and adapted learning and their extensions.

To this end, we develop a model for technology adoption/investment planning based on the key concepts we have discussed, which takes advantage of these theoretical perspectives. The diagram in Figure 2 is a representation that suggests a set of planning actions based on our perspective. The actions include an initial assessment of the technology being considered. This is preceded by the initial information gathering process through interactions with other stakeholders, cheap talk, and market-based information shar-

ing. The rational expectations and adaptive learning perspective recognizes the managers' bounded rationality and the fact that they may have access to dissimilar information, causing information asymmetry. Consequently, our model suggests that each manager should wait some time and collect more information through the same previous mechanisms.

After this waiting period, the managers should re-assess the potential value of the technology using the newly-acquired information, which include the other stakeholders' assessments. If there is any change in the assessment, the managers should go back to the waiting period and gather more information. The process repeats until there is no more change in the assessment, signifying the reaching of a consensus on the potential value of the technology. At this point, the managers may proceed with the actual technology adoption and investment, if the consensus potential value of the new technology is greater than its cost.

INSERT FIGURE 2 ABOUT HERE

RATIONAL EXPECTATIONS IN TECHNOLOGY INVESTMENTS: APPLICATION

In this section, we further develop our arguments about rational expectations-based technology investment decision-making based on the model introduced earlier. We also explore the process that leads to a market-wide consensus for investments, something particularly relevant for a technology that exhibits strong network effects.

The Role of Rational Expectations in Technology Investment Planning

As our model in Figure 2 shows, the rational expectations and adaptive learning theory basically suggests that managers will invest a reasonable amount of time to gather all relevant information from all possible sources and process the information optimally to learn about the potential value of a new technology. This implies that managers do not simply follow what others have done although they may learn from the experience of others. This is completely different than the concept of *herd behavior* [Bikchandani et al. 1992, 1998], where a manager simply follows the action of another manager and ignores her own information. *Herding* or *groupthink* defies the very basic assumption of economic behavior that decision-makers as economic agents do the best they can with the information they have.

The practical implication of the rational expectations and adaptive learning perspective is that managers should not make any major IT investment decision before they feel comfortable with their knowledge about the technology. This is important to keep in mind particularly because the speed at which IT evolves can cause the error of rushing into investing in the latest technology so as to stay ahead of the competition or, at least, not to be left behind. Rushing may often lead to disastrous results as the trend for most new and emerging technologies is to go through the phase of inflated expectations when unrealistic projections occur, causing any estimates to involve high levels of variance in terms of costs, benefits, and

risks.

Determining how long to wait and how much new information to collect before reassessing the new technology is key in our model. The amount of waiting time should be determined based on how fast the new technology develops its presence in the market and how costly the information about the new technology is. Bhattacharya et al. [1986] revealed that costly information acquisition may lead to an infinite delay in the adoption of a profitable new technology. This is an important consideration in our model and it serves as the rationale for our assumption that managers will gather information about the technology from different sources including cheap talk, which can and often does matter, since even a limited common interest may make it meaningful [Farrell and Rabin 1996]. Other low-cost information sharing and transmission among managers can occur through their participation in industry conferences, the development of technology vendor-supported pilot projects, and increasingly widespread knowledge of the technological innovations. The presence of these sometimes costless and usually low-cost information sources would prevent an infinite delay in the adoption of a profitable new technology. Our model is consistent with Jensen [1988a], who found that if information costs are positive but sufficiently small, the optimal policy for a firm may be represented by the process of “wait, buy new information, wait, buy new information, adopt.”

Our model requires managers to repeatedly wait and reassess the technology’s value and underlying risks, until there is no more change in the assessment. As we have discussed, the main reason for the waiting and reassessment approach is that managers have bounded rationality, which can mean either limited access to information or limited ability to process the available information or both. Consequently, our model suggests that a manager’s ability to collect and make the most of the information plays a key role in the IT investment/adoption decision-making process. The impact of a manager’s capacity to obtain and evaluate information is analyzed by Jensen [1988b], who demonstrated that a greater information capacity entails not only faster learning but also a more rigorous adoption criterion, which tends to make firms adopt later. Furthermore, Thijssen et al. [2001] study adoption timing when costless new information arrives according to a Poisson stochastic process, to capture the intensity of information arrival. They show that the firm will choose to wait for even more signals as new information arrives faster.

The main challenge in any technology investment/adoption decision-making process is to identify the timing of investment/adoption which, according to our model, is the time when new information does not change a manager’s assessment of the new technology any further. In the rational expectations and adaptive learning theory’s terminology, it is the time when the rational expectations equilibrium point is reached. The theory suggests that this timing occurs when all managers involved in the information exchange and cheap talk reach a consensus on their assessments on the value and risks of the technology. At this point, all acts of learning are complete, in the sense that there is no more incentive on the part of

managers to change their assessments. This implies that managers can actually leverage cheap talk to identify timing of investment/adoption by constantly exchanging their assessments.

Rational Expectations and Market-Wide Consensus on Technology Value

The ideas related to market-wide consensus can be exemplified using RFID (radio frequency identification) adoption and implementation. Although RFID technology holds great promise in areas that range from national security to aggregate supply chain management for corporations to specific consumer applications (e.g., smart shopping carts in supermarkets), several main issues continue to challenge the use of the technology [Curtis et al. 2007]. In the pharmaceutical industry, for instance, a recent study indicates RFID adoption has been slower than expected despite several leading pharmaceutical companies' positive experiences in testing it, as well as encouragement from the U.S. Food and Drug Administration (FDA) to investigate the technology [*RFID Journal* 2007]. The pharmaceutical market is actually a perfect incubator for RFID applications because it has high-value products and high volumes, making it easier to justify investment and to recognize economies of scale. The market is also compliance-driven, which means that it is possible to impose adoption timelines by creating a sense of urgency for the technology. However, the industry must agree on several issues before widespread adoption can occur. The issues include which frequency to use, whether there are standards for sharing data and for integrating data with back-end systems [Roberti 2006]. All these require a consensus among all the stakeholders in the industry. Once these issues are resolved and a consensus is reached, a domino effect will most likely follow, since the pharmaceutical value chain is heavily integrated with the consumer packaged goods, retail, and health-care supply chains.

RFID is an example of technology that relies on network effects to thrive and the rational expectations and adaptive learning perspective works particularly well with this kind of technology. This is because a manager with rational expectations that considers a technology with network effects will make sure that the other managers will also adopt the same technology; otherwise, the manager faces the risks of being stranded. *Stranding* occurs when only a manager or two decide to adopt the technology and the others decide not to, eliminating the chance for the adopters to realize the expected network benefits. We maintain that to avoid such risks, managers will choose to adopt the technology at about the same time: when they learn that all managers are ready to adopt. We call this phenomenon *clustered adoption* [Au and Kauffman 2003, 2005]. This necessitates each manager to continuously monitor the perceptions on the potential value of the technology of the other managers and adjust their own accordingly. This causes the migration in perceptions on potential value over time. Each manager might begin with different value expectations due to different information and capabilities that they possess but over time will adjust their perceptions and expectations. And since they have a mutual goal of getting the most benefit from the technology based on the common understanding that most of the benefit will come from network effects,

each manager will actually try to share as much information as possible and find the cheapest way to do so.

The need for managers to reach a consensus creates interesting dynamics in the IT investment and adoption decision-making process. Managers must now monitor each other's actions and perhaps take their signal from each other before making a technology investment/adoption decision. They should be aware, however, that there may be some exceptions to the rational expectations adaptive learning technology adoption process. This is because, along with this process, some managers may decide to conduct a pilot test, and some may even decide to adopt early before a consensus is reached. We can argue that an early technology adoption or investment decision is based more on risk-taking behavior than rational expectations. In other words, managers who are more averse to risk will still make a decision later when enough information has become available and has been processed appropriately and, more importantly, a consensus has been reached. This demonstrates the need for each manager to assess the risk tolerance of others who influence their decision-making process.

MANAGING POTENTIAL-TO-REALIZED VALUE TRAJECTORIES: AN EXTENSION

The theoretical model discussed previously suggests that managers should expect to see the phenomenon of drift or migration of technology value over time. In this section, we discuss a methodology that managers can use to manage the value trajectory of their technology investments better. We discuss how this perspective can be extended to treat settings in which technology investment planners and managers wish to manage the value trajectory for potential to realized value.

Market-Wide Consensus vs. Potential Value of Technology Investment

To better manage the value trajectory of technology investments, managers must first have a methodology or a tool that will enable them to objectively measure the potential and realized value of an IT investment. In this section, we will discuss a new methodology proposed by Goh and Kauffman [2006] that applies at the industry level, involving a production economics-based *potential value measurement model* (hereafter PVMM). The methodology uses the *Malmquist productivity index* to chart out the potential and realized value of investments in United States industries. The Malmquist productivity index is a non-parametric metric introduced by Caves et al. [1982] that measures the details of efficiency changes over time by economic units. The specification of this measurement model is flexible and can be generalized to measure the potential and realized value of firm-level, business-process and other activity-level IT investments. To apply this methodology, the user needs to have historical technology investment data, along with information on other factors of production and measures of the technology investment output. These include benefits such as process improvement data, cost savings information or evidence of revenue gains. Based on the historical data, PVMM permits the analyst to construct an upper boundary on the

potential value, which further enables the gap between the realized value and potential value to be assessed.

The model is designed to handle multiple technology production inputs and multiple outputs. This is helpful, because the benefits of technology often occur in different forms in various areas in the organization. Since the outputs do not have to be aggregated to a common measure (e.g., aggregate revenues or transactions), this facilitates a more accurate and informative estimation of the technology's potential value. The potential value of technology investments changes with accordance to new information made available to the manager. PVMM can assess technology investments across multiple periods of time, so that with each successive time period new investment and performance data will update and re-plot the boundary of potential value. The constant update of this boundary of potential value is useful to managers as it reflects the dynamic nature of value conversion hence providing realistic estimation to match investors' expectations.

PVMM has various uses for technology investors including: (1) estimating and updating expected value of existing project, (2) evaluating additional and complementary investment, and (3) *post hoc* assessment of managerial investment decisions. The use of this model for estimating existing projects is straightforward and involves the direct application of existing investment data available, as described in the previous paragraph. In the remainder of this section, we focus on describing the use of this model for evaluating additional investment. The model affords the user to obtain estimates of potential value for the impending investments, and this facilitates users to better evaluate the project as it is in its planning and implementation stages. Potential value projection is essential as it can be readily used as a gauge to assess additional complementary technology investment based on prior expectations. Technology investments often occur in various stages and one key information investors need is the projection of the potential benefits of the investment and how additional investment will complement and augment the potential value of existing investments in subsequent time periods. This information, however, is not readily and sufficiently estimated using conventional financial valuation techniques such as ROI or NPV [Devaraj and Kohli 2002]. Conventional financial valuation techniques focus mainly on cash flow and are unable to incorporate the risk profile, intangible benefits and stochasticity of IT investments.

PVMM is appropriate for this purpose, as by design, it decomposes the value conversion process for multiple time periods into (1) the change in potential value and (2) the change in realized value. Without getting into the calculus of the formulation, in multiple time periods where subsequent technology investments are being made, one expects the value conversion process to shift. This shift can be measured by either the change of potential value – where subsequent investments provide greater (or less) option value, or a change in realized value – where subsequent investments are more (or less) readily absorbed into the organizational processes to realize its benefit along the value trajectory curve. By populating the

measurement model with historic data that contains key parameters of technology investments made at multiple stages, the measurement model breaks down the shift in value conversion process at each stage of technology investment. Managers are able to observe the projected change in potential or realized value from one investment project to another to make a more informed decision for additional investment at different stages of the corporate IT plan. We next discuss the use of this measurement perspective for *post hoc* assessment of the quality of managerial decisions.

Managerial Decisions and the Realization of Technology Investment Value

Managerial performance is reflected by how well decisions are made in light of the information available and how these decisions are subsequently translated into firm performance. Technology investments are usually made based on prior beliefs and expectations about the payoff. An effective investment decision making process involves accurately weighing the potential benefits against the projected costs of investment to obtain an objective assessment of the investment plan. Having a model that measures the potential and realized value of IT investments like PVMM not only serves as a forecasting tool but also a *post hoc* quality assessment tool for managerial decisions. There are two ways to use PVMM for quality assessment on managerial decisions. First, the model can be used to measure the precision of the decision that is made (i.e., a decision assessment). Second, the model can be used to assess the effectiveness of the actions that follow from the decision result in payoffs for the firm (i.e., an action assessment).

Decision assessment involves evaluating the variance between manager's predicted potential value and actual potential value of the investment. In the accompanying text box, we provide a more precise description of how this assessment can be conducted using our modeling approach, PVMM. In this context, an *action assessment* involves evaluating the effectiveness of the managerial actions that follow throughout the cycle of investment for value realization. This assessment is performed mainly at the end of the implementation phase and can be extended to multiple time periods after the implementation is completed due to lags in the flow of the value payoffs.

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When the implementation is completed, the realized value of the investment at that point is not likely to match the potential value, for the technology needs time to be fully absorbed in the organization's business processes to achieve its maximum ability to create value. Similar to what we would do when we assess an IT investment decision, we compute the potential value of the investment at the end of implementation using PVMM, and compare this value against the realized value at various points in time after completion. The realized value in this case is measured using identical metrics and the gap between the potential and realized value signals the effectiveness of managerial actions in managing the implementation process to yield the realized value of the investment.

CONCLUSION

In this chapter, we have sought to provide some new ideas for how IT investment planning might be approached with a rational expectations planning perspective in mind. We have also made an effort to show how this perspective can be applied in practice, through its application in typical settings and through the introduction of some important concepts that help to structure senior managers' thinking.

Contributions

Our primary contribution to academic research is to provide a theoretical synthesis that relates rational expectations to concepts of potential and realized value of IT investments. In this case, rational expectations and adaptive learning theory recognizes the gap in the potential and realized value, and explains how such a gap can be minimized given sufficient time. We illustrate how the rational expectations hypothesis can be operationalized and implemented using production economic techniques, as a basis for exploring the payoffs of IT investments. Although this is a first step towards creating a synthesis of these two different theoretical paradigms, our effort is important in establishing a meaningful conceptual understanding of the theoretical underpinnings for rational expectations in IT investments. We highlight a model for measuring the potential and realized value of IT that helps extend the IS literature on IT value measurement. We also incorporate economic theory and management science methods that offer particular leverage for understanding this complex problem. We show how the application of this model will facilitate future research by enabling researchers to better understand the gap between the potential and the realized value of IT investments.

In this chapter, we have illustrated some ways in which a measurement model can be used by practitioners for future technology planning, and to assess current initiatives and evaluate past investments. This will aid practitioners in making optimal investment decisions and to better plan and implement their technology initiatives. We draw practitioners' attention to the ways that information can shape their expectations about investment payoffs and how new information is likely to affect the value trajectory for their IT investment alongside existing investments. By highlighting this process in our writing, we hope to establish a more in-depth understanding in senior managers' minds about the nature of the IT value conversion process. Finally, we have suggested and described various practical applications for the use of a *potential value measurement system* for practitioners. We hope this proposal will spawn new and valuable ideas related to the management of technology investments under conditions of uncertainty.

Limitations

Our objective in this chapter has been to showcase some newly-available theoretical and methodological perspectives that will serve to stimulate discussion among IS researchers and senior managers who are charged with making IT investment decisions. Although we have not presented empirical support in this chapter – instead, leaving that for future research – this does not undermine the usefulness of the

ideas that we have proposed. We have covered some of the relevant empirical literature in this domain on behalf of the reader, and we hope that this will encourage more empirical research on IT investment and evaluation practices from the rational expectations point of view.

In discussing the uses of PVMM, we suggest using historic investment data of technology investments, which may be difficult to acquire by firms that have limited prior experience in technology implementation. Despite this operational limitation, the benefits of the measurement system should not be overlooked. We believe that this application is still well-suited for software vendors and consulting firms that have access to a large amount of past investment data and have an interest in further developing it into a rational expectations-based forecasting tool.

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Text Box 1. Decision Assessment Using the Potential Value Measurement Model (PVMM)

We now provide a detailed illustration of our *potential value measurement model* (PVMM). We begin by assuming that the original managerial estimation of potential value is based on some other means of evaluation outside the scope of PVMM. For the purposes of this discussion, we will assume these estimates are based on some kind of heuristics for the assessment of IT value (e.g., order of magnitude of returns, Delphi assessments among a group of stakeholders, or individual “guesstimates,” etc.). The assessment can occur in all stages throughout the entire lifecycle of the investment. In the planning stage, the investment decision is made based on initial expectations and estimation of the potential benefits. We capture this initial heuristic-based estimate with the notation V for value in $V_{Planning}^{Heuristic}$. The subscript *Planning* represents the planning phase and the superscript *Heuristic* represents the evaluation heuristic that is used.

As the IT investment moves into the implementation stage, managers will have a greater sense of the technology in terms of its progress in implementation by the rate of its adoption and the functionality benefits that support value creation. Based on this latest information, they can heuristically update their projection of potential benefits, $V_{Implementation}^{Heuristic}$, with the subscript *Implementation* representing the implementation phase. At completion, managers will be fully informed of the technology’s capabilities, the organizational resistance or acceptance that has been experienced, and the qualities and influence of the business environment in which the technology is operating. This will permit them to update $V_{Implementation}^{Heuristic}$ to the final estimation of potential value, $V_{Completion}^{Heuristic}$, with the subscript *Completion* representing the completion phase of the investment cycle. To compare the accuracy of these heuristic-based estimates, we use PVMM to compute the potential value of the investment at the time of completion, V^{PVMM} . Estimates for V^{PVMM} should consist of performance metrics that are identical to the measures used to measure the value in the planning, implementation, and completion phases. The variances between V^{PVMM} and each of the prior managerial estimates will be quality indicators of the managerial investment decision. Overall, smaller variances tend to suggest higher decision quality, with managerial forecasts being highly reflective of the actual situation. One expects the variance to be larger for estimates in the early planning stages than when the investment is completely implemented, as we have seen in other research (e.g., on software development metrics in Banker et al. 1993, 1994).

Thus, it should be the case that: $\left| V^{PVMM} - V_{Planning}^{Heuristic} \right| > \left| V^{PVMM} - V_{Implementation}^{Heuristic} \right| > \left| V^{PVMM} - V_{Completion}^{Heuristic} \right|$. By definition, a positive variance in value, $V^{PVMM} > V^{Heuristic}$, for any of the heuristics indicates that the PVMM estimate is higher than the managerial estimate; a negative variance indicates the opposite. The presence of a negative variance suggests sub-optimal decision making as managers are over-estimating the potential value of the IT investment at different phases of investment. Although a positive variance may seem to be beneficial to the organization, in fact, it suggests that the managers may have adopted a risk-averse stance – and hence the lower estimation of value potential – and are making sub-optimal decisions for the firm by missing out on investment opportunities. This may be symptomatic of underinvestment in IT, a common problem where there are risks and uncertainties, information asymmetries, agency problems, and incomplete contracts between business partners [Han et al. 2004].

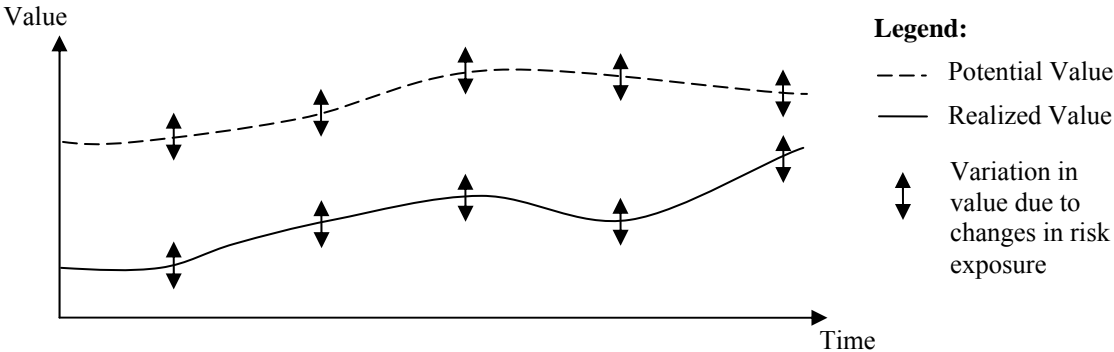
Table 1. Sources of Risk, Uncertainty and Incomplete Information

SOURCE	COMMENTS
Technology and innovation, vendor risks	Technology changes and emerging innovations are continuous in the marketplace, but the timing of their introduction is unknown. Vendors behind the technologies are of key concern, especially their willingness to support the chosen technology and their strategic commitment to a vision that is in line with the investor's needs relative to the technology.
Consumer acceptance	Consumers exhibit different rates of adoption and acceptance of technology-based products and services, depending upon the market segment to which they are introduced.
Management support, organization	Senior management commitment to a technology project, and stability of organizational structure and strategy intent are similarly critical, but often they cannot be guaranteed.
Operational and business process performance	Operational performance of a newly-implemented technology subject to a period of "work out" and refinement, so that it is possible to achieve maximum productivity and organizational performance with respect to it in different business and organizational processes.
Stakeholder support	Stakeholder acceptance of the technology implementation that occurs around an investment is also crucial, but may not be locked in prior to when the investment occurs. Stakeholders (e.g., buyers and suppliers, financial and accounting managers, industry and technology partners) have different goals in principal-agent terms, and the extent to which they have an incentive to support a given technology investment is not always clear.
Standards and externalities	Standards are either in question or stabilized for a period of time until the next major technology change occurs. For this reason, it is natural that managers may express uncertainty about how network externalities will develop in the marketplace, and what standard will become dominant.
Competition and Entry	The firm faces external risks and uncertainties in addition to changing technology, especially the uncontrollable actions of major competitors who may roll out similar technology-based products and services, and other unexpected new competitors who may leapfrog the competition by introducing innovative new processes and products that diminish the value of the existing ones.
Financial issues	Most organizations experience significant demand on their base of capital for all kinds of projects and uses – in addition to those that require capital commitment for technology investment projects. As a result, most organizations must endure periods of "scale-back" or "deferral" of additional necessary investments and the restructuring of large-scale IT investments, creating additional uncertainty for initial investments.

Table 2. Definitions for Primary Terms and Concepts from Rational Expectations Hypothesis

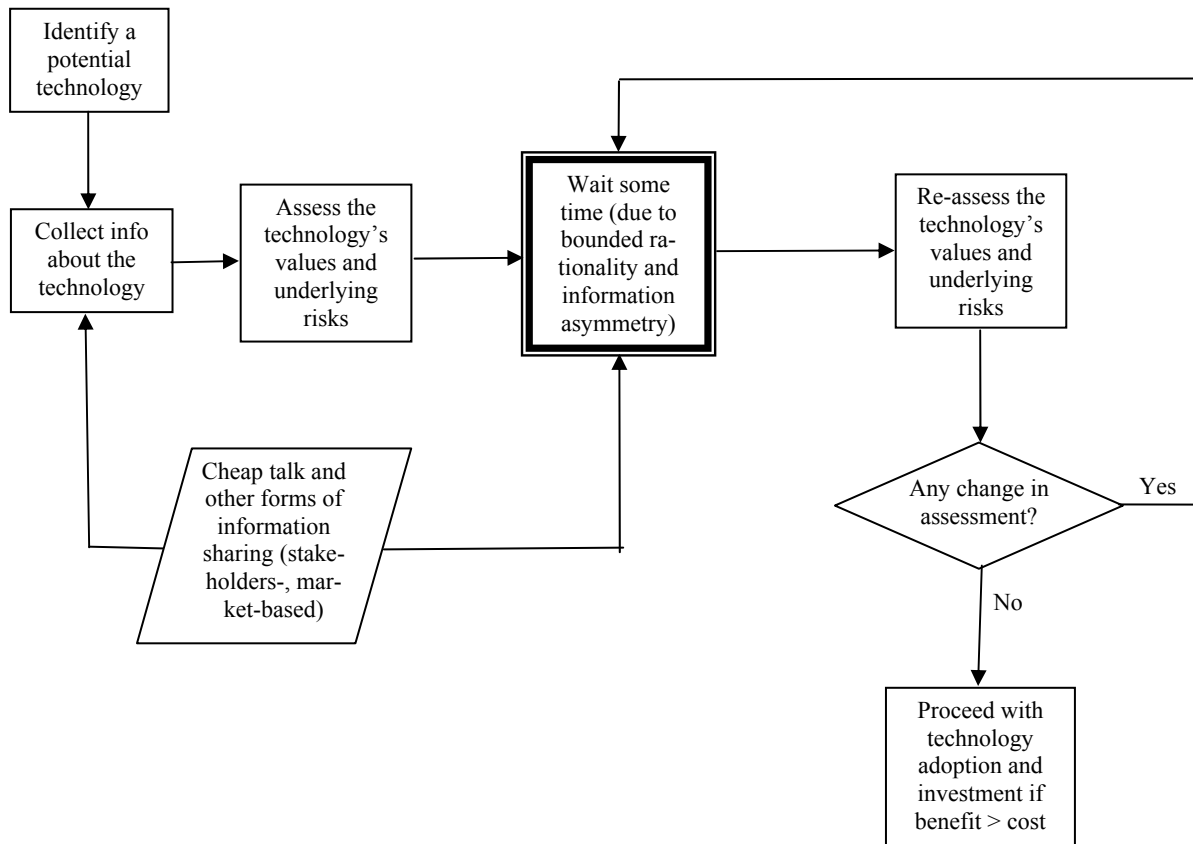
TERM	DEFINITION
Rational Expectations Hypothesis (REH)	A theory formulated by Muth [1961] that suggests that economic agents form their expectations on the basis of the “true” structural model of the economy in which their decisions are made, and that on average, these expectations are essentially the same as the predictions of the relevant economic theory.
Bounded Rationality	Recognizes the limited cognitive capacity of humans in decision making when they face problem complexity under the constraints of time and lacking information [Schwartz and Zozaya-Gorostiza 2003].
Adaptive Learning	Framework based on REH. Assumes that economic agents know the true equilibrium structural relations of the economy but—due to bounded rationality—are not allowed to learn the actual values of the parameters in the equilibrium relations [Muth 1961].
Rational Expectations Equilibrium (REE)	Equilibrium condition characterized by three features: all markets clear at equilibrium prices; every agent knows the relationship between equilibrium prices and private information of all other agents; and the information in equilibrium prices is exploited by all agents in making inferences about private information of others [Muth 1961].

Figure 1. Impacts of Changes in Risk Exposure on Potential and Realized IT Investment Value



Note: This figure is a theoretical illustration of the potential and realized value of an IT investment and does not represent any specific empirical result. Both the potential value and realized value of IT can drift upwards or downwards over time, depending on the organizational, environmental, technological and competitive forces that affect the risk exposure of the investment.

Figure 2. Rational Expectations Adaptive Learning IT Investment/Adoption Planning Model



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