

Enterprises as Systems: Essential Challenges and Approaches to Transformation

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ABSTRACT

The nature of enterprises as systems is considered. This exploration begins with discussion of the work of enterprises, with emphasis on challenges rather than routine operations. This reflects a desire to support enterprises as they address essential challenges. Situations where enterprise transformation is needed to successfully deal with challenges are then discussed. The nature of enterprise transformation is discussed in terms of ends, means, and scope, as well as perspectives, approaches, and solutions. This leads to elaboration of a portfolio of important research issues that suggests a wealth of potential means for supporting people in enterprises to accomplish the work of these enterprises. © 2005 Wiley Periodicals, Inc. Syst Eng 8: 138–150, 2005

Key words: enterprise systems; enterprise transformation; strategic management; system of systems

1. INTRODUCTION

When members of the technology community talk about systems, they often are thinking of airplanes, process plants, factories, transportation networks, and

command and control systems, to name just a few typical domains. Within these domains, concerns often focus on the effectiveness, efficiency, and safety of these systems. Pursuit of these issues may cause one to take great interest in the operators, maintainers, and perhaps designers of these systems. Consequently, in the past several decades, an enormous amount has been learned about how to support design and operation of such systems [e.g., see Sheridan and Ferrell, 1974; Sheridan, 1992, 2002; Rasmussen, 1986; Rasmussen

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and Goodstein, 1994; Sage, 1992, 1995; Sage and Rouse, 1999].

These types of systems are certainly very important. However, their importance to our economies and societies should be kept in perspective. There are thousands of commercial airplanes and hundreds of nuclear power plants, for example, and many thousands of people involved in their operations. In contrast, a much more ubiquitous type of system is the enterprise. An enterprise is a goal-directed organization of resources—human, information, financial, and physical—and activities, usually of significant operational scope, complication, risk, and duration. Enterprises can range from corporations, to supply chains, to markets, to governments, to economies.¹

If we consider this full range, there are millions of enterprises and billions of people involved in these systems. Despite their prevalence, enterprises are seldom considered to be systems. Instead, the focus is on engineering or manufacturing, or perhaps finance or sales, or maybe human resources. One might pursue optimal designs of products, processes, supply chains, etc. Or perhaps one might be concerned with managing the uncertainties of revenues and costs. This emphasis on maximizing, or minimizing, one attribute in isolation from others is sometimes termed suboptimization. One makes sure to get one thing “right” but, in the process, ignores everything else.²

However, computer and communications technologies are leading to everything becoming more integrated—everything connects to everything. We decrease our potential success when we try to design and manage functions within the enterprise independently of each other. The interactions are important, indeed essential to fully leveraging the enterprise’s assets—human, information, financial, and physical—to the greatest benefit for all stakeholders. This requires that we look at the whole enterprise as a system, rather than as a collection of functions connected solely by information systems and shared parking lots.

It could be argued that the issues just raised are not the province of systems engineering. However, in our experience working with a wide range of enterprises, we have found that other disciplines are not sufficiently systems oriented. They either focus on functional silos, or think in terms of “installing” a solution that, they

hope, will inherently integrate the enterprise. The perspectives and expertise epitomized by this journal are needed to truly pursue a systems-oriented view of enterprises.

This paper addresses the nature of enterprises as systems.³ This exploration begins with consideration of the work of enterprises, with emphasis on strategic challenges rather than routine operations. This reflects a desire to support enterprises as they address essential challenges. We then discuss those situations where enterprise transformation is needed to successfully deal with these challenges. The nature of enterprise transformation is discussed in terms of ends, means, and scope, as well as perspectives, approaches, and solutions. This leads to elaboration of important research issues whose pursuit is central to both understanding and enabling transformation. The portfolio of research issues outlined suggests many potential means for supporting people in enterprises to accomplish the work of these enterprises.

2. ESSENTIAL CHALLENGES

What do enterprises do? There are lots of meetings, much typing and filing, and many things are lifted and stacked. There are innumerable tasks and activities. It is important that this work be productive, safe, and rewarding. However, we cannot approach enterprise as systems at this level.

We need to begin with the work of the enterprise as a system, rather than the jobs, tasks, and activities of the many people that work in the enterprise. To an extent, we need to conduct a work domain analysis of an enterprise (Rasmussen, Pejtersen, and Goodstein, 1994; Vicente, 1999). This analysis should begin with consideration of the goals and objectives of the work of enterprises.

Goals and objectives might be considered in terms of revenues, profits, market share, etc., for the private sector, and budgets, constituencies served, and so on for the public sector. However, this level of analysis tends to be idiosyncratic. Instead, we should begin with the recognition that all enterprises face similar strategic challenges—shown below—that must be appropriately understood and addressed for enterprises to succeed (Rouse, 2001).

¹Supply chains can be viewed as extended enterprises linking upstream and downstream providers and consumers of raw materials, components, products, services, and so on. Markets can be viewed as further extensions, often involving several supply chains.

²“Systems of systems” where component systems have goals and priorities that are not fully aligned with enterprise goals and priorities appear to be more prone to such suboptimization (Sage and Cuppan, 2001).

³It is important to distinguish enterprise systems from enterprises as systems. For example, ERP (Enterprise Resource Planning) systems are often referred to as enterprise systems. ERP can certainly be important to enterprises as systems, but they are by no means synonymous. Interestingly, if ERP architecting and integration are based on a view of the enterprise as a system, then many of the difficulties encountered with ERP initiatives might be mitigated (Economist, 1999).

- Growth: Increasing Impact, Perhaps in Saturated/Declining “Markets”
- Value: Enhancing Relationships of Processes to Benefits & Costs
- Focus: Pursuing Opportunities & Avoiding Diversions
- Change: Competing Creatively While Maintaining Continuity
- Future: Investing in Inherently Unpredictable Outcomes
- Knowledge: Transforming Information to Insights to Programs
- Time: Carefully Allocating the Organization’s Scarcest Resource

There are a variety of ways of approaching these challenges (Collins and Porras, 1994; Collins, 2001; Rouse, 2001). Despite the pronouncements of a plethora of management gurus, there is no “silver bullet” that handles all these challenges. Strategic management involves understanding which challenges are central and adopting a reasonable approach among the many possibilities.

As shown in Figure 1, *growth* has to be the goal. Growth can be cast in terms of economic, behavioral, and/or social impacts, or possibly in terms of improved quality, service, and responsiveness. The key point is that growth is a must—the only alternative is decline. Enterprise stasis is not a stable state. Hence, growth must be pursued or decline is assured.

It should be emphasized that share price, earnings per share, revenues, market share, and so on reflects just one perspective on growth. Impact can be measured in many ways. Enterprises can improve the quality of their offerings, the benefits of their services for their con-

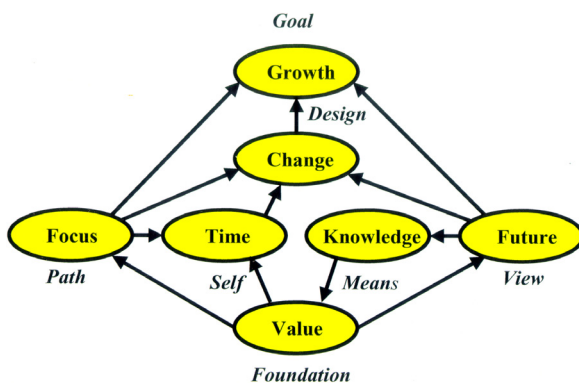


Figure 1. Relationships among challenges. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

stituencies, and/or the influence of their activities and communications without necessarily growing financially or in terms of staff and facilities. Indeed, in some situations, growth of impacts may have to be pursued while such human, financial, and physical resources are declining.

There are, admittedly, situations where graceful decline may be the appropriate goal. In such cases, the enterprise transformation of interest might be from providing value to providing nothing, perhaps in the sense of doing no harm in the process. Ideally, one might like to assure a “soft landing” for the enterprise’s stakeholders. This unusual, though not improbable, case involves many concerns beyond pursuit of negative growth, e.g., liability and tax implications of ceasing operations, which are beyond the scope of this paper.

Value provides the foundation for growth. Understanding the nature of value, its evolution or migration, and the consequent growth opportunities are critical elements of this challenge (Slywotsky, 1996; Slywotsky and Morrison, 1997). One then, of course, must devise a value proposition and associated business processes to secure this growth. Understanding and enhancing the value streams that provide value to constituencies are keys to successful growth (Womack and Jones, 1996).

Focus provides the path to growth. Pursuit of opportunities and avoidance of diversions can be quite difficult (Rouse, 1998), particularly in the presence of significant organizational learning disabilities (Senge, 1990), or when the organization is trapped in single-loop learning (Argyris and Schon, 1978). Equally difficult is *change* in terms of designing the enterprise to pursue this path (Rouse, 1993). Both focus and change can create enormous organizational and cultural change problems (Collins and Porras, 1994; Collins, 2001). Strong leadership is crucial during such transitions (Charan and Colvin, 1999; Bennis and O’Toole, 2000; Rouse, 2001).

The nature of the *future*, especially the long-term future, exacerbates the difficulties of focus and change. Not only are the magnitudes and timing of investment returns uncertain—the very nature of the returns is uncertain (Burke, 1996). Further, most large enterprises have difficulty taking advantage of new ideas, even when they are due to their original investments (Christensen, 1997).

The uncertainties and risks associated with an enterprise’s view of the future create needs for hedges against downsides, while still being focused on the upsides. Option-based thinking can provide the needed balance between these two perspectives (Luenberger, 1997; Amram and Kulatilaka, 1999; Boer, 1999, 2002). Options provide ways for addressing an enterprise’s future,

contingent opportunities and needs (Rouse and Boff, 2004).

Knowledge is the means by which enterprises increasingly address these challenges. It can be quite difficult to transform data, information, and knowledge into programs of action and results (Whiting, 1999; Zack, 1999). This involves both understanding the roles of information and knowledge in problem solving and decision making in different domains (Rouse, 2002), as well as the ways in which archival knowledge and people with knowledge can meet these needs (Cook and Brown, 1999; Brown and Duguid, 2000).

Time is an overarching challenge for leaders of enterprises. To a great extent, leaders define themselves by how they spend their time (Rouse, 1994, 2001). Transformational leadership involves devoting personal time to those things that will create lasting value (Kouzes and Posner, 1987; George, 2003). Time is the scarcest of leaders' resources, much more than financial and physical resources. Nevertheless, leaders often report being trapped by urgent but unimportant demands for their time (Covey, 1989; Miller and Morris, 1999). This is a classic challenge for senior management (Oncken and Wass, 1974; Mintzberg, 1975).

Considering the nature of the above challenges, what do executives or teams of executives do? One might imagine that they spend time creating models, analyzing tradeoffs, and attempting to optimize allocations of resources. However, the fact is that executives and managers spend their time reacting to their environments, negotiating compromises, and "satisficing" much more than optimizing (Mintzberg, 1975; Simon, 1957, 1969). In general, they have to consider and balance the perceptions, concerns, and desires of the many stakeholders in their enterprises.

To understand and support these executives, we need to adopt a similar human-centered philosophy (Rouse, 1991, 1992, 1993). Understanding and supporting the interests of an enterprise's diverse stakeholders—and finding the "sweet spot" among the many competing interests—is a central aspect of discerning the work of the enterprise as a system and creating mechanisms to enhance this work.

3. ENTERPRISE TRANSFORMATION

There is a wide variety of ways to address the essential challenges just outlined (Collins and Porras, 1994; Collins, 2001; Rouse, 2001). Process improvements and other incremental changes may be sufficient for a particular enterprise's challenges. However, in some cases, addressing these strategic challenges may involve enterprise transformation, i.e., fundamental changes in

terms of relationships to markets, product and service offerings, market perceptions, and/or cost pressures (Hammer and Champy, 1993). Understanding and supporting transformation are critical to enhancing enterprises as systems.

A framework for understanding the nature of transformation is shown in Figure 2. The goal or ends pursued via transformation tends to significantly differentiate initiatives. The approach or means adopted for transformation pursuits relates to both the goals pursued and the nature and competencies of the enterprise. The ends and means, as well as extent of integration of the enterprise, influence the scope of transformation.

The ends of transformation can range from greater cost efficiencies, to enhanced market perceptions, to new product and service offerings, to fundamental changes of markets. The means can range from upgrading people's skills, to redesigning business practices, to significant infusions of technology, to fundamental changes of strategy. The scope of transformation can range from work activities, to business functions, to overall organizations, to the enterprise as a whole.

We have found this framework to provide a useful categorization of a broad range of case studies of enterprise transformation. Considering transformation of markets, Amazon leveraged IT to redefine book buying, while Wal-Mart leveraged IT to redefine the retail industry. Illustrations of transformation of offerings include CNN redefining news delivery, Motorola moving from battery eliminators to radios to cell phones, UPS transforming from solely package delivery to being a provider of integrated supply chain management services, and IBM moving from an emphasis on selling computer products to providing integrated technology services. Examples of transformation of perceptions include Dell repositioning computer buying and Starbucks repositioning coffee buying. The many instances of transforming business operations include Lockheed Martin merging three aircraft companies and Newell resuscitating numerous home products companies.

The costs and risks of transformation increase as the endeavor moves farther from the center in Figure 2. Initiatives focused on the center (in green) will typically involve well-known and mature methods and tools from industrial engineering and operations management. In contrast, initiatives towards the perimeter (in red) will often require substantial changes of products, services, channels, etc., as well as associated large investments.

It is important to note that successful transformations in the outer band of Figure 1 are likely to require significant investments in the inner bands also. In general, any level of transformation requires consideration of all subordinate levels. Thus, for example, successfully changing the market's perceptions of an enter-

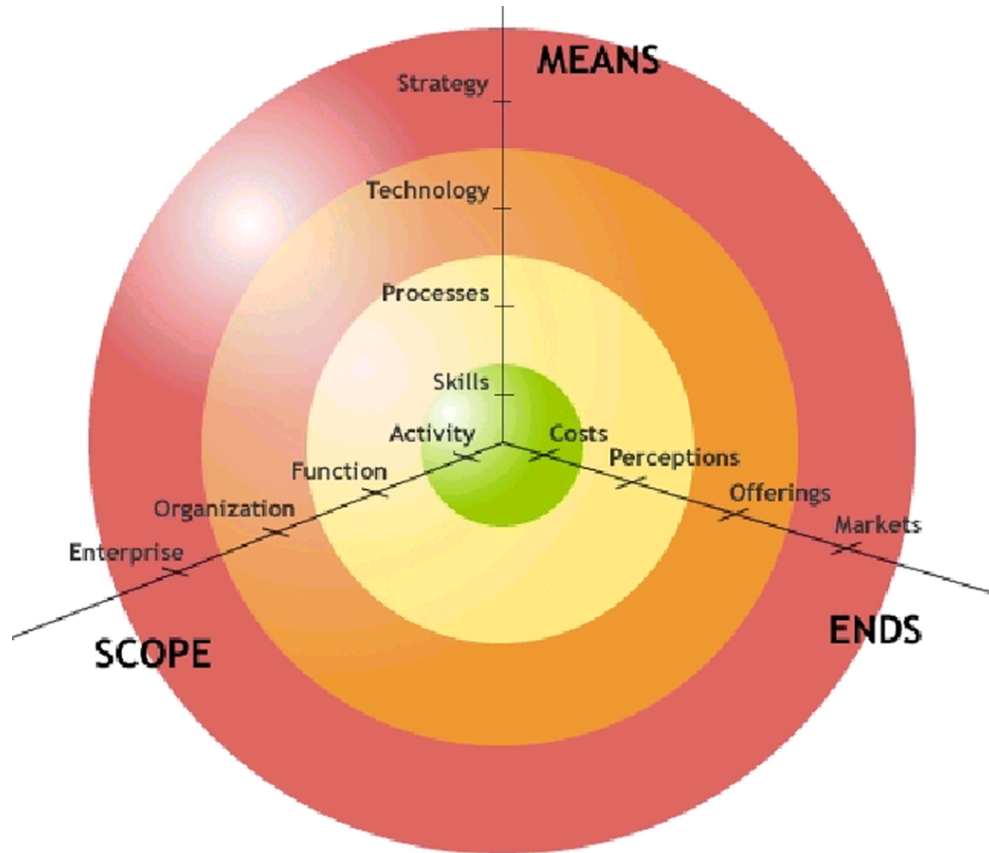


Figure 2. Transformation framework. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

prise's offerings is likely to also require enhanced operational excellence to underpin the new image being sought. As another illustration, significant changes of strategies often require new processes for decision making, e.g., for R&D investments (Roussel, Saad, and Erickson, 1991; Matheson and Matheson, 1998; Miller and Morris, 1999; Rouse and Boff, 2004).

3.1. Perspectives on Transformation

There are basically four alternative perspectives that tend to underlie perceived needs for transformation:

- Market and/or technology *opportunities*—the lure of greater success prompts transformation initiatives.
- Market and/or technology *threats*—the danger of anticipated failure prompts transformation initiatives.
- *Competitors'* initiatives—others' transformation initiatives prompt recognition that transformation is necessary to continued success.

- Enterprise *crises*—steadily declining market performance, cash flow problems, etc., prompt recognition that transformation is necessary to survive.

The perspectives driven by external opportunities and threats often allow pursuing transformation long before it is forced on management, increasing the chances of having resources to invest in these pursuits, leveraging internal strengths and mitigating internal weaknesses. In contrast, the perspectives driven by external competitors' initiatives and internally-caused crises typically lead to the need for transformation being recognized much later and, consequently, often forced on management by corporate parents, equity markets, or other investors. Such reactive perspectives on transformation often lead to failures.

3.2. Approaches to Transformation

Transformation initiatives driven by external opportunities and threats tend to adopt strategy-oriented approaches such as:

- Markets Targeted, e.g., pursuing global markets such as emerging markets, or pursuing vertical markets such as aerospace and defense
- Market Channels Employed, e.g., adding web-based sales of products and services such as automobiles, consumer electronics, and computers
- Value Proposition, e.g., moving from selling un-bundled products and services to providing integrated solutions for information technology management
- Offerings Provided, e.g., changing the products and services provided, perhaps by private labeling of outsourced products and focusing on support services.

On the other hand, transformation initiatives driven by competitors' initiatives and internal crises tend to adopt operations-oriented approaches including:

- Supply Chain Restructuring, e.g., simplifying supply chains, negotiating just-in-time relationships, developing collaborative information systems
- Outsourcing & Offshoring, e.g., contracting out manufacturing, information technology support; employing low-wage, high-skill labor from other countries
- Process Standardization, e.g., enterprise-wide standardization of processes for product and process development, R&D, finance, personnel, etc.
- Process Reengineering, e.g., identification, design, and deployment of value-driven processes; identification and elimination of non-value creating activities
- Web-Enabled Processes, e.g., online, self-support systems for customer relationship management, inventory management, etc.

It is essential to note, however, that no significant transformation initiative can rely solely on either of these sets of approaches. Strategy-oriented initiatives must eventually pay serious attention to operations. Similarly, operations-oriented initiatives must at least validate existing strategies or run the risk of becoming very good at something they should not be doing at all.

Recognitions of perspectives and adoption of appropriate approaches should be determined by a clear understanding of the current and emerging situations faced by the enterprise (Rouse, 1996). Delusions about the current situation can completely undermine strategic thinking about opportunities, threats, competitors, and crises (Rouse, 1998). Consequently, the approaches

adopted may not match the underlying needs of the enterprise.

3.3. Enterprise Solutions

Many approaches to transformation, especially those that are operations-oriented, are pursued in the context of information technology "solutions" such as:

- Enterprise Resource Planning (ERP)
- Customer Relationship Management (CRM)
- Supply Chain Management (SCM)
- Sales Force Automation (SFA).

The large investments required to deploy these types of solutions need to be understood in the context of how they help enterprises to address essential challenges and, in many cases, fundamentally transform. "Installing" these solutions is only a beginning, as many enterprises have discovered after the fact (Economist, 1999).

The architecting of such enterprise information systems should reflect the enterprise as a system, or system of systems (Sage and Cuppan, 2001). Integration across the component systems should consider the primary value streams of the enterprise (Rouse and Boff, 2001, 2003). Particular attention should be paid to how information and knowledge are shared and support creation and execution of programs of action that enhance value (Rouse, 2001, 2002).

Ideally, these types of enterprise solutions are viewed as just a piece of the transformation puzzle, albeit a large one. Addressing and resolving the people and organizational issues associated with these solutions are often the thorniest part of the road to success. Understanding work processes, both as they are and should be, is usually central. Training and aiding of personnel—at all levels—also tends to be very important, as does alignment of incentives and rewards with new processes.

4. RESEARCH ISSUES

The essential challenges of strategic management, as well as the overarching challenge of enterprise transformation, suggest a large number of research issues. Figure 3 portrays several broad categories of issues. A number of initiatives within these categories are described below.

4.1. Best Practices

As noted earlier, there is a wealth of practices available with which to address the essential challenges as well as enterprise transformation (Collins and Porras, 1994;



Figure 3. Research issues in enterprise transformation. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Collins, 2001; Rouse, 2001). An important research issue concerns the extent to which any of these practices can be declared “best” practices, at least for specific types of situations and enterprises with particular characteristics. Quite frankly, many published practices tend to be reasonable and good ideas that are reported to have worked someplace at least once.⁴

To declare a practice as “best,” we need to measure the benefits of employing the practice relative to alternative practices. Addressing the challenges, as well as transformational approaches to the challenges, tends to take quite a bit of time, and measuring the benefits takes even longer. As the medical profession knows well, it is very difficult to conduct studies over many years and maintain support and commitment, as well as control.

This reality has led us to focus on what enterprises have done in the past and the consequences of these initiatives. We are using a database of the yearly and quarterly reports of all public companies worldwide, as well as major analysts’ projections and assessments of these companies’ performance, over the past 20–30 years. We are sleuthing what transformation initiatives these companies undertook and the subsequent benefits of these undertakings, including the time frame within which benefits typically emerge.

As we have discussed this research with various senior executives, in both private and public sectors, several have asked that we not limit ourselves to just best practices. They have indicated keen interest in worst practices. Specifically, they would like to know what types of transformation practices have never

⁴Of course, it can be quite reasonable to proceed with a good, but less than best practice, perhaps because it is important to act immediately. Nevertheless, it is important to understand how well practices work and why some practices might work much better than others.

worked in any measurable manner. They expect that this will eliminate many candidate approaches.

This points up the need to understand the whole distribution of practices, not just the tails of best and worst. Such understanding will enable understanding of the internal and external factors that influence the success of practices, e.g., role of leadership, nature of industry, and state of economy. Thus, the notion of best practices is clearly a multidimensional construct rather than a one size fits all “silver bullet.”

This research on best—and worst—practices will tell us what really has worked, including the conditions under which it worked. Also very important is the fact that this research is providing deep grounding on current practices and experiences implementing these practices. This grounding provides a foundation for looking further out. We are particularly interested in the 3–5-year time horizon to be able to understand the opportunities, threats, problems, and issues likely to affect enterprises just beyond their current planning horizon. The following subsections consider this time horizon and beyond. This is a perfect place for enterprise-oriented research to focus.

4.2. Methods and Tools

To pursue science-based engineering approaches to understanding, designing, and managing enterprises as systems, we need methods and tools. Fortunately, there is a wide variety of systems-oriented concepts, principles, methods, and tools with which one can pursue the essential challenges and, if necessary, transform the enterprise (Sage and Rouse, 1999; Rouse, 2001). In fact, the wealth of alternatives poses the problem of understanding how all these approaches fit together or, at least, where one or the other applies.

For example, when is Total Quality Management, Six Sigma, Business Process Reengineering, or Lean Transformation the best approach? At a methodological level, when should one employ models based on queuing networks, systems dynamics, Petri nets, or agent-based simulation? We are in the process of trying to make sense of the many alternatives and provide guidelines—and guidance—for what to use where.

More fundamentally, we are concerned with formal modeling of enterprises. One needs to understand both the “as is” and “to be” enterprise and the nature of the transformations for getting from one to the other. This is difficult because we need to determine how alternative representations interact with the range of mathematical machinery that can be brought to bear, while also being able to incorporate essential economic, behavioral, and social phenomena.

Beyond the difficulty of formally representing the “as is” and “to be” enterprise, it can be difficult to simply characterize the “as is” enterprise. People within the enterprise often have remarkably little perspective for the business processes to which their activities contribute. They may also be defensive and apprehensive regarding possible changes.

This can be particularly difficult when activities are part of the “overhead” that does not clearly contribute to the value streams of the enterprise. Such activities are likely candidates for being outsourced or eliminated. Even when these activities are required for regulatory reasons, for example, people can be concerned that their jobs are at risk.

At this point, we are working with methods drawn from engineering, computing, and architecture. These three disciplines pursue formal methods for quite different reasons—engineering to represent the physical flows in the system, computing to represent the information flows, and architecture to represent human flows within and among physical spaces. Enterprises, of course, include all these types of flows. We need methods that enable representation and manipulation of these different flows across a set of computationally compatible tools.

These models, methods, and tools are likely to provide the basis for aiding leaders of enterprises in that they will enable making sense of and portraying what is happening in the enterprise, as well as developing and evaluating potential courses of action (Mykityshyn, 2004). A rudimentary example is provided by a suite of tools we developed to address market situation assessment, new product planning, and technology strategy (Rouse and Howard, 1995, Rouse et al., 2000, Rouse, 2001). This suite integrates multistakeholder, multiattribute models, Quality Function Deployment, technology/market maturity models, production learning curves, option pricing models, and expert systems to address the enterprise challenges of growth and value. These tools draw upon representations from marketing, engineering, manufacturing, finance, operations research, and artificial intelligence.

One of the difficulties in employing these and other method and tools concerns the ability to estimate needed parameters, preferably as probability distributions rather than point estimates. Despite the wealth of data typically collected by many enterprises, it usually requires substantial effort to translate these data into the information and knowledge needed by these methods and tools. This leads us to consideration of information technologies.

4.3. Enterprise Technologies

Current and emerging enterprise technologies are both driving and enabling enterprise transformation. Computer and communications technologies are central. Information technology (IT) is a broad description. Most people see IT as the key to transformation. Yet, as just noted, simply “installing” these technologies does not fully address enterprise challenges.

The central concern in this research area is not with what technologies will emerge, but instead with the implications of their adoption if they do emerge. In particular, the focus is on organizational implications and strategy/policy issues associated with these implications (Rouse and Acevedo, 2004). Thus, the issue is not whether it will happen, but the implications if it does happen.

A good example of an emerging technology or capability is knowledge management, including its key enabler—collaboration technology (Rouse, 2001, 2002; Rouse and Acevedo, 2004). Fully leveraging this technology/capability requires a deep understanding of how knowledge is—and could be—generated and shared in an enterprise, as well as its impact on important metrics of enterprise success. The issue is not so much about how the technology functions as it is about how work currently gets done and could be done with these capabilities (Cook and Brown, 1999; Brown and Duguid, 2000).

Another good illustration of an emerging enterprise technology relates to the area of identity management. How should one authenticate who and what is connected to the enterprise network? The relevant technologies include Public Key Infrastructure (PKI), Common Access Cards (CAC), Biometrics, and Radio Frequency Identification (RFID). Our research is focused on the interoperability, security, and privacy implications of adopting these technologies to provide the needed functionality and performance within various IT systems, i.e., authentication, authorization, confidentiality, integrity, nonrepudiation, availability, etc. An additional important issue is the total cost of ownership of such capabilities.

Another area is wireless communications and mobile computing. Basole (2004) addresses the implications for enterprises that entertain these technologies. One implication may be greater reliance on virtual organizations and less use of traditional workspaces. Ashuri (2004) looks at the strategic decision to move towards a balance of virtual and traditional workspaces. The value of both mobile and virtual technologies depends on how they affect work and productivity.

4.4. Organizational Simulation

When enterprises entertain major, transformational changes, they typically perform a wealth of feasibility and financial analyses. At some point, they may determine that “it’s worth it.” However, there still may be reluctance among key stakeholders. The problem is likely to be that economic analyses do not usually address behavioral and social concerns. Spreadsheet models and colorful graphic presentations seldom provide a sense of what the changes will feel like.

Organizational simulation can address these concerns (Rouse and Boff, 2005). Immersive simulations can enable decision-makers and other stakeholders to experience the future, act in that future, and have the future react to them. If this is a positive experience, then decision-makers can proceed with increased confidence. On the other hand, if problems are encountered, the future can be redesigned before the check is written.

This research draws upon traditional modeling and simulation as well as artificial intelligence, gaming, and entertainment. Our overriding premise is that people are more likely to embrace those futures that they can experience beforehand. Embracing these futures will, in turn, enable enterprise transformation by mitigating the human and organizational concerns that often undermine transformation initiatives.

It is also useful to note that this element of the research portfolio tends to generate comments of “wow” more often than other elements. The immersive experience tends to be compelling. Of course, that is exactly the point. Enterprise transformation can be strongly facilitated and sustained by compelling experiences of the post-transformation future.

This can be particularly important in environments where some of key stakeholders do not find financial analyses and spreadsheet presentations convincing. For example, the public, politicians, unions, etc., may need to experience infrastructure innovations—new modes of public transportation, for instance—before they will support such initiatives.

Simulation of organizational futures can be particularly useful if it allows for unintended consequences to emerge. This is quite possible when a range of stakeholders “play the game” and react differently than expected to the environment and to each other. In some cases, participants may subvert the game, i.e., work around the rules, and prompt discoveries and insights that possibly lead to innovations in strategy, doctrine, and strategic thinking in general (Rouse and Boff, 2005).

Organizational simulations can offer interactive glimpses of the future, enable the design of operational procedures in parallel with system design, and provide

rich, ready-made training environments once systems are deployed. This may result in enterprise transformation being an adventure rather than a dreaded threat. In particular, transformation can perhaps be an adventure that the key stakeholders design and redesign as they experience it.

4.5. Investment Valuation

Starting with best practices, we employ methods and tools to design the transformed enterprise, enabled by emerging enterprise technologies, and experienced via organizational simulation. This nevertheless begs the question, “What’s it worth?” How should we attach value to the investments needed to transform the enterprise?

Of course, this question has been with us for a long time. We just need to project revenues, costs, and profits (or savings) and discount these time series to get a Net Present Value (NPV). Unfortunately, most of the investment for transformation occurs in the near-term while much of the return from transformation occurs in the long-term. Aggressive discount rates—adopted because of the large uncertainties—will render long-term payoffs near worthless.

This phenomenon also impacts investments in R&D, as well as investments in education, the environment, and so on. The value of any long-term initiatives with upstream investments, downstream returns, and large uncertainties will suffer from discounted cash flow analysis. This raises a question of the fundamental purpose of such investments.

Should an enterprise invest in transformation solely to fix today’s problems? For example, should the R&D budget of an enterprise be justified solely on the basis of the likely contributions to today’s product and service offerings? The answer clearly is, “No.” Investments in R&D should provide the enterprise options for meeting contingent downstream needs, many of which are highly uncertain in nature and impact (Rouse and Boff, 2001, 2003, 2004).

In this area, we are researching alternative option-pricing models for valuation of long-term investments such as R&D, economic development, and transformation. We have conducted numerous case studies and, as a result, influenced many investment decisions. It is clear that options for the future are exactly what most enterprises need. These models and methods enable them to determine what these options are worth.

This research has provided several insights, at least one of which is fundamental. Using NPV for valuation of long-term, highly uncertain transformation initiatives tends to emphasize preservation of investment capital. In contrast, using Net Option Value (NOV)

tends to maximize the value gained by the enterprise. In other words, using NPV minimizes risks to the transformation budget, while using NOV maximizes the benefits of transformation. We are in the process of determining how this contrast is affected by the magnitude, timing, and uncertainties associated with these investments.

4.6. Organizational Culture and Change

The above initiatives imply substantial changes of processes, practices, technologies, and measures of success. These changes must be pursued in the context of the organizational culture of the enterprise in question. Often this culture is not compatible with what will be needed to successfully transform. A lack of recognition of this mismatch is a fundamental organizational delusion that may enfeeble change initiatives (Rouse, 1998).

As depicted in Figure 3, our concern is not with organizational culture and change in general. The topic is far too immense. Instead, we are interested in culture and change as they relate to the other initiatives. For instance, we have pursued the implications of deploying of new enterprise technologies, e.g., collaboration suites, in terms of interactions with cultural norms of knowledge sharing and online work (Rouse and Acevedo, 2004).

One particularly interesting phenomena concerns enterprises' decisions to pursue transformation rather than, for example, incremental process improvements. A related phenomenon is the emerging recognition that transformational change is at hand despite never having explicitly decided to pursue such a fundamental initiative. Garcia (2004) is researching the antecedents of transformation decisions, including emergent decisions. Specifically, she is concerned with what drives and triggers such decisions and recognitions.

4.7. Research Methodology

Pursuit of the broad set of research issues and approaches outlined in this section requires a similarly broad set of research methods. Modeling representations can range from discrete-event to continuous-time models, to a range of network models, to rule-based and statistical models. Different disciplines bring a range of representations to the study of complex systems (Sage and Rouse, 1999; Rouse, 2003).

There is also a range of simulation and computational tools, with differences reflecting the variations of the modeling representations. Unfortunately, it is still rather difficult to move across representations and tools. Thus, hybrid representations such as needed for organizational simulation often must be hand-crafted (Rouse and Boff, 2005). Lack of powerful, easy-to-use tools

tends to drive up the time, costs, and risks when modeling complex enterprise systems.

Another methodological issue concerns identifying, collecting or accessing, and interpreting data. In many cases, data that one would assume would easily be available has not been captured or has been archived in difficult-to-access forms. Thus, data for benchmarking, model fitting, and validating predictions can be quite expensive to obtain, often prohibitively. Ongoing developments of enterprise information systems should improve this situation, but not without some forethought.

4.8. Summary

The research portfolio summarized in Figure 3 constitutes the puzzle pieces of a foundation for understanding and supporting enterprise transformation. We need to understand best practices to move beyond an endless stream of reasonable, yet unproven ideas. Methods and tools are important to increasing the rigor of this work, while also making it more efficient. Emerging enterprise technologies both drive and enable the transformations designed with these methods and tools. Organizational simulation provides a laboratory for enterprise experimentation, as well as furnishes a means to communicate with stakeholders less open to purely analytical arguments. Investment valuation provides new methods and tools for assigning value to transformation initiatives with highly uncertain, long-term returns. Finally, understanding organizational culture and change is essential to successful implementation of any of these ideas.

5. CONCLUSIONS

Understanding enterprises as systems—or as a system of systems—is critical to moving beyond piecemeal transformations. This understanding is also important to creating better enterprise systems that can support transformation rather than just incremental improvements of collections of enterprise functions. Overall, the goal is for these huge investments to yield greater returns, sooner.

Fundamental research is necessary to provide a firm foundation for achieving this goal. This research is inherently highly multidisciplinary and must address somewhat messy, complex problems laced with technological, economic, behavioral, and social issues. The research outlined here can certainly contribute to understanding the apparent complexity of these problems. However, we must also create the means for coping with the complexity of reality if we are to improve this reality.

Understanding enterprises as systems is necessary to facilitating and sustaining enterprise transformation. Previous functionally oriented solutions have resulted in suboptimization and substantially less benefit than possible with more integrated solutions that involve architectures premised on a system of systems perspective. The “macro” perspective advocated here embraces multiple views of the enterprise and, thereby, can take advantage of the concepts, principles, methods, and tools of many disciplines—this strongly reflects both the philosophy and substance of systems engineering and management. The resulting level of integration and interoperability, both theoretically and practically, we believe will prove to be the key to successful enterprise transformation.

The perspectives and expertise epitomized by this journal are needed to frame and pursue this research, as well as facilitate deploying the results of research initiatives. Given the inward focus of the many disciplines essential to these pursuits, success will require considerable “intellectual integration.” Systems engineers, as is often the case, will have to serve as facilitators and communicators that see the connections and distinctions of most importance.

REFERENCES

- M. Amram and N. Kulatilaka, *Real options: Managing strategic investment in an uncertain world*, Harvard Business School Press, Boston, 1999.
- C. Argyris and D.A. Schon, *Organizational learning: A theory of action perspective*, Addison-Wesley, Reading, MA, 1978.
- B. Ashuri, Framing strategic tradeoffs between traditional and virtual organizations and workspaces, *Proc IFAC Symp Anal Model Eval Hum-Machine Syst*, September 2004.
- R. Basole, The value and impact of mobile information and communication technologies, *Proc IFAC Symp Anal Model Eval Hum-Machine Syst*, September 2004.
- W. Bennis and J. O’Toole, Don’t hire the wrong CEO, *Harvard Bus Rev* (May–June 2000), 78, 171–176.
- F.P. Boer, *The valuation of technology: Business and financial issues in R&D*, Wiley, New York, 1999.
- F.P. Boer, Financial management of R&D, *Res Technol Management* 45(4) (2002), 23–35.
- J.S. Brown and P. Duguid, Balancing act: How to capture knowledge without killing it, *Harvard Bus Rev* (May–June 2000), 78, 73–80.
- J. Burke, The pinball effect: How Renaissance water gardens made the carburetor possible and other journeys through knowledge, Little, Brown, Boston, 1996.
- R. Charan and G. Colvin, Why CEOs fail, *Fortune* (June 21, 1999), 68–78.
- C.M. Christensen, *The innovator’s dilemma: When new technologies cause great firms to fail*, Harvard Business School Press, Boston, 1997.
- J.C. Collins, *Good to great: Why some companies make the leap and others don’t*, Harper Business, New York, 2001.
- J.C. Collins and J.I. Porras, *Built to last: Successful habits of visionary companies*, Harper Business, New York, 1994.
- S.D.N. Cook and J.S. Brown, Bridging epistemologies: The generative dance between organizational knowledge and organizational knowing, *Org Sci* 10(4) (1999), 381–400.
- S.R. Covey, *The seven habits of highly effective people*, Simon & Schuster, New York, 1989.
- Economist, ERP RIP? *The Economist* (June 24, 1999).
- D. Garcia, Enterprise transformation: Forces and processes of change, *Proc IFAC Symp Anal Model Eval Hum-Machine Syst*, September 2004.
- B. George, *Authentic leadership: Rediscovering the secrets to creating lasting value*, Jossey-Bass, San Francisco, 2003.
- M. Hammer and J. Champy, *Reengineering the corporation: A manifesto for business revolution*, Harper Business, New York, 1993.
- J.M. Kouzes and B.Z. Posner, *The leadership challenge: How to get extraordinary things done in organizations*, Jossey-Bass, San Francisco, 1987.
- D.G. Luenberger, *Investment science*, Oxford University Press, Oxford, UK, 1997.
- D. Matheson and J. Matheson, *The smart organization: Creating value through strategic R&D*, Harvard Business School Press, Boston, 1998.
- W.L. Miller and L. Morris, *Fourth generation R&D: Managing knowledge, technology, and innovation*, Wiley, New York, 1999.
- H. Mintzberg, The manager’s job: Folklore and fact, *Harvard Bus Rev* (July–August 1975), 53, 49–61.
- M. Mykityshyn, Enterprise transition/transformation: Conceptual frameworks for understanding nonlinear growth dynamics, *Proc IFAC Symp Anal Model Eval Hum-Machine Syst*, September 2004.
- W. Oncken, Jr. and D.L. Wass, Management time: Who’s got the monkey, *Harvard Bus Rev* (November–December 1974), 52.
- J. Rasmussen, *Information processing and human-machine interaction*, Elsevier, Amsterdam, 1986.
- J. Rasmussen, A.M. Pejtersen, and L.P. Goodstein, *Cognitive systems engineering*, Wiley, New York, 1994.
- W.B. Rouse, *Design for success: A human-centered approach to designing successful products and systems*, Wiley, New York, 1991.
- W.B. Rouse, *Strategies for innovations: Creating successful products, systems, and organizations*, Wiley, New York, 1992.
- W.B. Rouse, *Catalysts for change: Concepts and principles for enabling innovation*, Wiley, New York, 1993.
- W.B. Rouse, *Best laid plans*, Prentice-Hall, Englewood Cliffs, NJ, 1994.
- W.B. Rouse, *Start where you are: Matching your strategy to your marketplace*, Jossey-Bass, San Francisco, 1996.
- W.B. Rouse, *Don’t jump to solutions: Thirteen delusions that undermine strategic thinking*, Jossey-Bass, San Francisco, 1998.

- W.B. Rouse, *Essential challenges of strategic management*, Wiley, New York, 2001.
- W.B. Rouse, Need to know: Information, knowledge and decision making, *IEEE Trans Syst Man Cybernet Part C* 32(4) (2002), 282–292.
- W.B. Rouse, Engineering complex systems: Implications for research in systems engineering, *IEEE Trans Syst Man Cybernet Part C* 33(2) (2003), 154–156.
- W.B. Rouse and R. Acevedo, Anticipating policy implications of emerging information technologies, *Inform Knowledge Syst Management* 4(2) (2004), 77–93.
- W.B. Rouse and K.R. Boff, Strategies for value: Quality, productivity, and innovation in R&D/technology organizations, *Syst Eng* 4(2) (2001), 87–106.
- W.B. Rouse and K.R. Boff, Value streams in science & technology: A case study of value creation and Intelligent Tutoring Systems, *Syst Eng* 6(2) (2003), 76–91.
- W.B. Rouse and K.R. Boff, Value-centered R&D organizations: Ten principles for characterizing, assessing & managing value. *Syst Eng* 7(2) (2004), 167–185.
- W.B. Rouse and K.R. Boff, (Editors), *Organizational simulation: from modeling and simulation to games and entertainment*, Wiley, New York, 2005.
- W.B. Rouse and C.W. Howard, “Supporting market-driven change,” *The digital MBA*, D. Burnstein (Editor), Osborne McGraw-Hill, New York, 1995, pp. 159–184.
- W.B. Rouse, C.W., Howard, W.E., Carns, and E.J. Prendergast, Technology investment advisor: An options-based approach to technology strategy, *Inform Knowledge Syst Management* 2(1) (2000), 63–81.
- P.A. Roussel, K.N. Saad, and T.J. Erickson, *Third generation R&D: Managing the link to corporate strategy*, Harvard Business School Press, Boston, 1991.
- A.P. Sage, *Systems engineering*, Wiley, New York, 1992.
- A.P. Sage, *Systems management for information technology and software engineering*, Wiley, New York, 1995.
- A.P. Sage and C.D. Cuppan, On the systems engineering and management of systems of systems and federations of systems, *Inform Knowledge Syst Management* 2(4) (2001), 325–345.
- A.P. Sage and W.B. Rouse (Editors), *Handbook of systems engineering and management*, Wiley, New York, 1999.
- P.M. Senge, *The fifth discipline: The art and practice of the learning organization*, Doubleday/Currency, New York, 1990.
- T.B. Sheridan, *Telerobotics, automation, and human supervisory control*, MIT Press, Cambridge, MA, 1992.
- T.B. Sheridan, *Human and automation: Systems design and research issues*, Wiley, New York, 2002.
- T.B. Sheridan and W.R. Ferrell, *Man-machine systems: Information, control, and decision models of human performance*, MIT Press, Cambridge, MA, 1974.
- H.A. Simon, *Models of man: Social and rational*, Wiley, New York, 1957.
- H.A. Simon, *The sciences of the artificial*, MIT Press, Cambridge, MA, 1969.
- A.J. Slywotsky, *Value migration: How to think several moves ahead of the competition*, Harvard Business School Press, Boston, 1996.
- A.J. Slywotsky and D.J. Morrison, *The profit zone: How strategic business design will lead you to tomorrow’s profits*, Times Books, New York, 1997.
- K.J. Vicente, *Cognitive work analysis: Toward safe, productive, and healthy computer-based work*, Erlbaum, Mahwah, NJ, 1999.
- R. Whiting, Knowledge management: Myths and realities, *Inform Week* (November 22, 1999), 42–54.
- J.P. Womack and D.T. Jones, *Lean thinking: Banish waste and create wealth in your corporation*, Simon & Schuster, New York, 1996.
- M.H. Zack, Developing a knowledge strategy, *California Management Rev* 41(3) (1999), 125–145.



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