Information and Knowledge Perspectives in Systems Engineering and Management for Innovation and Productivity through Enterprise Resource Planning

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ABSTRACT

This article provides an overview of perspectives associated with information and knowledge resource management in systems engineering and systems management in accomplishing enterprise resource planning for enhanced innovation and productivity. Accordingly, we discuss economic concepts involving information and knowledge, and the important role of network effects and path dependencies in influencing enterprise transformation through enterprise resource planning.

Keywords: enterprise intergration; enterprise resource planning; enterprise transformation; information resouce management; innovation; knowledge management; knowledge sharing network effects; operational effectiveness; path dependency; systems engineering; systems management

INTRODUCTION

Many have been concerned with the role of information and knowledge and the role of this in enhancing systems engineering and management (Sage, 1995; Sage & Rouse, 1999) principles, practices, and perspectives. Major contemporary attention is being paid to enterprise transformation (Rouse, 2005, 2006) through these efforts. The purpose of this work is to discuss many of these efforts and their role in supporting the definition, development, and deployment of an enterprise resource plan (ERP) that will enhance transformation of existing enterprises and development of new and innovative enterprises.

Economic Concepts Involving Information and Knowledge

Much recent research has been conducted in the general area of information networks and the new economy. Professors Hal R. Varian and Carl Shapiro have published many papers and a seminal text, addressing new economic concepts as they apply to contemporary information networks. These efforts generally illustrate how new economic concepts challenge the traditional model, prevalent during the Industrial Revolution and taught throughout industry and academia over the years. In particular, the book *Information Rules* (Shapiro & Varian, 1999) provides a comprehensive overview of the new economic principles as they relate to today's information and network economy. The book addresses the following key principles:

- Recognizing and exploiting the dynamics of positive feedback
- Understanding the strategic implications of lock-in and switching costs
- Evaluating compatibility choices and standardization efforts
- Developing value-maximizing pricing strategies
- Planning product lines of information goods
- Managing intellectual property rights
- Factoring government policy and regulation into strategy

These concepts have proven their effectiveness in the new information economy and have been fundamental to the success of many information technology enterprises introducing new ideas and innovations into the marketplace. Paramount to an enterprise's success in reaching critical mass for its new product offering is the understanding and implementation of these new economic concepts.

Economides (1996) has also been much concerned with the economics of networks. He and Himmelberg (1994) describe conditions under which a critical mass point exists for a network good. They characterize the existence of critical mass points under various market structures for both durable and non-durable goods. They illustrate how, in the presence of network externalities and high marginal costs, the size of the network is zero until costs eventually decrease sufficiently, thereby causing the network size to increase abruptly. Initially, the network increases to a positive and significant size, and thereafter it continues to increase gradually as costs continue to decline. Odlyzko (2001) expands on the concept of critical mass and describes both the current and future growth rate of the Internet and how proper planning, network budgeting, and engineering are each required. He emphasizes the need for accurate forecasting, since poor planning can lead to poor choices in technology and unnecessary costs.

Economides and White (1996) introduce important concepts with respect to networks and compatibility. They distinguish between direct and indirect externalities, and explore the implications of networks and compatibility for antitrust and regulatory policy in three areas: mergers, joint ventures, and vertical restraints. They also discuss how compatibility and complementarity are linked to provide a framework for analyzing antitrust issues. Strong arguments are made for the beneficial nature of most compatibility and network arrangements, with respect to vertical relationships, and policies are set forth to curb anti-competitive practices and arrangement. Farrell and Katz (2001) introduce concepts of policy formulation in preventing anti-competitive practices and, in addition, explore the logic of predation and rules designed to prevent this in markets that are subject to network effects. This work discusses how the imposition of the leading proposals for rules against predatory pricing may lower or raise consumer welfare, depending on conditions that may be difficult to identify in practice.

Research conducted on these economic concepts establishes a solid foundation and baseline for further research in the area of enterprise resource planning and new technology innovations (Langenwalter, 2000). In this work, he extends the traditional enterprise resource planning (ERP) model to incorporate a total enterprise integration (TEI) framework. He describes TEI as a superset of ERP and also describes how it establishes the communications foundation between customer, manufacturer, and supplier. Each entity is linked internally and externally, allowing the TEI system to enhance performance and to provide process efficiencies that reduce lead times and waste throughout the supply chain. This work illustrates how ERP is uniquely integrated with customers and suppliers into the supply chain using TEI and how it significantly improves customer-driven performance. The model for this includes five major components: executive support, customer integration, engineering integration, manufacturing integration, and support services integration. These components are essential for integrating all information and actions required to fully support a manufacturing company and its supply chain. TEI presents a strategic advantage to an enterprise, rather than just improving operating efficiencies. The TEI framework provides the enterprise a competitive edge by:

- Maximizing speed and throughput of information and materials
- Minimizing response time to customers, suppliers, and decision makers
- Pushing decisions to the appropriate levels of the organization
- Maximizing the information made available to the decision-makers
- Providing direct integration into the supply chain

In addition to the technology, TEI also incorporates stakeholders. People are empowered at all levels of the enterprise to improve the quality of their decision-making. One result of this is MRP II (Manufacturing Resources Planning) systems. MRP II evolved from MRP (Material Requirements Planning), which was a method for materials and capacity planning in a manufacturing environment. Manufacturing plants, to plan and procure the right materials in the right quantities at the right time, used this method. MRP became the core planning module for MRP II and ERP. MRP was later replaced by MRP II, which expanded the MRP component to include integrated material planning, accounting, purchasing of materials for production, and the shop floor. MRP II integrated other functional areas such as order entry, customer service, and cost control. Eventually, MRP II evolved into enterprise resource planning (ERP), integrating even more organizational entities and functions such as human resources, quality management, sales support, and field services. ERPs became richer in functionality and involved a higher degree of integration than their predecessors MRP and MRP II.

Another very well-known contributor to the field of enterprise resource planning is Thomas H. Davenport (2000). In *Mission Critical: Realizing the Promise of Enterprise Systems*, the need to take a customer or product focus when selecting an operational strategy is emphasized. To enable this, a direct connection should exist between the daily operations and the strategic objectives of the enterprise. This is made possible through the use of operational data, that is used to enhance the operational effectiveness of the enterprise. Operational data is defined by the organization seeking to measure the operational effectiveness of its environment. Operational data may be defined in terms of various parameters such as cycle time (CT), customer response time (CRT), or MTTR (mean time to repair). These are only a few of the parameters, and they are contingent on the operational strategy the organization is seeking to adopt. For example, an organization that seeks to reduce cycle time (CT) for processing orders in order to minimize cost may look to capture CT in its operational data. This data is captured over time as process efficiencies are instituted within the existing order process. Operational effectiveness is then determined by comparing the future CT state of the order process with that of its initial CT benchmark. For example, if cycle time to process an order was originally 15 minutes, and after the process efficiencies were instituted, CT was then 5 minutes, then operational effectiveness improved by 10 minutes. Now it takes fewer resources to process orders, thus reducing operational costs.

Davenport (2000) introduces a data-oriented culture and conveys the need for data analysis, data integrity, data synthesis, data completeness, and timely extracts of data. Data is used across organizational boundaries and shared between the various entities in an effort to enhance operational effectiveness. For example, transaction data must be integrated with data from other sources, such as third-party vendors, to support effective management decision-making. One's ability to interpret and analyze data can effect the decisions that are made and the confidence management has in pursuing particular ongoing decisions. Davenport believes that a combination of strategy, technology, data (data that is relevant to the organization), organization, culture, skills and knowledge assist with developing an organization's capabilities for data analysis. When performing data analysis, various organizations may have similar results, but with different meanings. He indicates that a typical corporation may have divisions that have a need to store customer data in different customer profile schemes. Therefore, a common shared master file between the divisions may not be feasible. This approach takes on more of a distributed approach versus a centralized approach to data management. The operational effectiveness of each of these divisions will vary based on the benchmarks and target improvements they have set for themselves.

Christopher Koch (2006) supports Davenport's data concept and elaborates on the value of an ERP and how it can improve the business performance of an enterprise. He demonstrates the value of an ERP by integrating the functions of each organization to serve the needs of all stakeholders. The associated framework attempts to integrate all organizational entities across an enterprise onto a single-systems ERP platform that will serve the needs of the various entities. This single platform replaces the standalone systems prevalent in most functional organizations such as human resources, finance, engineering, and manufacturing, thereby allowing people in the various organizations to access information not only in the most useful manner but also from their own perspectives. This information may be the same shared data used between the organizations or may vary, based on the need of each of the organizations. Each organization in the enterprise and its stakeholders will have their own set of requirements for accessing, viewing and manipulating their data. Data management may even take on a hybrid of a centralized and distributed approach. Some organizations may need a view of the same data, while others may have their own unique data requirements. Koch (2006) indicates that there are five major reasons why an enterprise adopts an ERP strategy:

1. Integrate financial information
2. Integrate customer order information
3. Standardize and speed up manufacturing processes
4. Reduce inventory
5. Standardize human resources (HR) information

Each organization within an enterprise has its own requirements for an ERP. They may share the same ERP solution; however, the ERP may be designed to support the specific business need of each organization. Some organizations may have a need to view the same data. For example, a sales and customer care-focused organization may need to view the same customer profile data to access customer contact information. In comparison, a human resources-focused organization may not need to be privy to this same information. They may be more interested in accessing internal employee personnel records for employee performance monitoring. The senior executive level of an enterprise will also have its own unique data requirements in order to make key strategic and tactical decisions. This executive level may need the capability to access data from each of the organizational units in order to effectively manage the operations of the business. The organizations, within an enterprise each have their own instances of an ERP with respect to accessing data and implementing processes. Some organizations may share a common process such as the order fulfillment process. For example, this process may be shared between organizational entities such as sales, operations, and revenue assurance. Sales would complete a service order, operations would deliver the service, and revenue assurance would bill the customer. However, there are processes that are only unique to a particular organization. For example, the marketing organization may not be interested in the escalation process used by operations to resolve customer issues. This process is unique to operations and, as a result, the ERP would be designed for such uniqueness. The design of an ERP should, of course, take organizational data and process requirements into account and support management of the enterprise and its inter-workings in a transdisciplinary and transinstitutional fashion (Sage 2000, 2006).

William B. Rouse had produced very relevant and important popular work surrounding new technology innovation with respect to the enterprise. In *Strategies for Innovation*, Rouse (1992) addresses four central themes to introduce strategies for innovation in technology-based enterprises. Rouse discusses the importance of strategic thinking and how some enterprises fail to plan long term. This is based on the notion that "while people may want to think strategically, they actually do not know how(p. 3)." He emphasizes the need for stakeholders to understand the solutions offered as a result of new innovation, and how strategies are critical for ensuring successful products and systems. Most importantly, these strategies must also create a successful enterprise for developing, marketing, delivering, and servicing solutions, thus leading to the need for human-centered planning, organization, and control. These are among the approaches needed to stimulate innovation in products and services (Kaufman & Woodhead, 2006).

Rouse (1992) describes the need for applying a human-centered design methodology to the problem of enhancing people's abilities and overcoming their limitations. In the process of planning, organizing, and controlling an enterprise, he illustrates how technology-based enterprises differentiate themselves from each other based on their core product technologies. This strategic strength is based on the unique value that the core product can provide to the marketplace. He indicates that the enterprise should continuously analyze the market and measure core product value to determine the benefits that can be provided. Assessing and balancing the stakeholders' interests will be necessary to ensure success of the core product. Stakeholders consist of both producers and consumers. Each may have a stake in the conceptualization, development, marketing, sales, delivery, servicing, and use of the product. The three key processes highlighted in this work are: strategic planning, operational management, and the engineering/administration, vehicles used by the enterprise to assist stakeholders with pursuing the mission of the enterprise.

Rouse further addresses strategic approaches to innovation in another one of his books. In *Essential Challenges of Strategic Management* (Rouse, 2001), he illustrates the strategic management challenges faced by all enterprises and introduces best practices for addressing these challenges. He disaggregates the process of strategically managing an enterprise into seven fundamental challenges. The essential challenges he describes, which most enterprises are confronted with, are: growth, value, focus, change, future, knowledge, and time. Growth is critical to gaining share in saturated and declining markets and essential to the long-term well-being of an enterprise. A lack of growth results in declining revenues and profits, and, in the case of a new enterprise, there is the possibility of collapse. He describes value as the foundation for growth, the reason an enterprise exists. Matching stakeholders' needs and desires to the competencies of the enterprise, when identifying high-value offerings, will justify the investments needed to bring these offerings to market. While value enhances the relationships of processes to benefits and costs, focus will provide the path for an enterprise to provide value and growth. Focus involves pursuing opportunities and avoiding diversions, that is, making decisions to add value in particular ways and not in others are often involved. For example, allocating too few resources among many projects may lead to inadequate results or possible failure.

The focus path is followed by another path called change. An enterprise challenged with organizational re-engineering, downsizing, and rightsizing often takes this change path. The enterprise will continue to compete creatively while maintaining continuity in its evolution. As the nature of an organization changes rapidly during an enterprise's evolution, managing change becomes an art. According to Rouse (2001), investing in the future involves investing in inherently unpredictable outcomes. He describes the future as uncertain. The intriguing question is, "If we could buy an option on the future, how would we determine what this option is worth(p. 6)?" A new enterprise will be faced with this challange when coming into the marketplace.

The challenge of knowledge is transformation of information from value-driven insights to strategic programs of action. Determining what knowledge would make an impact, and in what ways, is required. This understanding should facilitate determining what information is essential and should provide further elaboration on how it is to be processed and how its use will be supported. The most significant challenge identified is that of time. A lack of time is the most significant challenge human resources. Most people spend too much time being reactive and responding to emergencies, attending endless meetings, and addressing an overwhelming number of e-mails, all of which cannibalize time. As a result, there is little time for addressing strategic challenges. Carefully allocating the scarcest resource of an organization is vital to the future of an enterprise. Some of the best practices Rouse (2001) has presented in addressing the seven strategic challenges may be described as follows.

Growth: Buying growth via strategic acquisitions and mergers; fostering growth from existing market offerings via enhanced productivity; and creating growth through innovative new products and brand extensions.

Value: Addressing the nature of value in the market; using market forces in determining the most appropriate business process; and designing cost accounting system to align budgets and expenditures with value streams.

Focus: Deciding what things to invest in and those things to be avoided or stopped; and linking decisions or choices to organizational goals, strategies, and plans.

Change: Instituting cross-functional teams for planning and implementing significant changes; and redesigning incentive and reward systems in order to ensure that people align their behaviors with desired new directions.

Future: Employing formal and quantitative investment decision processes; and creating mechanisms for recognizing and exploiting unpredictable outcomes.

Knowledge: Ensuring that knowledge acquisition and sharing are driven by business issues in which knowledge has been determined to make a difference; using competitive intelligence and market/customer modeling to provide a valuable means for identifying and compiling knowledge.

Time: Committing top management to devoting time to challenges; and improving time management, executive training, and development programs, in addition to providing increased strategic thinking opportunities.

Gardner (2000) takes a complementary approach to the enterprise and to innovation by focusing on the valuation of information technology. He addresses the difficulties of defining the value of new technologies for company shareholders using integrated analytical techniques in his book *The Valuation of Information Technology*. Gardner presents methodologies for new enterprise business development initiatives and presents techniques for improving investment decisions in new technologies. This 21st-century approach to valuation avoids making investment decisions on an emotional basis only, in favor of predicting shareholder value created by an information technology system before it is built. Determining the contribution an information technology system makes to a company's shareholder value is often challenging and requires a valuation model. Gardner suggests that the primary objective of information technology systems development in business is to increase the wealth of shareholders by adding to the growth premium of their stock. The objective of maximizing shareholder wealth consists of maximizing the value of cash flow generated by operations. This is accomplished by generating future investment in information technology systems. As an example, this could be a state-of-the-art enterprise resource planning system, which could easily maximize what we will call operational velocity and, as a result, maximize shareholder wealth. The process that Gardner suggests using would be to first identify the target opportunity, align the information technology system to provide the features the customer wants in a cost-effective manner, and then to accurately measure the economic value that can be captured through this.

Some of the techniques Gardner uses to compute economic value are net present value (NPV), rate of return (ROR), weighted average cost of capital (WACC), cost of equity, and intrinsic value to shareholders of a system. Each of these techniques may be used to determine aspects of the shareholder value of an information technology system. The results from computing these values will assist an enterprise with making the right decisions with respect to its operations. For example, if the rate of return on capital is high, then time schedule delays in deploying an information technology system can destroy enormous value. Time to market becomes critical in this scenario. Gardner suggests that it may be in the best interest of the company to deploy the system early by mitigating the potential risk and capitalizing on the high rate of return. A risk assessment must be performed to ensure that the customer relationship is not compromised at the expense of implementing the system early. If the primary functionality of the system is ready, then the risk would be minimal, and the other functional capabilities of the system may be phased in at a later time.

If the rate of return is low, however, schedule delays will have a lesser effect on value and deployment of a system does not immediately become crucial to the success of the enterprise. This approach to predicting value takes a rational approach to decision making by weighing the rewards and risks involved with an information technology system investment. The author suggests moving away from the more intuitive approach of valuation often practiced in the high-tech industry, which is said to be very optimistic, spotty, and driven by unreasonable expectations from management. Gardner describes this intuitive practice as a non-analytical approach to assessing the economic viability of an information technology system. This practice primarily ignores the bare essentials that management must consider in assessing whether the economics of an information technology system are attractive. Gardner has established an analytical framework for analyzing the economics of information technology systems. His process is comprised of the three following steps:

1. Identify the target customer opportunity.
2. Align the information technology system to cost-effectively provide the features the customer wants.
3. Measure the economic value that can be captured.

The result of utilizing the framework is the quantification of the shareholder value created by an information technology system.

Boer (1999) also has much discussion on the subject of valuation in his work on *The Valuation of Technology*. He illustrates links between research and development (R&D) activity and shareholder value. In addition, he identifies the languages and tools used between business executives, scientists, and engineers. The business and scientific/engineering communities are very different environments and are divided by diverse knowledge and interest levels. Bridging the gap between these communities is made possible through the process of valuation, which fosters collaboration and communication between both communities. Boer identifies the link between strategy and value and addresses the mutual relationship between corporate strategy and technology strategy. He introduces tools and approaches used to quantify the link between technological research and commercial payoff within the value model of an enterprise.

This value model is comprised of four elements: operations, financial structure, management, and opportunities. The opportunity element is most critical to the future growth of an enterprise. The options value of an enterprise and how it is addressed strategically will determine the fate of an emerging enterprise. Boer illustrates how productive research and development creates options for the enterprise to grow in profitability and size. He views R&D as a component of operations, since this is the point at which new technology is translated into commercial production. In the competitive marketplace, the enterprise evolves in order to generate opportunity and growth. R&D serves as the vehicle for converting cash into value options for the enterprise. Boer introduces R&D stages (conceptual research, feasibility, development, early commercialization), where the level of risk, spending, and personnel skills vary. Each stage of the R&D process allows management to make effective decisions regarding the technology opportunity and performs levels of risk mitigation. R&D can be instrumental in decreasing capital requirements with results of a very high rate of return on the R&D investment. The art of minimizing capital requirements requires good and effective communication between the scientific/engineering and business communities. This will allow both communities to share their views and foster the need for driving this essential objective.

Some of the methods Boer uses for asset valuation are similar to Rouse's methods. Boer uses discounted cash flow (DCF), NPV, cost of money, weighted average cost of capital, cost of equity, risk-weighted hurdle rates for R&D, and terminal value methods for assessing valuation. In accelerated growth situations, as in the case of an emerging enterprise, Boer emphasizes that the economic value is likely to be derived from the terminal value of the project, not from short-term cash flows. A lack of understanding of terminal value can compromise the analysis of an R&D project. R&D can be a cash drain, and the outcomes are difficult to predict. Boer's techniques provide a vehicle for converting cash into opportunity and creating options for the enterprise.

Another work that addresses valuation is entitled *The Real Options Solution: Finding Total Value in a High-Risk World* (Boer, 2002). Here, the author presents a new approach to the valuation of business and technologies based on options theory. This innovative approach, known as the total value model, applies real options analysis to assessing the validity of a business plan. All business plans are viewed as options. These plans are subject to both unique and market risks. While business plans seem to create no value on a cash flow basis, they do become more appealing once the full merit of all management options is recognized. Since management has much flexibility in execution, the model offers a quantifiable approach to the challenge of determining the strategic premium of a particular business plan. Boer defines total value as "the sum of economic value and the strategic premium created by real options (p. vii)." He presents a six-step method for applying this model in a high-risk environment for evaluating enterprises, R&D-intensive companies, bellwether companies, capital investments, and hypothetical business problems. His method reveals how changes in total value are driven by three major factors: risk, diminishing returns, and innovation.

Boer's option theory efforts provide the enterprise with a vehicle for computing the strategic premium to obtain total value. This six-step method to calculate total value is comprised of:

1. Calculation of the economic value of the enterprise,
2. Framing the basic business option,
3. Determining the option premium,

Table 1. Comparison of ERP models

ERP Models				
Contributor	**Model**	**Strategy**	**Challenge**	**Objective**
Gary A. Langenwalter	Total enterprise integration (TEI) framework	• Integrates customer, manufacturer, and supplier • Provides competitive edge by: maximizing speed of information, minimizing response time, pushing decisions to the correct organizational level, maximizing information available to decision-makers, and direct integration of supply chains	• Establishing seamless communication • Multi-functional integration	• Incorporate all stakeholders • Empower people at all levels of the organization • Improve quality of decision-making
Thomas H. Davenport	Operational data model	• Introduces data-oriented culture • Supports a customer and product focus • Uses operational data to measure operational effectiveness	• Defining organizational boundaries • Enhancing operational effectiveness	• Define operational performance parameters • Measure operational effectiveness • Support effective decision-making
Christopher Koch	Business performance framework	• Supports data sharing • Integrates financial information • Integrates customer order information • Standardizes manufacturing process • Reduces inventory • Standardizes HR information	• Centralized and distributed approach to data management • Establishing requirements for accessing, viewing, and manipulating data	• Integrate all organizational entities across a single systems platform • Manage enterprise in transdisciplinary and transinstitutional fashions

Table 1. continued

William B. Rouse	Strategic innovation model	• Introduces a strategic approach to innovation • Focuses on the need for human-centered planning, organization, and control • Differentiating from the competition based on core product technologies	• Enhancing people's abilities and overcoming their limitations • Essential challenges: growth, value, focus, change, future, knowledge, and time	• Support strategic planning, operational management, and engineering • Ensure the successful innovation of products and systems
Christopher Gardner	Valuation model	• Presents methodologies for new enterprise business development initiatives • Determines the contribution an enterprise system makes to a company's shareholder value	• Defining the value of new technologies • Mitigating the potential risk and capitalizing on the high rate of return	• Increase shareholder wealth • Maximize the value of cash flow generated by operations
Peter F. Boer	Options model	• Bridges the gap between the business and scientific/engineering communities • Introduces research and development that creates options for the enterprise to grow in profitability and size	• Identifying the link between corporate strategy and technology strategy • Minimizing capital requirements • Understanding terminal value of a project	• Introduce research and development stages for assessing technology opportunities • Determine strategic premium created by real options

4. Determining the value of the pro forma business plan,
5. Calculating the option value, and
6. Calculating total value.

Options theory approached to valuation leverage on elements of uncertainty such as these afford enterprise managers major investment opportunities. This was not common using more traditional valuation methods such as NPV- and internal rate of return (IRR)-based calculations. As Boer (2002) illustrates, the new options theory emphasizes the link between options, time, and information. Boer states: "Options buy time. Time produces information. Information will eventually validate or invalidate the plan. And information is virtual (p. 106)." This theory and its extensions (Boer, 2004) may well pave the way for a new generation of enterprise evolution and enterprise innovation.

Rouse (2005, 2006) is concerned with the majority of these issues in his development of systems engineering and management approaches to enterprise transformation. According to Rouse, enterprise transformation concerns change, not just routine change but fundamental change that substantially alters an organization's relationships with one or more of its key constituencies: customers, employees, suppliers, and investors. Enterprise transformation can take many forms. It can involve new value propositions in terms of products and services and how the enterprise should be organized to provide these offerings and to support them. Generally, existing or anticipated value deficiencies drive these initiatives. Enterprise transformation initiatives involve addressing the work undertaken by an enterprise and how the work is accomplished. Other important elements of the enterprise that influence this may include market advantage, brand image, employee and customer satisfaction, and many others.

Rouse suggests that enterprise transformation is driven by perceived value deficiencies due to existing or expected downside losses of value; existing or expected failures to meet promised or anticipated gains in value; or desire to achieve new, improved value levels through marketing and/or technological initiatives. He suggests three ways to approach value deficiencies: improve how work is currently performed; perform current work differently; and/or perform different types of work. Central to this work is the notion that enterprise transformation is driven by value deficiencies and is fundamentally associated with investigation and change of current work processes such as to improve the future states of the enterprise. Potential impacts on enterprise states are assessed in terms of value consequences.

Many of the well-known contributors in the field of enterprise resource planning presented had developed their own unique model. Each had established a strategy to address the evolution and growth of the enterprise. Differences between the models varied based on the challenge presented and the final objective to be achieved by the enterprise. A comparison of the ERP models presented is illustrated in Table 1.

Fundamentally, system engineering and system management are inherently transdisciplinary in attempting to find integrated solutions to problems that are of a large scale and scope (Sage, 2000). Enterprise transformation involves fundamental change in terms of reengineering of organizational processes and is also clearly transdisciplinary as that success necessarily requires involvement of management, computing, and engineering, as well as behavioral and social sciences. Enterprises and associated transformation are among the complex systems addressed by systems engineering and management. Rouse's efforts (2005, 2006) provide a foundation for addressing these issues and the transdisciplinary perspective of systems engineering and management provide many potentially competitive advantages to deal with these complex problems and systems.

Network Effects and Their Role in Enterprise Resource Planning

In today's information economy, introducing new technologies into the marketplace has become a significant challenge. The information economy is not driven by the traditional economies of scale and diminishing returns to scale that are prevalent among large traditional production companies. It has been replaced by the existence of network effects (also known as network externalities), increasing returns to scale and path dependence. This is the core economic reality, and not at all a philosophy, which has revolutionized traditional economic theories and practices, resulting in a new approach to economic theory as it pertains to the information economy.

There are a number of market dynamics or external variables that impact the success of any new technology entering the market. The most common variable is the element of network effects. A product exhibits network effects when its value to one user depends on the number of other users. Liebowitz and Margolis (1994) define network effects as the existence of many products for which the utility that a user of them derives from their consumption increases with the number of other agents that are also utilizing the product, and where the utility that a user derives from a product depends upon the number of other users of the product who are in the same network. Network effects are separated into two distinct parts, relative to the value received by the consumer. Liebowitz and Margolis (1994) denote the first component as the autarky value of a technology product, the value generated by the product minus the other users of the network. The second component is the synchronization value, the value associated when interacting with other users of the product. The social value derived from synchronization is far greater than the private value from autarky. This social value leads the way to increasing returns to scale, by creating path dependence (also known as positive feedback) and influencing the outcome for network goods. These efforts and others are nicely summarized in Liebowitz (2002) and Liebowitz and Margolis (2002).

Path dependence is essential for a company to reach critical mass when introducing new technologies into the market. As the installed customer base grows, more customers find adoption of a new product or technology of value, resulting in an increase in the number of consumers or users. Consumer choices exhibit path dependence for new products as others realize their value, eventually leading to critical mass. Path dependence is simply an effect whereby the present position is a result of what has happened in the past. The path dependence theory demonstrates that there are a number of stable alternatives, one of which will arise based on the particular initial conditions. Path dependence is evident when there is at least persistence or durability in consumer decision-making. Decisions made by early adopters can exhibit a controlling influence over future decisions or allocations made by late adopters. These product decisions are often based on the individual arbitrary choices of consumers, persistence of certain choices, preferences, states of knowledge, endowments, and compatibility. The outcome may depend on the order in which certain actions occur based on these behavioral determinants.

Network effects, increasing returns, and path dependence can be better illustrated when applied to the concept of a virtual network. The virtual network has similar properties to a physical or real network, such as a communications network. In such networks, there are nodes and links that connect the nodes to each other. In a physical network, such as a hard-wire communications network, the nodes are switching platforms and the links are circuits or telephone wires. Conversely, the virtual network nodes may represent consumers and transparent links represent paths, as driven by network effects and path dependence, that impact consumer behavior. The value of connecting to the network of Microsoft Office users is predicated on the number of people already connected to this virtual network. The strength of the linkages to the virtual network and its future expansion is based on the number of users who will use the same office applications and share files.

Path dependence can easily generate market dominance by a single firm introducing a new technology. This occurs when late adopters latch onto a particular virtual network, because the majority of users already reside on this infrastructure and have accepted the new technology. As more consumers connect to the virtual network, it becomes more valuable to each individual consumer. Consumers benefit from each other as they connect to the infrastructure. The larger network becomes more attractive to the other consumers who eventually become integrated. A communications network can best illustrate this concept. For example, additional users who purchase telephones and connect to a communications infrastructure bring value to the other users on the network, who can now communicate with the newly integrated users. This same concept applies to the virtual network and has the same impact. Real and virtual networks share many of the same properties and, over time, are destined to reach a critical mass of users.

New and emerging startup enterprises seeking to take advantage of network effects and path dependence when launching a new technology or innovation in the marketplace must have a reliable and operationally efficient enterprise resource planning (ERP) solution in place. The ERP solution must be capable of attaining operational velocity to address market demands. Miller and Morris (1999) indicate that traditional methods of managing innovation are no longer adequate. They suggest that as we make the transition to fourth generation R&D, appropriate complex timing for innovations remains a significant challenge. These authors assert that as new technologies and new markets emerge, management must deal with complexity, enormous discontinuities, increasing volatility, and the rapid evolution of industries. The challenge becomes that of linking emerging technologies with emerging markets through methods such as an ERP solution to bridge this link and to allow new emerging enterprises, or established mature enterprises seeking to transform themselves, to adapt quickly to the dynamics of the marketplace. The solution supports both continuous and discontinuous innovation as defined by Miller and Morris (1999). This form of innovation works well when customer needs in a competitive environment can be met within existing organizational structures.

In contrast to this, discontinuous innovation may bring forth conditions emanating from fundamentally different new knowledge in one or more dimensions of a product or service, and offer significantly different performance attributes. Discontinuous change potentially brings about change in a deep and systematic way. It offers a potential lifestyle change to customers that can be dramatic. Miller and Morris (1999) note, for example, the transition from typewriters to personal computers for producing written documents. In part, this occurred because customers no longer were satisfied with the existing framework of capability offered by the typewriter. New knowledge, organizational capabilities, tools, technology, and processes changed the behavior and desires of the customer. In addition to this change was also the change resulting in supporting infrastructure. Miller and Morris (1999) emphasize that discontinuous innovation affects not only products and services but also the infrastructures integral to their use, as well as extensive chains of distribution that may involve a plethora of affiliated and competing organizations.

As the threat of unexpected competition surrounds any new enterprise entering the market, the risk associated with technology shifts and the compression of the sales cycle make successfully managing discontinuous innovation a necessary challenge for success. We must be able to gauge how the market is evolving and what organizational capabilities must exist to sustain competitiveness as a result of this evolution. Because innovation usually requires large capital infusions, decreasing the time for appearance of a positive revenue stream is critical to the success of the enterprise. This decrease in time is made possible through operational velocity attainment, which requires changes in existing implementation strategies and organizational capabilities. This requires a collaborative effort between the various involved organizations to understand what is needed to support new innovations. Responsibility for supporting new innovation is not only supported by internal organizations but by such external organizations as suppliers, customers, and partners. Organizational structure, capabilities, and processes are fundamental to an evolutionary ERP model and serve as the framework for supporting new technology adoption in the marketplace.

The information economy is driven by network effects (also termed demand-side economies of scale or network externalities). Network effects support path dependence and are predicated on Metcalfe's Law, which suggests that the value of a network goes up as the square of the number of users (Shapiro & Varian, 1999), or on recent suggested modifications to this (Briscoe, Odlyzko, & Tilly, 2006). Positive effects occur when the value of one unit increases with an increase in the number of the same unit shared by others. Based on this premise, it is possible to create an enterprise resource planning model that influences positive feedback from human behavior in adopting new technologies and accelerates critical mass early in the deployment phase of the product development lifecycle, by attaining operational velocity. Operational velocity is defined in terms of speed in delivering products or services to market, meeting all customer expectations in a timely manner, and decreasing the time for appearance of a positive revenue stream as much as possible. This ERP model would support the integration of data, standardization of processes, order fulfillment, inventory control, supply-chain management, and customer relationship management (CRM) as critical drivers to result in enterprise transformation.

William B. Rouse, in his work *Strategies for Innovation* (Rouse, 1992), states "A prerequisite for innovation is strategies for making stakeholders aware of enabling technology solutions, delivery of theses solutions in a timely fashion, and providing services that assure the solutions will be successful. These strategies must not only result in successful products or systems, they must also create a successful organization—an enterprise—for developing, marketing, delivering, and serving solutions" (p. 2). His philosophy encompasses the human-centered design approach that takes into account the concerns, values, and perceptions of all stakeholders during a design initiative. This approach entertains the views of all the stakeholders, balancing all human considerations during the design effort.

Traditionally, when designing an enterprise resource planning solution, very few enterprises are easily able to think strategically. Most are only concerned with today's products and services and the financial profits and revenue growth realized in the short term. They often fail to properly forecast future growth and to properly scale their ERP in order to meet the potential consumer demands of the future. An enterprise must be able to plan for and respond to future demands by analyzing the market and evaluating the impact that their core product technologies will have in the marketplace. Market demand will drive consumer needs and desire for these core product technologies, as well as the type of ERP that will be used to support these products. An effective ERP must be capable of assessing and balancing all stakeholders' interests consciously and carefully. The market share that an enterprise is able to acquire for its core product technologies can be tied to how well an ERP is developed, deployed, and implemented in order to provide the operational support infrastructure needed. Many of the traditional success factors for an enterprise have been their position in the marketplace, achievements as innovators, productivity, liquidity and cash flow, and profitability. In order for an enterprise to grow and mature, it must be able to respond to market demand in a timely manner. Responding to market demand includes timely delivery of products and services, immediate attention to customer problem/resolution, and continuous process improvements. Operational velocity attainment becomes the focus and the critical success factor in the execution of an evolutionary ERP strategy, thus supporting the long-term vision of the enterprise by ensuring a strategic advantage for the enterprise.

A well-thought-out ERP strategy will require advanced planning to determine how each of the organizations will be integrated in supporting the long-term objective. Critical to the success of an enterprise is how well its associated organizations can adapt to organizational change, as the company begins to mature and demand increases for the new innovative products and services. Change may include the type of culture that is fostered, tools used, and level of knowledgeable resources required to make the organizational transitions. Most importantly, customer experiences becomes the focus. How fast an enterprise can service customers to meet their expectations may determine how soon it meets revenue expectations. The quality of on-time customer service could impact the number of future sales. A good product or service, combined with excellent customer service, may drive more business for the enterprise, decreasing the time taken to meet revenue forecasts. The mechanism used to drive customer on-time service becomes what we call an evolutionary ERP model. In order for new core technology products to become acceptable to a newly installed base of customers, service delivery and customer response times must be minimized as much as possible. True enterprise growth and profitability can be made possible through this model for emerging enterprises delivering new innovations to the marketplace. The model takes into account the long-term vision of the enterprise, which is a key to its consistent success. Rouse (1992) states this well when he says that many technology-based startup companies are very attracted to learning about new technologies, using these to creating new products, and hiring appropriate staff to accomplish these. Such activities may get the product, resulting from the enterprise vision, into the marketplace. Initial sales and profit goals may be achieved. He appropriately notes that without a long-term vision, plans for getting there, and an appropriate culture; no amount of short-term oriented activity will yield consistent long-term success.

The strategic advantages that a well-defined, developed, and deployed ERP brings to the enterprise are: integration across the enterprise, communication, operating efficiencies, modeling, and supply chain management. These effective strategies assist with bridging the overall corporate strategies with the organizational objectives. Integration across the enterprise supports the following organizational objectives:

- Maximization of speed and throughput of information,
- Minimization of customer response times,
- Minimization of supplier and partner response times,
- Minimization of senior management response times,
- Decision-making authority pushed to the appropriate levels within the organization, using work flow management,
- Maximization of information to senior management,
- Direct integration of the supply chain,
- Reduction of inventories,
- Reduction in order-to-ship time,
- Reduction in customer lead times, and
- Total quality integration.

Communication links the enterprise to both the suppliers and the customers. Good communication between supplier and the enterprise can help reduce design errors, foster good supplier and enterprise relationships, reduce enormous costs, reduce the supplier's time to respond to the enterprise, and improve performance and market adoption of a new core technology product.

Langenwalter (2000) indicates in his work on enterprise resource planning that integrating the design process with customers can surface customer responses with respect to their true needs. He emphasizes the voice of the customer (VOC) as a proven methodology that addresses the true needs and expectations of the customer. VOC serves as basic input to the evolutionary ERP model. Key customer considerations in achieving operational velocity using this model are ranked customer expectations, performance metrics, and customer perceptions of performance.

In *The Valuation of Technology*, Boer (1999) is also concerned with these customer considerations by including the concept of the value proposition from the customer's viewpoint. He emphasizes that stakeholders must find useful ways to determine the value added in every step of the business process from the viewpoint of the customer. The enterprise must exist to deliver value to the extent that it improves operational performance and/or lower costs through new or enhanced products, processes and services. For example, the operations of an enterprise will focus on procuring equipment and materials from vendors and suppliers to produce products on time and within budget. The operations objective is to meet customer demand through scheduling, procurement, implementation, and support, to meet the ever-changing needs of the customer environment. These changes must be measured so that the operations of the enterprise may be able to meet the needs of the marketplace. Such flexibility of operations in the marketplace is essential in keeping up with the dynamic needs of the customer.

In the new technology age, markets are moving much faster than traditional predictive systems suggest. Flexibility therfore becomes an essential and necessary element in achieving operational velocity. To achieve this, Langenwalter (2000) introduces a new measurement system that recognizes the ever-changing dynamics of products, customers, workers, and processes. His approach is based on the assumption that all products have life cycles and should have four key metrics: profitability, time, quality, and company spirit. Encompassing this approach would be the execution of a continuous process improvement initiative, with respect to the operational component of the product lifecycle. He proposes that the enterprise measure each organizational contribution to profit for the entire lifecycle of the product. An ERP can effectively measure the contribution to margin that a sales organization may make on new product releases. Unprofitable products can be immediately identified and retired. In comparison, an ERP can also track the total lifecycle cost that a manufacturing organization incurs when producing a product. Total profit and loss (P&L) responsibilities can be tracked and material procurement and cost strategies can be evaluated to enhance profitability to the extent possible. Other organizational facets such as engineering and marketing can increase profits, by accessing customer profile information from an ERP and trending product demand for various new features and functionality. Incorporating new design considerations in future product releases may also increase potential profitability, as more high-end products are released.

The element of time is an important metric and is truly a measure of process, although process efficiencies can also translate into cost savings. Langenwalter (2000) describes three key time dimensions: time to market, time to customer, and velocity. Each is a component of operational velocity. In achieving operational velocity, time to market is critical for new technology adoption. It is crucial for new enterprises to launch their core technology product(s) on time, in order to sustain long-term product profitability. This is especially true if new technology is involved. Langenwalter (2000) indicates that a study performed by the McKinsey Consulting Group reflects that a six-month delay in entering a market results in a 33% reduction in after-tax profit over the life of the product. In addition, the six-month delay is five times more costly than a 50% development-cost overrun and approximately 30% more costly than having production costs 10% over budget.

An ERP should be capable of monitoring product development and manufacturing processes to ensure timely delivery of products to market. Such items as customer requirements, technical viability, manufacturing costs, production volumes, staffing levels, work order priorities, material requirements, and capacity requirements can be accessible via the ERP, and allow both the engineering and manufacturing components in an organization to respond to product demands quickly. The ERP supports time to market in that these two organizations are able to ensure efficient product development manufacturing processes and organizational communication in launching new products to market. The ERP, so enabled, becomes the common domain and communications intermediary between engineering and manufacturing.

Time to customer is the next most critical dimension, or aspect, of time as described by Langenwalter (2000). This time dimension is focused on reducing lead times to customers. For example, manufacturers look to reduce the lead-time it takes to produce a product, component, or assembly. Although it may have taken weeks to produce a particular component, improved manufacturing capabilities may now enable this process in only two days. This may have been accomplished through the use of an ERP, which made it possible to track performance metrics of the various manufacturing processes. As a result of isolating various inhibiting manufacturing processes and improving these processes, time to customer was reduced significantly, thus supporting the operational velocity objective of the enterprise.

Another good example is customer care, achieved by responding to a product fault scenario and providing technical support capability to the customer for fault resolution. Response to a customer call may have originally taken 72 hours to resolve the problem due to the lack of an effective scheduling tool for the timely dispatching of technical support field resources. With the integration of a resource-scheduling tool within ERP, customer care can now respond perhaps within four hours and provide timely customer support. Velocity, the final dimension that Langenwalter presents, is defined as the total elapsed time consumed by a process divided by the actual value-added time contributed by the same process.

The quality metric of the product life cycle, as described by Langenwalter, focuses on continuous improvement. Quality metrics are very much tied to what may be called an evolutionary enterprise resource planning architecture framework. Operational velocity is only as good as the product and the service that is delivered. Any compromise in quality may translate to potential customer attrition and/or the degradation of market share. A good ERP should be capable of tracking product component failure rates and product design flaws, so that immediate action may be exercised on the part of the enterprise. Speed without quality only becomes a formula for failure. Product failures are not the only inhibitors of quality. A lack of knowledgeable and skilled resources can compromise quality, and this describes Langenwalter's last critical metric – company spirit. He emphasizes the fact that people are the ones who develop relationships with customers and suppliers, eventually leading to new products and processes. This metric goes outside much traditional thinking. However, during the enterprise startup technology revolution, company spirit is generally the most important element of survival and success among enterprises. This leads to a greater sense of ownership and responsibility among the people involved. An enterprise without a healthy team spirit and aggressive workforce has little chance of success.

Rouse (1992) introduces yet another interesting growth strategy that further supports the concept of operational velocity for new technology adoption. He describes a strategy for growth via enhancing productivity through process improvement and information technology. This approach leads to higher quality and lower cost of products and services and, eventually, to greater market share and profits. Enterprise performance is not as visible as product performance, so the money and time saved on process refinements often go unnoticed. Each approach has its own value. Rouse describes product value as the foundation for growth and indicates that the challenge of value concerns matching stakeholders' needs and desires to the enterprise's competencies in the process of identifying high-value offerings that will justify investments needed to bring these to market. Value to the customer is dependent on the particular market domain. The most noticeable form of value comes in the form of new innovations that meet a customer's economics or needs. Customers quickly realize the benefits of a new technology product; however, the real value is determined at the enterprise level, where customer support becomes critical. Technology products are sophisticated and require a high level of customer support when potential problems arise. After the sale of the product, the relative performance of the enterprise becomes the focus of the customer. Lack of timely and quality support can erode consumer confidence and eventually erode market share for an enterprise.

After the launch of its first product, an enterprise is immediately under the scrutiny of the public. Often, early adopters of new technologies can either make or break an emerging enterprise. Early adopters will assess the enterprise on product quality, delivery, and customer support. If the product is reliable and performs well, then delivery and customer support become the two most critical criteria that a customer will evaluate. It is usually the shortfalls in these two areas that diminish consumer confidence and challenge the credibility of a new enterprise. An enterprise that has an ERP strategy to address these criteria is better positioned for success. If the ERP is designed well, it will allow the enterprise to ensure quality delivery and customer support to the end users. The true value to the customer is realized in enterprise performance as opposed to product performance. Historically, customers have been prone to pursue other vendors because of lack of customer support, moreso than with average product performance. The result of a well-executed ERP strategy enables the enterprise to react immediately and consistently, enabling the organizational components to focus their human and financial capital in the right areas.

Rouse describes the challenge of focus as deciding the path whereby the enterprise will provide value and grow. Rouse (2001) introduces some common challenges in and impediments to an organization's decision making, including:

- Assumptions made,
- Lack of information,
- Prolonged waiting for consensus,
- Lack of decision-making mechanisms,
- Key stakeholders not involved, and
- Decisions made but not implemented.

An enterprise is capable of addressing these challenges if it institutes an ERP solution during its evolution. The ERP solution will bridge many of the communication gaps common among enterprises that are often organizationally disconnected. A good ERP solution will support information sharing, track performance metrics, and archive information, thus providing methods and tools in supporting rapid decision making and furthering the concept of operational velocity. Many times, senior management is unable to focus on key areas due to lack of information and decision-making tools. This problem can be overcome by integrating these capabilities with the ERP. An ERP can scale easily to meet the business needs. The enterprise that plans for growth through its evolution can scale more easily and adapt to change.

Rouse (2001) states that "given a goal (growth), a foundation (value), and a path (focus), the next challenges concern designing an organization to follow this path, provide this value, and achieve this goal" (pp. 5-6). The climate of the enterprise changes rapidly and dramatically throughout its evolution. As new core technology products are launched, the environment is subject to change. Enterprises find ways to scale their infrastructures to meet growth, fend off competition, restructure, reengineer, and support virtual organizations. The objective of change is to improve quality, delivery, speed, and customer service. All of this is made possible through a well-integrated ERP. An ERP capable of facilitating change allows the enterprise to foster new opportunities for growth and reward. As an enterprise evolves over time into a major corporation, business practices change and a paradigm shift occurs over several phases of maturation. The ERP can assist an enterprise in transitioning new business philosophies and practices and to help pave the way for future growth. There is a major need to anticipate future opportunities and threats, plan for contingencies, and evolve the design of the enterprise so that the plans are successful.

The value of the future is difficult to estimate; this realization has lead to another interesting concept, the option value of an enterprise. As previously mentioned, Boer (2002) is a major proponent of options value as applied to the enterprise. This concept explores investment decisions based on buying an option on the future and determining what that option is worth. An enterprise must plan for future growth and weigh the various investment alternatives available. These include looking at the following:

- Strategic fit,
- Financial payoff,
- Project risk and probability of success,
- Market timing, and
- Technological capability of the enterprise.

The above factors weigh into the decisions made to invest in the future. It is through investments in education, training and organizational development that the enterprise is enabled to meet future objectives through resource allocation.

Other investments in research and development technology make decision-making much more complex. However, they may yield promising future results if planned well and integrated with other decisions taken. Investments in R&D require knowledgeable resources that can influence the abilities of an enterprise to provide value. Knowledge management becomes a key element in the overall ERP strategy. Rouse (2001) indicates that knowledge management and knowledge sharing (Small & Sage, 2006) will promote an integrated approach to identifying, capturing, retrieving, sharing, and evaluating an enterprise's information assets. This may be achieved by applying knowledge management concepts to the ERP strategy. A sound return on investment (ROI) model for an ERP should assess the dynamics of the enterprise, changes needed, and projected savings from these changes. The changes themselves should be measurable. An ERP must be planned carefully and, most importantly, well-executed with all resource considerations made during its evolution. The benefits derived from a well-executed ERP should reveal improvements in task management, automation, information sharing, and process workflow. Each of these components improves the most scarce resources that people face within the enterprise, that of time.

Time is a key ingredient for gaining organizational control. An ERP system with integrated tools and methods for communicating and modeling assists human resources with time management. Time management can be a critical problem and human resources can easily find themselves becoming reactive versus proactive in their day-to-day activities. Rouse (2001) emphasizes that it is important to increase the priority given to various long-term strategic tasks, especially since they too often suffer from demands for time from the many near-term operational tasks. A well-integrated ERP supports time management and allows human resources to gain control of their time and allocate it across the appropriate tasks. It further supports the need for long-term planning by supplying various tools and methods for enhancing strategic thinking. The tools and methods integrated within the ERP should improve both the efficiency and effectiveness of time allocation to tasks. An ERP that is incapable of handling the challenge of time diminishes the true value of the ERP. Time management is a crucial component in achieving operational velocity and must be controlled, in order for the enterprise to respond quickly to customer demands.

The seven challenges to strategic management of Rouse (2001) are all critical elements that need to be considered when designing an ERP. A well-designed ERP helps position the enterprise well in the market and gives it a strategic advantage. The true gauges of success of an enterprise, with a successfully executed ERP, will be reflected in how it is positioned in the marketplace. Rouse (1992) has identified five gauges of success:

1. Standings in your markets,
2. Achievements as an innovator,
3. Productivity,

4. Liquidity and cash flow, and
5. Profitability.

Each of these gauges of success is tied to shareholder value. Gardner (2000) also raises a major consideration about designing an ERP in his book *The Valuation of Information Technology*. He asks the questions:

What contributions will an information technology system make to a company's shareholder value? How can an information technology system be constructed to create shareholder value? In other words, not just determine the effect of a system on shareholder value but guide the activities involved in its construction in the first place. (p. 63)

He emphasizes the need to predict the shareholder value that will be created by an information system before it is actually built. In the context of an ERP, the objective is to increase the wealth of shareholders by adding premium growth to their stock. An ERP can improve the asset utilization of an enterprise by allowing shareholders to increase their returns on invested capital. The traditional approach to increasing shareholder wealth consists of maximizing the value of the cash flow stream generated by an operational ERP. The cash flow generated from the ERP is allocated among the shareholders and debt holders of the enterprise. Shareholder value is traditionally measured by using the DCF method, which is central to the valuation of assets and the return they generate in the future. Boer (1999) addresses the DCF method well in his book *The Valuation of Technology*. He defines the premise of the DCF method "as a dollar received tomorrow is worth less than one in hand today" (p. 63). The question that arises from this premise is how much should one invest today in order to earn a dollar tomorrow. To address this, Boer presents one of the common DCF methods known as net present value.

The NPV method can be used to compute the value of tomorrow's dollar. Boer properly defines NPV as "the present value of a stream of future cash flow less any initial investment (p. 98)." NPV addresses the time value of money, which is essential for developing an ERP strategy, with the objective of attaining operational velocity. Gardner (2000) illustrates how this has a significant effect on the management of ERP systems. If the rate of return is high, schedule delays in deploying an ERP can erode value, which makes time to market critical; and since short product life generates as much value as long product life, there should be little resistance in replacing legacy systems. In comparison, if the rate of return is low, delays have little effect on value, and a longer product lifecycle is feasible, thereby allowing for a more thorough systems development effort. Gardner extends the NPV method to an ERP system and illustrates how shareholder value is created by changes in the present value of the cash flow to shareholders due to the use of the ERP system.

The DCF method illustrated here focuses solely on the economic value of the enterprise. Boer (2002) introduces a concept known as the options value of the enterprise in his book *The Real Options Solution: Finding Total Value in a High-Risk World*. The options method is presented as a means to value the strategic capital of an enterprise. This method is known as the total value model and combines the economic value and strategic value of the enterprise, and also takes into account three major drivers that affect value: risk, diminishing returns, and innovation. Enterprises satisfactorily releasing new technologies into the marketplace normally increase their strategic value if consumers adopt these new technologies to meet their needs. New technology adoption in the marketplace can vary based on need, price, standards, and other related factors. Once the need is recognized, operational velocity becomes critical to answering the customer's needs. How fast customers can be served and cared for will drive the strategic value of the enterprise. A well-designed and executed ERP can assist with operational velocity attainment by improving efficiencies, speed, and time to market. Boer's total value model uses a six-step approach to computing the total value of an enterprise. His practical six-step approach encompasses the following:

Step 1. Calculate the economic value of the enterprise, where free cash flow (FCF) is defined as the actual cash flow minus the amount of cash that must be reinvested: *Economic Value = FCF / (Cost of Capital – Growth Rate).*

Step 2. Frame the basic business option and identify strategic options. For example, leasing space at another site and expanding the enterprise may yield additional future revenue. Here, investment in an ERP system may yield future revenue, as a result of enhancing operational velocity.

Step 3. Determine the option premium, which is the premium paid or expenditures incurred to make the plan actionable. For example, this may include the option cost of technology, people, partners, financing, systems, and R&D.

Step 4. Determine the value of the pro forma business plan, where NPV is computed to determine valuation of the enterprise

Step 5. Calculate the option value. Here, the Black-Scholes option formula is used using five key elements: value of the underlying security, strike price, time period of the option, volatility, and risk-free rate.

Step 6. Calculate total value according to *Total Value = Economic Value + Strategic Value.*

Boer's model computes the true value of the enterprise taking options thinking into consideration, thus reflecting real life and the strategic payoff that can result if an enterprise is successful. To clarify the concept, Boer makes an interesting analogy by illustrating the strategic value of a common family with a low standard of living. The family's principal economic activities concern the income produced. Costs such as mortgage, utilities, and gas are set against this revenue. Any savings are stored away as additional income. The income and expenses mentioned thus far only reflect the economic value of the family. The potential strategic value lies in the education of its children. Education could pay off in the long term and increase the family's standard of living. However, there are also significant market risks. Once the children are educated, the marketplace may not demand their skills, or they may not meet the various job requirements of their profession. In comparison, an enterprise may have potential strategic value in a new technology that it develops. The enterprise may have sufficient venture capital to cover R&D expenses for the next few years. Once the technology goes to marketplace for the first time, the enterprise has first mover advantage in the market if it attracts enough early adopters to build market momentum. Critical mass can be achieved as momentum for the product accelerates. However, there could be the risk of competitors with a similar technology that may go to market during the same time frame. In addition, the competitor may have a similar product with different performance standards, which adds to the competitive nature of the situation. This leads to a race for market share and ultimate establishment of the preferred technology standard between the products.

Strategic value is not always predictable, and the dynamics of the market change constantly. A negative impact on strategic value could result in zero return; this results in a loss of venture capital to cover the R&D expenses. There is evidence during the past five years that a number of startup technology enterprises never arrived at fruition in strategic value. The strategic value represents the potential revenue that could be realized if market conditions are ideal for the enterprise. Gardner (2000) estimates the revenue opportunity for an enterprise using *Annual Revenue = ;Annual Market Segment Size x Annual Likelihood of Purchase x Annual Price*. The terms in this relation are time dependent and are critical to new technology adoption in the marketplace. Forecasting potential annual revenue requires understanding the purchasing decisions and patterns customers will make. Decreasing the time for appearance of a positive revenue stream for an enterprise, a new technology into the marketplace is highly desirable. The mechanism for achieving this objective is the evolutionary enterprise resource planning architecture framework, which will accelerate critical mass early in the deployment phase of the product development lifecycle by achieving operational velocity. Thus , the work established by the early pioneers of ERP and technology valuation methods has laid the foundation for a new ERP paradigm to evolve and support operational velocity attainment.

Network Elements Influencing Path Dependence and Network Effects

Consumers who become completely satisfied with a new technology product or innovation realize the value proposition derived from this new creation. For example, the value of a digital subscriber line (DSL) at home brings value to the home PC user who now has high-speed access to the Internet. The home user is no longer confined to the limiting speed capability of a 56 Kbps dial-up modem. As more users adopt DSL, due to its broadband capabilities, increasing returns to scale and path dependence are achieved. The economy has shifted from the supply-side economies of scale, based on the traditional industrial era of mass production driven by unit costs, to increasing returns to scale (also known as demand-side economies of scale) driven by consumer attitudes and expectations. Strategic timing is vital with respect to demand-side economies of scale. First, introducing an immature technology into the marketplace may result in negative feedback from potential consumers. For example, potential design flaws, functional limitations and constrained feature sets may overshadow the true value of the technology, making it less attractive to potential consumers. In addition, moving too late in the market means not only missing the market entirely but also the opportunity to acquire any significant market share. Moving without an effective ERP strategy compromises new customer acquisition and customer retention.

The marketplace is subject to various network elements that influence path dependence and network effects of new technology adoption. These network elements directly impact consumer decision-making and lead to the formulation of consumer perceptions and expectations of new technology. Network elements can be defined as economic, business, regulatory, market, and technological influences that impact consumer decision making relative to new technology adoption. Understanding what drives consumer behavior and how it can be controlled allows innovators and technologists to achieve better success in launching new products while gaining market acceptance.

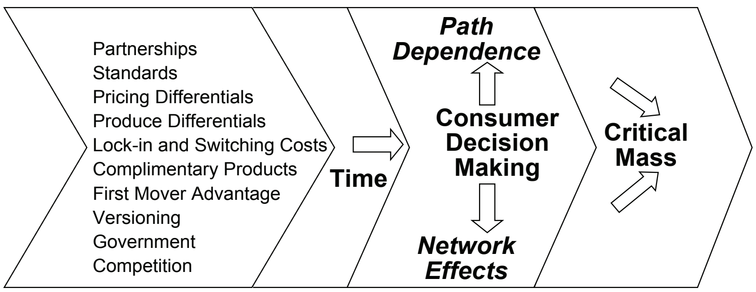
In *Information Rules*, Shapiro and Varian (1999) identify 10 primary network elements that influence consumer decision-making. They describe how these network elements impact consumer decision making with respect to new technology adoption. The network elements described are: partnerships, standards, pricing differentials, product differentials, lock-in and switching costs, complementary products, first mover advantage, versioning, government, and competition. Figure 1 reflects these 10 primary network elements that influence consumer decision making over time. These network elements will shape consumer choice, based on the degree of consumer confidence, need, desire, satisfaction, and comfort with adopting a new technology. The degree that these human traits will vary among consumers will determine the speed with which a new technology will be adopted. Consumers will most likely fall into three categories of adoption: early, evolving, and late. As a technology becomes popular, consumer decision-making becomes positive with respect to new product acquisition. Early adopters of the technology will begin to generate demand for the product.

Based on the success of the initial product, more consumers will see and understand the value proposition realized by the early adopters. A large number of consumers begin to evolve connecting to the network of users. At this stage, consumer choice begins to exhibit path dependence and network effects. As the network of users begins to accelerate, critical mass is realized. Critical mass occurs when a large enough customer-installed base is established, as a result of positive feedback derived from the growing number of adopters. The network continues to expand until these late adopters eventually interconnect and the product reaches maturity in the marketplace. Network elements are also critical to consumer decision-making and can impact the destiny of a new technology if unrecognized. A good illustration of this was the competition between Beta and VHS in the 1970s. Beta was believed by most to be clearly superior to VHS in quality; however, VHS was the de-facto standard among consumers due to its compatibility. Operational velocity is one of the most fundamental critical success factors influencing adoption of new technology the presence of network elements. Operational velocity is a factor that needs the most attention and the one that can easily be controlled by implementing an effective ERP model. Since understanding the influence network elements have on achieving critical mass is essential, a narrative follows describing each one of the elements shown in Figure 1.

The first network element reflects partnerships, which provide a strategic advantage. New technology enterprises, possessing a leading-edge niche product in the marketplace, may find that one or more partnerships, with major players offering a complementary product suite, may be the answer to acquiring critical mass early in the game. An emerging enterprise would have the opportunity to immediately sell its new product to the existing installed customer base of its partner. This existing installed customer base may have taken the partner years to establish and grow, thus offering an advantage to a new enterprise, which has not yet established customer relationships or gained brand name recognition. An opportunity to sell into an existing installed base of customers, by gaining the visibility and credibility via a strong strategic partner, can shorten the sales cycle and accelerate critical mass. Alliances can even be established through suppliers and rivals as a means of accelerating critical mass attainment. It would also be advantageous for the enterprise to offer incentives when possible. Consumer confidence may be won, along with new customer acquisitions, by allowing customers who are undecided over a new technology to sample or test the new product.

The next element reflects standards. Standard setting is one of the major determinants when it comes to new customer acquisitions. Consumer expectations become extremely important when achieving critical mass, especially as each competitor claims they have the leading standard. Standards organizations try to dispel any notions or perceptions as to which company drives the predominant standard; however, most of these standards groups are comprised of industry players, each of whom attempts to market their own agendas. Most will try to influence the direction of standards setting for their own best interests. Standards are necessary for the average consumer, who

Figure 1. Network elements



wants to reduce potential product uncertainties and lock-in (defined as consumers forced to use a non-standard proprietary product). The product that consumers expect to be the standard will eventually become such, as standards organizations and large industry players begin to shape and mold consumer expectations. Standards increase the value of the virtual network and build credibility for new technologies introduced into the market.

One strategy often used among new and aggressive companies in order to gain market momentum is that of pricing differentials. This network element can ignite market momentum by under-pricing competitors and targeting various consumer profiles. Some enterprises may use various pricing strategies to offer incentives to new customers. As a result, this may be an effective strategy, since some customers may be more price sensitive and may not be as influenced by factors such as standards. A common pricing strategy is differential pricing; this may take the form of personalized or group pricing. Personalized pricing takes the form of selling to each consumer at a different price. The focus is in understanding what the consumer wants and tailoring a price to meet the consumer's needs. Group pricing will set targets for various consumer profiles and group them accordingly. This affords flexibility to potential consumers and takes into account various price sensitivities that may impact decision-making. Consumer lock-in may be achieved through pricing strategies by offering incentives such as discounts, promotions, and the absorption of consumer switching costs.

Making product differentials available is another strategy that is very common in the technology industry and that can effectively influence consumer decision-making. Product differentials offer consumers a choice across several product derivatives. By designing a new product from the top down, the company can easily engage any potential competition by introducing the high-end solution first. Once the high-end consumers have been acquired, a low-end solution can be made available to capture the low end of the market. The low-end product also may be used to position the high-end product, when using an up-selling strategy. When introducing a new technology to the market, the market should be segmented based on several factors such as user interface, delay, image resolution, speed, format, capability, flexibility, and features. These factors help target and span various consumer profiles.

As various pricing schemes, product features, and functionality are offered to the consumer, the fears of lock-in and excessive switching costs enter into the decision-making. This network element is one of the most common ones that can halt adoption of a new technology, especially if consumers only deal with one vendor. Most consumers want to deal with two or more vendors in order to maintain a level of integrity among the suppliers offering the product or service. This alleviates the possibility of lock-in with any one particular vendor, as long as they share the same standard. Consumers who deal with only one supplier may face the possibility of lock-in and high switching costs should they decide to select another vendor later. If the existing supplier has not kept up with standards and new technology trends, the consumer may be bound by old legacy infrastructure, which could result in complications if the consumers can no longer scale their environment to meet their own business needs. Some enterprises may absorb the switching costs of a consumer to win their business, if it is in their own best interest, and also if they need to increase their customer base and market share to gain critical mass. New enterprises gaining minimal market momentum with cutting-edge technology product introductions may be more willing to take this approach.

A common competitive strategy used by many high-technology organizations is the selling of complementary products to their installed base of customers. These complementary product offerings can arrive internally within a company by entering new product domains, or externally by offering a partner's complementary product and leveraging on its core competencies.

One of the most challenging network

elements that an enterprise faces is having time to market a new innovation, better known as first-mover advantage. First-mover advantage is the best way to gain both market momentum and brand name recognition as the major provider of this new technology. Microsoft, Sun Microsystems, and Netscape serve as good examples of companies that have succeeded in gaining first mover advantage and that have become leaders in their industries (Economides, 2001). An early presence in the market place has allowed these companies to secure leadership positions throughout the years. We note, however, that Netscape has lost considerable market share to Microsoft's Internet Explorer for reasons that are also explainable by this theory.

Over the years, versioning has become a common practice among technology companies. The network element of versioning offers choices to consumers. Companies will offer information products in different versions for different market segments. The intent is to offer versions tailored to the needs of various consumers and to design them to accommodate the needs of different groups of consumers. This strategy allows the company to optimize profitability among the various market segments and to drive consumer requirements. The features and functions of information products can be adjusted to highlight differences and variations of what consumers demand. Companies can offer versions at various prices that appeal to different groups.

As observed with the Microsoft antitrust legislation proceedings, the government can impact the direction of new technology, whether it attempts to control a monopoly or fuel demand for new technologies (Economides, 2001). This network element can be the most restrictive in achieving critical mass. The government, in efforts intending to ensure that there are no illegal predatory practices that violate true competition, scrutinizes mergers and acquisitions involving direct competitors. There is every reason to believe that it will continue to focus on controlling genuine monopoly power and take action where necessary. All mergers and acquisitions are subject to review by the Department of Justice and the Federal Trade Commission. In addition, the government can serve as a large and influential buyer of new technologies. It can become a catalyst by financing, endorsing and adopting new technologies in order to accelerate their development, adoption, and use. Federal government IT spending on emerging technologies over the next several years can potentially aid those enterprises that are struggling for business and survival as a result of downturns in the economy.

Another network element that can restrict critical mass attainment is competition. Competition in the marketplace will continue as new enterprises are entering the market and presenting a challenge to some large established companies that are plagued by inflexibility and bureaucratic challenges. Companies will compete on new innovations, features, functionality, pricing, and, more importantly, standards. Information products are costly to produce but inexpensive to reproduce, pushing pricing toward zero. Companies that are challenged with a negative cash flow, and have limited venture capital, will need to devise creative strategies to keep themselves in the game. Margins begin to diminish as pricing reaches zero; a complementary set of products or services may be necessary or required to maintain a level of profitability. Knowing the customer, owning the customer relationship, and staying ahead of the competition are the major keys to survival.

Operational velocity is the critical success factor, making a much more profound impact on revenue and profit than the individual network elements described and illustrated in Figure 1. This critical mass determinant, which is the key to the success of an enterprise, is often given very little attention due to the organizational dynamics that take place. Operational velocity, as defined earlier, is speed in delivering products or services to market, meeting all customer expectations in a timely manner, and decreasing the time for appearance of a positive revenue stream as much as possible. This may appear to be a simple concept; however, it is very difficult to master. Without an evolutionary ERP approach, it will be quite challenging to scale a business to meet aggressive future customer demands. There exists a direct relationship between an effective evolutionary the ERP model and operational velocity attainment that allows an enterprise to scale its business accordingly while meeting customer demand in a timely manner. More importantly, there is a unique organizational process lifecycle and key behavioral influences that are essential to implementing an effective ERP model. Without these, the model becomes ineffective, in that ERP has not been implemented in an appropriate and effective manner.

Many enterprises lack any initial operations plan or back-office infrastructure to support new product launches in the marketplace. This is a major challenge in the commercial world, where time to market is critical and development of an effective ERP may be neglected in favor of seemingly more pressing and immediate needs. The primary focus of a new technology company is to amass customers immediately at minimal cost. Often a number of senior executives hired to manage a new enterprise come from sales backgrounds and have very little experience in running a company from a strategic IT, operations, and financial perspective. They sometimes lack the associated fundamental technical and non-technical skill sets, which can easily compromise the future of the business. This often stems from senior executives who come from large corporations but who lack the entrepreneurial experience necessary to launch new businesses. For example, they may fail to see the value of hiring a chief operating officer (COO) who has the required operations background and who understands how to run a business in its operational entirety. The importance of the COO role is later recognized, but many times it is too late as much of the infrastructure damage has already occurred.

Many of the chief executive officers (CEO) hired to lead new enterprises are prior senior vice presidents of sales. It is believed that they can bring immediate new business to the enterprise and begin instant revenue-generating activity. The sole focus becomes revenue generation and new customer acquisitions. The common philosophy is that the company will resolve the back-office infrastructure later. This is usually a reactionary approach to developing a back-office versus a proactive approach. The lack of a sound evolutionary approach in developing an ERP from concept to market maturity for new products can result in missed customer opportunities, customer de-bookings, loss of market share, lack of credibility, competitive threats and, most importantly, bankruptcy of the business.

Other potential plaguing factors that can impact implementation of an effective ERP strategy are undefined, or at least under-defined, organizational requirements, sometimes termed business rules, and lack of business process improvement (BPI—also known as workflow management) initiatives and strategies. Organizational requirements and BPI for supporting new product launches should be addressed early in the development phase of the new technology. How a product is supported and the relationship and communication between the respective support organizations will be vital to the success of the product. Quite often, organizational requirements and BPI are lacking due to limited understanding and use of contemporary IT principles and practices. Many of the savvy technologists who have started the enterprise may lack knowledge in formal methods, modeling, systems development, and integration. They may be great internal design engineers who have come across a new innovation or idea; however, they lack infrastructure knowledge for commercializing the new technology. This had been a common problem among a number of new enterprises. Most new enterprises that have succeeded with these challenges have first mover advantage, a positive cash flow to continue hiring unlimited human resources, and, although reacting late in the process, have implemented an infrastructure that could support the business. The infrastructure was a splintered systems environment lending only to a semi-automated environment. The systems migration strategy occured too late in the product launch phase to allow for a seamless automated process.

Another factor that often plagues the enterprise is the lack of IT personnel who have business-specific skills. Personnel in the IT organization who lack business skills in the various vertical markets such as engineering, manufacturing, healthcare, financial, legal, and retail may have a difficult time eliciting internal customer requirements when developing and implementing an ERP. They may also lack the various business skills internally, if they are unfamiliar with the business and technical requirements of the other functional organizational elements such as sales, marketing, finance, operations, engineering, logistics, transportation, manufacturing, human resources, business development, alliances, product development, legal, along with any other relevant enterprise elements.

Finally, not all employees hired into an enterprise come with an entrepreneurial spirit. Some still have a corporate frame of mind and do not become as self-sufficient as is necessary to keep up the pace. They have a tendency to operate in closed groups and do not interact well with other business units. A team philosophy and aggressive work ethic is essential in order to succeed in an enterprise environment.

The approach, suggested here, to achieving operational velocity is to develop an ERP model that meets the following 15 performance criteria:

1. Reduces service delivery intervals;
2. Maintains reliable inventory control;
3. Reduces mean-time-to-repair (mttr);
4. Enhances customer response time;
5. Establishes timely and effective communications mechanism;
6. Automates processes;
7. Creates tracking mechanisms;
8. Maintains continuous business process improvement;
9. Supports fault management through problem detection, diagnosis, and correction;
10. Manages customer profiles;
11. Monitors business performance;
12. Establishes best practices;
13. Creates forecasting tools;
14. Supports supply chain management; and
15. Integrates all systems within the ERP model such as sales tools, order entry, CRM, billing, and fault management.

These performance attributes are ones that companies have adopted to monitor, manage, support, and measure success of their operational environment. Companies are also continuously challenged with developing and implementing an effective model to support these attributes. The challenges stem primarily from a lack of knowledge and limited use of contemporary IT principles and practices. Enterprises must realize the need for appropriate performance metrics in order to measure success criteria and to plan for future growth and expansion.

Of all the network elements impacting the adoption of new technology, operational velocity is the most compelling, since it will influence customer expectations based on how quickly customer needs can be serviced. These needs may consist of rapid customer service response time, product delivery, problem resolution, and maintenance. Operational velocity, like the network elements, will influence consumer decision making on new technology adoption. If a new technology product has long delays in service delivery or lacks customer support, new customer acquisition and retention eventually become compromised. Under these circumstances, it is possible to lose business to the competition, which may be introducing a similar product into the marketplace. Consumers become disappointed, less patient and quickly begin to look for alternatives. The lack of a reliable operational infrastructure would have been the result of a poorly executed ERP. An effective ERP must be automated, capable of tracking, serve as a communications mechanism, and support various tools. If these criteria are recognized and controlled by the core team of an enterprise, the ERP can provide many benefits as the business begins to scale and the product begins to meet customer expectations. Network elements can influence the outcome of a new technology or the destiny of the product. Understanding the impact that the various network elements have on the enterprise can help position the business in taking on the challenges that prevail. The market timing of the product and the influence on customer decision making will determine the end result of critical mass attainment. An enterprise that prepares and develops strategies, and which takes into account the large number of potential network influences, will accordingly realize this end result. There are a number of complex adaptive system challenges associated with these, and these must be explored as well.

Many of the enterprise resource planning efforts cited in this paper can be traced to the three basic core elements of an ERP: people, process, and systems. Each of these elements were addressed in the various models and frameworks identified by early contributors in the field. As an ERP architecture evolves, each of the ERP elements goes through a maturity state. The evolution of a fully developed and integrated ERP architecture can be inferred from the phases of a basic systems engineering lifecycle. Table 2 illustrates this inference through a framework of key systems engineering concepts that can be applied to the development of an enterprise resource planning architecture.

This suggested framework could be used to develop an enterprise architecture using six key system engineering concepts. To support the ERP development effort, this 6x3 matrix of Table 2 could be used with the six general

Table 2. Key systems engineering concepts framework

Framework of key systems engineering concepts			
Concept Area	ERP Core Components		
	People	Process	Systems
Requirements definition and management	Organizational requirements elicited	High-level operational processes defined	System functions identified
Systems architecture development	High-level architecture developed by team	Architecture supports organizational processes	Systems defined to address organizational requirements
System, subsystem design	Unique data and functionality criteria addressed for each organization	Operational processes at the organizational level are developed	Organizational system components are designed
Systems integration and interoperability	Shared/segmented data and functionality is designed	Operational processes are fully integrated, seamless, and automated	All organizational system components and interfaces are fully integrated and interoperable
Validation and verification	Organizations benchmark and measure operational performance	Operational process efficiencies and inefficiencies are identified	System response time and performance are benchmarked and measured
System deployment and post deployment	Team launches complete and fully integrated ERP architecture	Operational readiness plan is executed and processes are live	Systems are brought online into production environment and supporting customers

system engineering concept areas as rows and the three columns depicting the core components of an ERP. This defines the structural framework for systems engineering concepts and their relevance in developing, designing, and deploying an enterprise architecture. ERP maturity states are represented in each of the quadrants of the 6x3 matrix. As an ERP matures, each of the maturity states is realized and can be directly correlated to its respective systems engineering concept. It can be seen from the framework that the phases of the systems engineering lifecycle can be applied to ERP development. The various ERP models presented in this paper revealed that a systems engineering paradigm may be inferred. The SE concept framework clearly illustrates a systems engineering orientation with respect to ERP.

SUMMARY

In this paper we have attempted to summarize the very important effects of contemporary issues surrounding information and knowledge management as they influence systems engineering and management strategies for enhanced innovation and productivity through enterprise resource planning. To this end, we have been especially concerned with economic concepts involving information and knowledge and the important role of network effects and path dependencies in determining efficacious enterprise resource planning strategies. A number of contemporary works were cited. We believe that this provides a very useful, in fact, a most-needed, background for information resources management using systems engineering and management approaches.

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