WHITE PAPER

****DRAFT; FOR DISCUSSION AND COMMENTS ONLY****

Massachusetts Institute of Technology

LEAN ADVANCEMENT INITIATIVE (LAI): A LEARNING COMMUNITY FOR ENTERPRISE TRANSFORMATION THROUGH HOLISTIC ENTERPRISE SYSTEMS THINKING

Kirkor Bozdogan, Ph.D.

Center for Technology, Policy and Industrial Development
Engineering Systems Division
Massachusetts Institute of Technology
Cambridge, MA

March 31, 2008

Version 3.0

Contact: For more information, please contact the author at: bozdogan@mit.edu, Tel: 617 253-8540; Fax: 617 258-7845

Introduction

This white paper gives an overview of the Lean Advancement Initiative (LAI), defines LAI's focus, outlines the central ideas and concepts driving LAI's approach, explains the similarities and differences between LAI's approach and various continuous process improvement methods, and highlights how all of these approaches can be used in combination most effectively to achieve enterprise change and transformation. The paper is addressed at a general business, government and academic audience interested in enterprise transformation, with particular focus on the role of the Lean Advancement Initiative as a unique industry-government-academic partnership dedicated to the creation of a learning community for enterprise transformation through holistic enterprise systems thinking.

Accordingly, the paper is designed to address a number of specific questions:

- What is the Lean Advancement Initiative (LAI)?
- What is LAI's focus?
- What is LAI's approach -- what are the overarching ideas, concepts and principles guiding LAI's work?
- Why has LAI adopted this approach – what are the major reasons behind it?
- What are the similarities and differences between LAI's approach and the various continuous process improvement methods -- such as Lean Thinking, Six Sigma, Total Quality Management (TQM), Theory of Constraints (TOC), and Business Process Reengineering (BPR)?
- Where and how do these approaches -- LAI's approach and the various process improvement methods -- fit together in striving to change and transform enterprises?

What is the Lean Advancement Initiative (LAI)?

The Lean Advancement Initiative (LAI), formerly the Lean Aerospace Initiative (LAI), is a consortium of companies, government organizations and the Massachusetts Institute of Technology (MIT) organized to enable focused and accelerated transformation of complex enterprises. LAI represents a center of excellence worldwide, creating and deploying a cumulative and expanding body of knowledge on all aspects of enterprise transformation. LAI thus serves as a world-class laboratory of learning and experience that is open for membership internationally.

LAI is an open, inclusive, collaborative, self-governing, and evolving network of organizations jointly fostering and nurturing the development of a learning community. Knowledge creation, through objective and systematic research grounded in the real world, is central to LAI's mission. Knowledge creation is tightly linked to the development of a growing portfolio of implementation tools. LAI's stakeholders deploy these tools to bring about major change. Deployment activities, in turn, help generate new knowledge, which is harvested and widely shared. Moreover, LAI's stakeholders actively collaborate in implementing major deployment initiatives, such as in government organizations, to bring about fundamental change.

Thus, LAI represents a unique framework for collaborative learning and action. A *neutral forum*, facilitated by MIT, ensures dialogue and mutual learning. Creating a *common knowledge base* is critical for accelerating the process of fundamental change. The stakeholders share a *common*

vocabulary, facilitating effective communication among them. Having MIT serve as a *trusted change agent* has been indispensable to the creation of new knowledge and its translation into action. LAI's *transparency* has helped to create trust-based relationships across otherwise competitive enterprises. LAI's *governance mechanism* has proven to be self-corrective and adaptive, as priorities have changed over time. In addition, LAI's core *value creation model* has been remarkably resilient over many years, reflecting a varying but balanced mix of value delivery activities calibrated jointly to meet changing stakeholder needs and expectations. Finally, the *collective commitment* of LAI's stakeholders to work and learn together has cemented the program's progress and growing impact, even as the composition of LAI's stakeholder community has changed significantly over the years. These defining features of LAI have withstood the test of time. They together represent key complementary, positively-mutually-reinforcing, attributes of LAI, strengthened through a *virtuous circle* of knowledge creation, deployment, and relationship-building activities. In sum, this marks the hallmark of LAI and makes it such a unique partnership committed to working toward fundamental change and transformation.

LAI has grown and matured since its creation in 1993 to respond to a number of major challenges facing the aerospace industry in the aftermath of the fall of the Berlin Wall – massive defense cutbacks, stagnant market environment facing commercial aerospace, the need for affordability rather than performance at any cost as the new imperative in defense acquisition, and the need for the aerospace industry to survive and succeed in such a radically new environment.

Since then, LAI has gone through a number of phases. The program's formative years concentrated on helping to bring about fundamental change in both industry and government operations in defense aerospace in order to achieve greater affordability, increased efficiency, higher quality, and enhanced technological capability leading to a stronger national defense industrial base. This was accomplished by building upon, expanding and applying basic lean concepts and principles that had been discovered and documented earlier through the MIT-based International Motor Vehicle Program (IMVP).

The program's scope was broadened in 1996 through the inclusion of both the military space and commercial aerospace sectors. Over time, through LAI's research and growing family of implementation tools, Lean Thinking has evolved from eliminating waste on the factory floor to creating value for multiple enterprise stakeholders, by taking an extended enterprise perspective. LAI's remarkable journey has been documented in Earll Murman, *et al.*, ***Lean Enterprise Value: Insights from MIT's Lean Aerospace Initiative*** (Palgrave, 2002). As defined in the book, "lean thinking is the dynamic, knowledge-driven, and customer-focused process through which all people in a defined enterprise continuously eliminate waste with the goal of creating value." (p. 90).

What is LAI's focus?

LAI's shared vision, mission, strategic imperatives, and operating model drive its current intellectual and action agenda and focus. LAI's vision is to **"enable enterprises to effectively, efficiently, and reliably create value in a complex and rapidly changing environment."**

To reach this vision, LAI's mission is to **"enable focused and accelerated transformation of complex enterprises through the collaborative engagement of all stakeholders to develop and institutionalize principles, processes, behaviors and tools for enterprise excellence."**

Focus: Value Creation Domains

LAI strives to carry out its mission by focusing on three main value creation domains which together define LAI's focus: DEPLOYMENT, RELATIONSHIPS, and KNOWLEDGE CREATION. LAI delivers value to all consortium member organizations through its collaborative activities in these three domains.

The **DEPLOYMENT** domain covers all LAI activities supporting enterprise transformation and knowledge exchange events. Typically, discrete enterprise transformation events involve enterprise-level focus, training and education, and testing and implementation of LAI's enterprise transformation tools, fostering "learning-by-doing." LAI's enterprise transformation engagements are provided on a "fee-for-service" basis if they involve hands-on deployment activities rather than the testing and development of new LAI implementation tools. Knowledge exchange events comprise an important thrust of LAI to engage the stakeholder community in a two-way sharing of information, views and expertise on a wide spectrum of topics ranging from enterprise architecting to transforming supplier networks. LAI's Educational Network (EdNet) represents a significant extension of LAI's educational outreach capability, spanning a network of over 30 educational institutions across the country. EdNet is a learning community dedicated to creating, deploying and continuously improving curriculum for enterprise excellence, by leveraging the expertise and resources of member educational institutions through collaborative innovation in education.

The **RELATIONSHIPS** domain represents LAI's unique role of providing a neutral forum for bringing together its stakeholder community for collaborative engagement, concerted action, and knowledge transfer through conferences, communities-of-practice roundtables, workshops, and web-based communications. Member organizations share lessons learned and engage in joint activities, such as benchmarking and value stream mapping of their linked activities to reduce waste, shorten lead-time, and improve quality.

The **KNOWLEDGE CREATION** domain refers to LAI'S research "engine" for developing new concepts, principles, methods, practices and tools for expanding LAI's cumulative knowledge base. MIT provides objective and systematic research on focused topics supporting enterprise transformation to ensure cutting-edge contributions to the existing body of knowledge. Streams of new knowledge are then integrated into new implementation tools, often with the active participation of top practitioners from member organizations. These tools are tested, validated and deployed at member organizations. Lessons learned from this process point to new research needs. A virtuous process is thus set into motion, ensuring continuous learning by all stakeholder member organizations.

LAI's knowledge creation activities are guided by four grand questions facing the stakeholder community that stem directly from the consortium's vision, mission and strategic imperatives:

- How can I understand how my organization/enterprise *currently* operates within its larger context?
- How can I define and evaluate the *future* possibilities for a more efficient and effective enterprise?
- How can I best manage the enterprise *change* process?
- What are the most effective *strategies* and tactics to achieve these future possibilities for my enterprise?

To address these questions, LAI pursues research to develop a cumulative knowledge base, concepts and principles, and implementation tools for enterprise transformation. The research concentrates on developing total end-to-end enterprise architecture-driven transformation frameworks, roadmaps, and metrics that managers can use to design and execute large-scale change efforts producing tangible bottom-line benefits.

LAI's research is organized into four research groups:

- ***Enterprise architecting and transformation --*** Research concentrates on developing holistic concepts and frameworks, unifying principles, methods and practices that managers can use to design and successfully execute their enterprise transformation efforts in an increasingly fast-paced, complex and uncertain external environment. Research focuses on four principal areas: enterprise architecting, enterprise integration (knowledge integration, IT-enabled enterprise integration), development of effective enterprise metrics, and computational enterprise modeling and simulation.
- ***Enterprise change management –*** Research stresses extensive case studies to discover major determinants of successful enterprise change, focusing on the configuration of key capabilities that, taken together, can be deployed to help ensure self-sustaining enterprise change and transformation.
- ***Enterprise systems engineering –*** Research is concerned with the development and validation of concepts and methods that go beyond the "classical" systems engineering practices in order to address enterprise-level challenges related to the design and development of complex systems in a systems-of-systems environment.
- ***Enterprise product development –*** Research seeks to develop an improved understanding of effective strategies, methods and practices for creating new products, as well as families of products, through the development and integration of enterprise-wide capabilities (functions, processes, engineering infrastructure systems) supporting product development, production and after-market customer support (logistics, sustainment, technology refresh).

Functions

LAI performs a number of key functions to deliver value to all stakeholder member organizations, encompassing industry and government organizations as well as MIT. These functions are: Perform research, Develop implementation tools, conduct enterprise transformation events, deliver training and education, provide communications, and foster collaboration.

Functions / Value creation domains		FUNCTIONS					
		Perform Research	**Develop Implementation Tools**	**Conduct Enterprise Transformation Events**	**Deliver Training & Education**	**Provide Communications**	**Foster Collaboration**
VALUE CREATION DOMAINS	**DEPLOYMENT**	• *Conduct research on implementation projects (capture lessons learned, identify new research questions)* • *Conduct action-research (track what works, why, how)*	• Host implementation events (simulation game, enterprise value stream mapping & analysis) • **Capture lessons learned** • **Maintain, improve & update tools**	• **Combine best tools for collaborative deployment** • **Conduct "for fee" enterprise transformation events** • **Improve toolset**	• *Organize knowledge exchange events* • *Provide workshops, tutorials & roundtables* • **Leverage LAI Educational Network**	• *Provide web-based communications* • *Provide regular news on LAI activities* • *Disseminate results of deployment activities*	• **Collaborate to transform (e.g., government organizations)** • Conduct joint value stream mapping & analysis (customer, key suppliers, lower-tier suppliers)
	RELATIONSHIPS	• Mentor & support LAI research • Sponsor case studies • Sponsor specially funded (customized) research and/or new students • Support surveys • **Identify research priorities**	• Support testing & validation of new tools • **Define common needs for "next-in-line" tools**	• Provide experts and curricula for delivery of special enterprise transformation events • **Share new insights gained from transformation events**	• *Organize annual conferences* • *Provide seminars on key topics* • *Evolve communities-of-practice*	• **Ensure effective communications throughout LAI community** • **Provide wider public communication of LAI products, events & results**	• **Ensure collaborative governance & strategy** • **Conduct collaborative benchmarking** • *Provide networking opportunities* • **Strengthen LAI membership**
	KNOWLEDGE CREATION	• *Perform research on major enterprise topics:* ➢ *Enterprise transformation and architecting* ➢ *Enterprise change management* ➢ *Enterprise systems engineering* ➢ *Enterprise product development* • *Communicate research progress & results at LAI events*	• *Develop and test new implementation tools* • *Integrate new & fielded tools* • *Review & revise research priorities and portfolio in light of "pull" for new tools*	• *Identify & perform new research on questions emerging from special enterprise transformation events* • *Review research priorities in light of implementation results*	• *Educate the next generation of leadership* • *Host special students and/or researchers participating in LAI research activities* • *Present research results at conferences*	• *Provide access to theses, reports, working papers, publications, presentations* • *Provide regular LAI news on new research topics & results*	• *Collaborate with other academic institutions & organizations* • *Collaborate with other MIT research centers & programs*

FIGURE 1.0 – LEAN ADVANCEMENT INITIATIVE (LAI) KNOWLEDGE CREATION DOMAINS AND FUNCTIONS

LEGEND: Roles and responsibilities: *Primarily MIT* **(***text in italics);* Primarily industry and government member organizations (plain text)*;* **entire LAI consortium -- industry, government, MIT (text in bold)**

Figure 1.0 provides a matrix showing the three main value creation domains (deployment, relationships, and knowledge creation, shown as rows) and the six functions, just listed, through which LAI delivers value to all stakeholders. The specific activities in each value creation domain (row) and within each function (column) describe salient illustrative activities LAI performs to create and deliver value to all member organizations by working collaboratively.

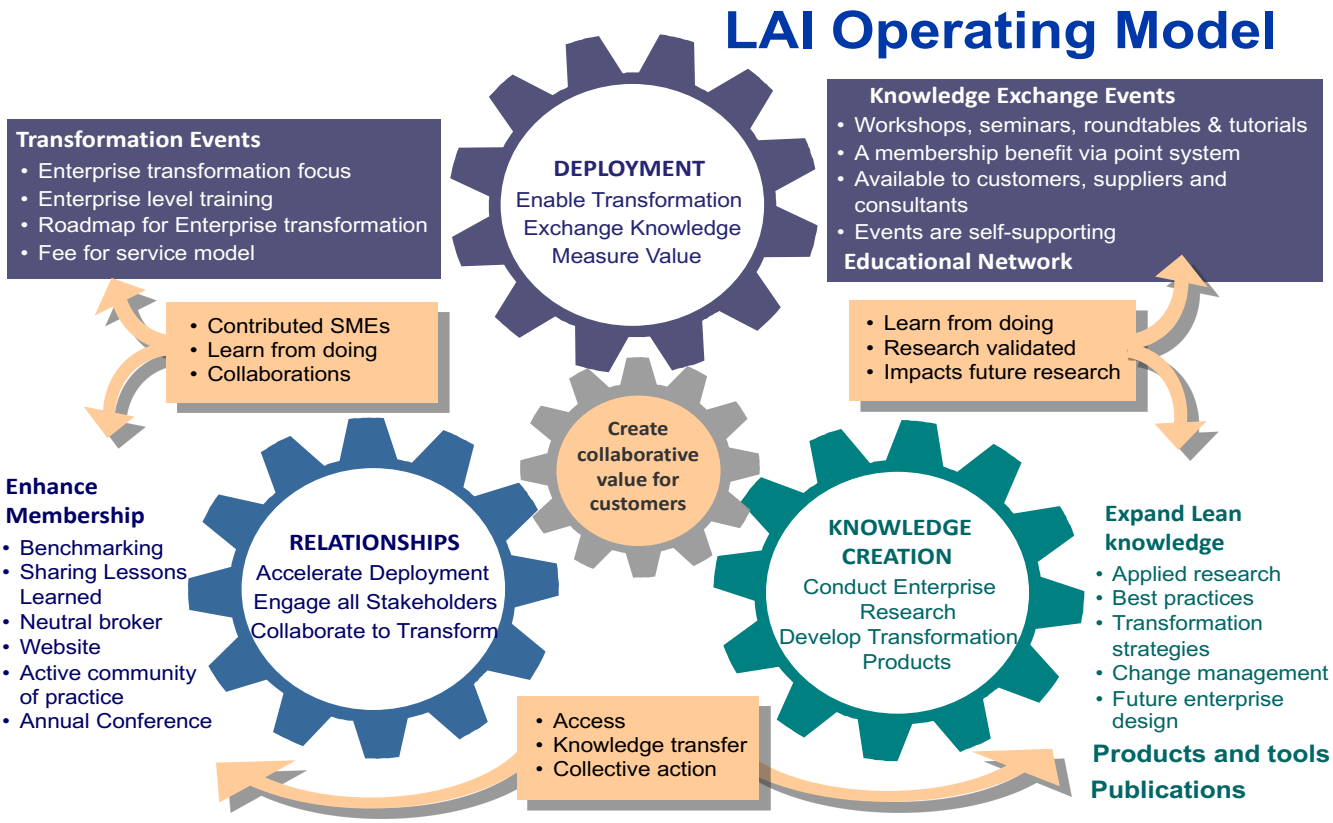

FIGURE 2.0 – LEAN ADVANCEMENT INITIATIVE (LAI) OPERATING MODEL

Figure 1.0 also shows the primary roles and responsibilities within the consortium. Activities shown in regular text format represent those performed primarily by LAI's industry and government stakeholder member organizations. Activities shown in *italics* are those primarily performed by MIT. Activities shown in **bold** text refer to those that are performed jointly and collaboratively by all member organizations, including MIT.

The basic message of Figure 1.0 is that LAI is a self-governing collaborative learning community dedicated to enterprise transformation through a continuous process of knowledge creation,

implementation, education and knowledge-sharing. This is why LAI is larger than the sum of its parts. This is also why LAI is a unique industry-government-academic partnership.

In order to carry out its value creation activities efficiently and effectively, LAI has adopted an operating model that is summarized in Figure 2.0. LAI's operating model shows the three major value-creation domains and how they are linked together through a virtuous cycle where progress within each value-creation domain, by pursuing the illustrative activities within each domain, provides complementary benefits enriching the others.

LAI's vision, mission, major value-creation domains, and the set of functions LAI performs to deliver value to all stakeholders, define the program's total focus. LAI's operating model is ember organizations, with their active hands-on participation and contribution. A signature

A signature characteristic of LAI is its unique research-driven, action-oriented, and multi-stakeholder-focused value creation and delivery model, with MIT serving as a critical catalyst for change, generating fresh knowledge, and providing a neutral platform where all member organizations work and learn together collaboratively, as a dynamic learning community, addressing the challenges of enterprise transformation.

What is LAI's approach – what are the overarching ideas, concepts and principles guiding LAI's work?

LAI adopts the ***Holistic Enterprise Systems Thinking*** approach in pursuing its research and action agenda. The discussion below summarizes the salient characteristics of LAI's approach and briefly describes its major conceptual building blocks, discusses the conceptual and practical "business case" for this approach, and highlights a set of guiding principles driving LAI's approach to achieving enterprise transformation.

LAI's *Holistic Enterprise Systems Thinking* approach:

- Starts with the working proposition that enterprises are *dynamic* systems -- purposeful complex adaptive socio-technical systems organized to create value for multiple stakeholders;
- Takes an end-to-end networked enterprise system perspective, defining the core enterprise's total value creation capability footprint;
- Provides an integrated strategic multiscale systems view of enterprises,
- Strives to evolve and apply general principles, concepts and principles governing the structure, dynamics, behavior and performance of large-scale complex enterprises to provide a knowledge-driven process of discovery and action guiding planned as well as emergent enterprise transformation;
- Employs *enterprise architecture* as a central unifying concept for designing and evolving effective, efficient, flexible and adaptive future enterprises;
- Develops and uses conceptual frameworks, analytical techniques, and computational enterprise modeling and simulation methods for diagnostics, evaluation, planning, and "what if" analyses in a virtual laboratory environment to assist decision-makers in designing and transforming their enterprises;
- Presents an integrated multi-level (strategic, tactical, operational) approach and management structure for implementing enterprise transformation.

Through the research and educational activities of its Engineering Systems Division, of which Lean Advancement Initiative (LAI) is a part, MIT is currently at the forefront of developing such

a new field – complex enterprise systems science, engineering and management – generating the requisite systematic knowledge base to design and execute architecture-driven total end-to-end enterprise transformation principles, frameworks, roadmaps and analytical tools.

LAI's *Holistic Enterprise Systems Thinking* approach encompasses a number of basic conceptual building blocks: ***enterprise, enterprise architecture, enterprise architecture model (modeling), enterprise architecture design (enterprise architecting),*** and ***enterprise transformation***. These are briefly described below.

An ***enterprise*** is defined as a purposeful socio-technical networked system organized to create value for its multiple stakeholders by performing its defined core missions, functions or businesses serving societal ends. This definition of enterprises is scalable, covering enterprises at different levels of size and complexity. A working taxonomy of enterprises at different levels of size and complexity, with examples, is given below:

- Individual plants, facilities or complexes (e.g., Lockheed Martin Fort Worth facility, U.S. Air Force Ogden Air Logistics Center);
- Program enterprises (e.g., Boeing 787 Dreamliner, F-35 Joint Strike Fighter Lightning II);
- Enterprise business units (e.g., Raytheon Integrated Defense Systems, Naval Air Systems Command – NAVAIR, Air Force Materiel Command);
- Large-scale complex enterprises (e.g., United Technologies Corporation, U.S. Army);
- Ultra-large-scale complex enterprises (e.g., U.S. Department of Defense);
- Industrial ecology (e.g., enterprise-of-enterprises, such as the aerospace industry, air transportation industry and the supporting technical and institutional infrastructure, linked together through symbiotic relationships).

Enterprises may take many forms, ranging from vertically integrated "command-and-control" organizations to highly networked enterprises organized around a central (focal, customer) enterprise. They may be loosely-coupled or closely-coupled, exhibiting highly disintegrated (federated) or highly integrated (organic) forms.

These enterprises, whatever their scale (size, complexity) or form, share a number of common characteristics, such as the following:

- They are ***complex adaptive systems***, interacting and co-evolving at multiple scales with their external environment (e.g., technology, market, institutional, policy);
- They are characterized by ***nonlinear interactions***, both internally and externally;
- They exhibit considerable ***interdependencies***, with a large number of interconnected parts;
- They show ***dynamic change***, undergoing continuous change in response to shifts in the the external environment;
- They demonstrate ***adaptive behavior***, learning and adjusting to external changes shaping their evolution, typically through some combination of learning, strategic choice and foresight;
- They embody ***emergence*** properties, where collective (aggregate) behavior at a given scale cannot be understood or predicted from studying microstructure and behavior at a lower scale;

- They demonstrate ***self-organization***, where complex interactions between the system's structure and emergence properties can create a new and different structure over time (e.g., how interactions over time between how information technologies and the enterprise's existing organizational structure might shape workflow at different organizational levels).

Enterprise architecture, as a new concept, refers to the abstract representation of a "real-life" enterprise's holistic design (gestalt, order, pattern, configuration), characterizing its the underlying complexity, structure, and causal dynamics by linking together and explaining the enterprise's purpose, structure, behavior and performance, as it co-evolves with changes in its external environment. The concept of *enterprise architecture* has its linguistic roots in the physical architecture of man-made artifacts (e.g., buildings, products, systems), but differs from such a physical notion of architecture in fundamental ways since it refers to a dynamic, not a static, concept of architecture. It captures the causal structure and behavioral dynamics of complex socio-technical systems *in motion*. The basic proposition underlying this concept is that an enterprise's underlying dynamic complexity can be discovered, represented and understood. Developing such a fundamental understanding of an enterprise's causal dynamics is essential for making informed choices shaping the enterprise's direction and rate of change. It must be noted that there is no universally best enterprise architecture that would serve as a role model for all enterprises to emulate; each specific enterprise must find its own best enterprise architecture, which can be defined and achieved using basic concepts and principles.

Enterprise architecture, as a construct, represents both a snapshot and a moving (motion-picture) blueprint of the enterprise's deep structure, strategic design, and behavioral dynamics. More specifically, *enterprise architecture:*

- Reveals the essential relationships *between* the enterprise as a holistic entity and its major constituent components;
- Captures the key interactions and interdependencies *among* the enterprise's major constituent components, showing how they are connected to each other and how they influence each other's behavior; and,
- Defines the interactions *between* the enterprise as a complex adaptive system and its changing external environment (enterprise landscape) in which it is embedded, as both the enterprise itself and its external environment, interact with each other and co-evolve over time.

The *enterprise as a holistic entity* is defined by its inherent *indivisible* attributes – its core purpose (vision, mission), values, principles, value creation model (its value exchanges with multiple stakeholders), norms and rules that are inextricably linked together and represent a *gestalt*, defining the enterprise's basic function, form and behavior. An enterprise's major constituent components may encompass, for example, its business model, governance, strategy, capabilities, people, organization, technology, processes, and enabling infrastructure.

Such an abstract representation of the enterprise's architecture is developed by discovering, mapping, articulating, and explicitly capturing the enterprise's underlying complexity, structure and behavioral dynamics, using natural language, causal maps, influence diagrams, and various enterprise ontologies (vocabulary, semantics, axioms, symbology). The process is guided by basic theory-grounded concepts, principles and techniques.

Enterprise architecture model (modeling) refers to the utilization of theoretically-grounded formal computational enterprise modeling and simulation techniques (e.g., system dynamics modeling, agent-based modeling, discrete event simulation) to develop a quantitative explanation of the enterprise's underlying architecture, capturing the enterprise's key structural properties, behavior, performance and evolutionary dynamics. The process of *enterprise architecture modeling* involves the development of a parsimonious quantitative representation of the enterprise's dynamic architecture. The resulting artifact (i.e., enterprise architecture model), after proper validation, serves descriptive, explanatory, predictive and educational purposes. The model can be used to define and assess the properties of the current-state enterprise architecture (e.g., fitness, stability, robustness) and to define and evaluate desired future-state enterprise architecture options (e.g., efficiency, flexibility, adaptiveness). Most importantly, the model can be used to conduct *in vitro* "what-if" simulation experiments in a virtual laboratory setting to test out the implications of alternative strategic management decisions. Perhaps the most important utility of the resulting model resides in its educational value, as it serves as a tool for interactive learning and forging a shared understanding of the enterprise as a holistic system.

Most of the recent research in the area of computational enterprise modeling and simulation has been concerned with "toy models" based on general principles and high-level abstractions focusing on organizational design, learning, and adaptation. These models are quite limited in terms of realism. However, computational enterprise modeling is coming of age and management-friendly and useful models can be designed to contain extensive organizational detail at multiple levels to simulate the interdependent behavior of a large number of agents (individuals, teams, departments, organizational units, networks of organizations). The available formal computational modeling methods, such as agent-based models as well as biologically-inspired modeling and computational approaches (e.g., genetic algorithms, NK modeling), can be particularly useful given the complex adaptive nature of enterprises as they are engaged in optimal search and adaptation in complex enterprise fitness landscapes.

The constructs of *enterprise architecture* and *enterprise architecture model* differ from such recently popularized frameworks as *enterprise information architecture,* a static picture of an enterprise's physical information infrastructure, and *enterprise architecture reference frameworks*, showing a "snapshot" picture of multiple views into which an enterprise is decomposed through basically a theory-free reductionist approach (e.g., Zachman , DODAF, FEA, FEAF, etc.). These frameworks serve different, although complementary, purposes; because they are essentially static pictures and are not grounded in theory-based concepts and principles guiding the thinking behind them, they represent inadequate means for designing and achieving enterprise transformation.

Enterprise architecture design (enterprise architecting), a related concept, is the deliberate process of designing the future architecture of the enterprise through the active participation of the key enterprise stakeholders – it is the process of applying holistic thinking to designing an enterprise's going-forward architecture that is expected to deliver the combination of desired enterprise attributes. Critically enabled by computational enterprise architecture modeling, the process involves defining (a) the current-state enterprise architecture; (b) defining the alternative desired future-state architecture design options; (c) evaluating the defined design options by using evaluation criteria and metrics; and (d) selecting the "best" solution option for execution, using selection criteria and methods. *Enterprise architecture*

design (enterprise architecting) serves as a compass, guiding the enterprise's transformation effort, and defines the "end-game" state embodying desired future enterprise attributes in an unfolding change environment with moving targets. It also, more broadly, makes use of the enterprise's cumulative knowledge base and the insights provided by the enterprise leadership.

Enterprise architecture design (enterprise architecting) stresses such concepts as congruence, coherence, cohesion, mutual fitness of the constituent elements or components that are so unified as a whole that properties of the whole cannot be derived from a simple summation of its parts. An overarching concern involves the achievement of not only *internal fit*, within the enterprise, but also *external fit* between the enterprise as a whole and the outside environmental contingencies facing it. Another important concern relates to balancing the conflicting needs for efficiency and innovation, an important management task as the enterprise seeks optimal search and adaptation in the face of complex, uncertain and turbulent environments.

Enterprise transformation is generally viewed as a fundamental change (systemic or deep change) in an enterprise's basic concept, structure and behavior. Enterprise transformation is examined through emphasis on a number of related themes or dimensions that together comprise a "template" or working framework for thinking about, planning, and executing enterprise change and transformation.

- *Context* -- Understanding enterprise-environment interactions and co-evolution over time, to define both internal and external conditions shaping the imperative for transformation, diagnose the presence and sources of the lack of "fitness" (internal, external), and define the set of contingencies to be considered in framing the enterprise's transformation strategy;
- *Time* – Specifying the time-period for the planned or intended transformation effort (e.g. near-term, 1-3 years; medium-term, 4-5 years, longer-term, 6-10 years), to help frame the internal and external conditions expected to affect the enterprise's performance and to decide whether to place relatively greater emphasis on the enterprise's internal or external interactions;
- *Outcome* – Defining and developing a shared understanding of the expected outcome or set of outcomes from the transformation process (i.e., the end result or future steady-state attributes the transformation process is expected to deliver, by identifying and evaluating any tradeoffs among multiple objectives or targeted enterprise attributes – greater efficiency, flexibility, adaptability, reconfigurability, etc.);
- *Scope* – Mapping the scope and substance of the transformation process, through an "open" inclusive process soliciting the inputs of the stakeholders, leadership and workforce at all levels (e.g., strategic reorientation, structural change, upgrading current capabilities, continuous process improvement);
- *Culture* – Defining and creating the conditions conducive to a culture of change, addressing issues of risks and rewards, incentives, career trajectories, conflict resolution mechanisms, potential barriers and means of overcoming them;
- *Strategy* – Choosing the strategy or mix of strategies for pursuing enterprise change and transformation, such as the pace of change (e.g., evolutionary, revolutionary), type of change strategy (e.g., planned, guided-emergent), time-phasing of the transformation effort with milestones, whether to follow a concurrent or sequenced change strategy);

- *Process* – Framing the transformation roadmap and implementation process (e.g., pilot projects, mapping the networks of functional and process interdependencies, planning how to coordinate interdependent change actions at multiple levels as well as over time);
- *Infrastructure* – Identifying and planning for enabling systems, information technology and systems, training and educational resources);
- *Methods and tools* -- Defining the methods and tools to be employed to bring about enterprise change and transformation (e.g., lean thinking, six sigma and related continuous process improvement methods; enterprise value stream mapping and analysis; enterprise architecting methods; enterprise change management capabilities framework; computational enterprise modeling and simulation);
- *Training and education* – Providing training and education to develop change agents with competence in change management processes and in the effective implementation of tools and methods; creating a closed-feedback-looped organizational learning process for capturing lessons learned from implementation projects and incorporating new insights into the next-generation deployment methods and training materials;
- *Management* – Defining the management structure for pursuing an integrated multilevel change process, encompassing active leadership engagement at all levels; assessing change management capabilities;
- *Evaluation* – Defining criteria, frameworks and methods for monitoring and evaluating progress towards achieving enterprise change and transformation objectives (e.g., self-assessment frameworks, performance metrics), as well as for performing post-implementation evaluation of the success of the transformation process.

Enterprise change may be *incremental* or *radical*. Typically, *incremental* change, through a continuous improvement process, leads to evolutionary change over a long span of time, in a relatively stable external environment, affecting values, strategies, systems and procedures. Incremental change may entail a process of small changes and adaptation involving improvisation and organizational learning, for instance through the employment of continuous process improvement methods to modify organizational processes and practices. Small changes may accumulate into big changes; however, the evidence for this is scarce. Incremental change, while important, does not necessarily ensure enterprise transformation.

Radical change represents discontinuous or "frame-bending" change marking a sharp break with the past, in the form of sudden bursts or "punctuations" that affect virtually all parts of the enterprise simultaneously – core values and beliefs, business model, strategy, processes. *Radical* change, caused largely by cataclysmic shifts in the external environment (e.g., technology, markets, national security environment, etc.), typically involves fast-paced revolutionary change and takes place over a relatively short period of time.

In general, enterprise change and transformation is *intentional*, the result of *planned change* efforts. Planned change typically involves a top-down programmed process to move the enterprise from its "unsatisfactory" current state to a defined future state by employing change theories, intervention strategies and coordinated actions at multiple levels designed to navigate the enterprise's transition over a defined period. In contrast with planned change, *emergent change* pursues a bottom-up, open-ended, process of improvisation, learning and adaptation to unfolding circumstances and conditions. Emergent change is consistent with some evidence that enterprise change, resulting in transformation, can occur through small micro-level changes that occur over time, where even an accidental small change may trigger cascading changes whose

ultimate consequences may be totally unintended or unanticipated. Thus, *emergent change* stresses the unpredictability of change and puts emphasis on "guiding" change by creating the right combination of conditions through which change can emerge in desirable directions through the interaction of a multitude of agents and variables within the enterprise.

Enterprises must choose the right transformation strategies. For example, when the enterprise's planned change time-horizon is near-term and its external environment is relatively stable, it may well pursue planned incremental change focused on enterprise integration and process improvement to achieve greater efficiency. However, when the enterprise's external environment is highly unstable or turbulent, it may make little sense to pursue planned incremental change and may instead be better off adopting an emergent change process stressing the achievement of greater flexibility.

Finally, *enterprise transformation* can be viewed as a fundamental change in an enterprise's current-state architecture through the design and application of proactive planned intervention strategies and methods or by pursuing emergent change strategies. Enterprises must learn how to manage both continuous and discontinuous change, where the latter affects virtually all aspects of their structure, behavior and performance (e.g., business model, strategies, processes), often resulting in a reinvention of the entire enterprise. In general, past efforts focusing on enterprise transformation have almost exclusively concentrated on continuous change, while neglecting discontinuous change.

LAI's holistic enterprise-architecture driven approach to enterprise transformation is guided by a number of organizing principles that reflect a distillation of cumulative research-based findings and empirical observations:

- *Adopt a holistic architecture-driven, knowledge-based, enterprise transformation strategy to effectively address interdependencies, manage complexity, and guide dynamics of change;*
- *Take an end-to-end "wide angle" extended enterprise perspective;*
- *Identify relevant stakeholders, determine their value exchange expectations, and create a robust value creation model to deliver value to all stakeholders, focusing on the customer;*
- *Develop a shared vision and common purpose driving enterprise transformation;*
- *Follow an inclusive collaborative transformation process enabling the creation of mutually-beneficial relationships;*
- *Ensure stability and flow within and across the enterprise to pursue the achievement of critical efficiency gains;*
- *Focus on greater efficiency (near-term) and sustainable growth (longer-term) if the external enterprise competitive or institutional landscape is relatively stable, but stress greater flexibility (near-term) and adaptiveness (longer-term) if the external enterprise competitive or institutional landscape is unstable or turbulent;*

- *Emphasize system optimization by empowering leadership at all levels to think globally while acting locally;*

- *Evolve an enterprise culture embracing change, establish the necessary infrastructure supporting change, invest in training and education, and design new incentive mechanisms;*

- *Foster a process of on-going organizational learning and develop dynamic organizational capabilities to motivate discontinuous change, unlock breakthrough solutions, and ensure sustainable enterprise transformation.*

Why has LAI adopted this approach – what are the conceptual and practical reasons for it?

What is the "business case" for LAI's *Holistic Enterprise Systems Thinking* approach? This important question is addressed below, by giving both the practical and conceptual reasons for the choice of this approach.

Practical Reasons

LAI's approach is tempered with a keen observation of the real world – on what works, what fails, and why.

It is often observed that many enterprise transformation initiatives employing lean six sigma principles and methods soon reach a plateau and rarely transcend beyond localized marginal operational improvements with no appreciable impact on bottom-line enterprise-level performance metrics.

There are several reasons that help explain why such an outcome is commonly observed. These reasons help inform and shape LAI's *Holistic Enterprise Systems Thinking* approach.

Four main reasons, in particular, can be quickly highlighted.

First, Lean Six Sigma (LSS) Continuous Process Improvement (CPI) initiatives -- Lean Thinking, Six Sigma, Total Quality Management (TQM), Theory of Constraints (TOC), Business Process Reengineering (BPR) -- often fall short of their promise because of serious constraints imposed by pre-existing enterprise architectures – obsolete business models or flawed strategies which once worked but are no longer relevant, adversarial governance structures that are out of step with today's environment calling for greater collaboration, business processes organized into functional silos that are no longer effective for today's operations requiring end-to-end visibility supporting continuous flow of goods and services. All too often enterprises become self--directed, trying to optimize within the four corners of the core enterprise while neglecting significant improvement opportunities across the entire extended enterprise. An example is the mistaken treatment of supplier networks as an afterthought, rather than at the front and center of the enterprise. An alternative, more holistic, approach would be to critically review the enterprise's prevailing ("as-is") architecture, to see whether and how it might be redesigned to improve the enterprise's structure, behavior and overall performance by eliminating existing constraints, misalignments, and behavioral rules causing perverse organizational outcomes.

Second, LSS CPI initiatives typically fail to address effectively the complexity and dynamics of today's large-scale enterprises, which are often characterized by nonlinear causal interactions and complex functional, process or organizational interdependencies. The nature of complexity may be quite different at different enterprise levels; methods effective at one level may fail at other levels. Still, a common assumption is that LSS CPI techniques are equally applicable at multiple enterprise levels. Top-level strategies may remain generally unconnected to deployment initiatives at operational levels. Also, in general, the time-dynamics of the change process in complex large-scale organizations are often poorly understood or often ignored. Further, the right configuration of change management capabilities may be lacking.

For these and other reasons, it is not altogether surprising that continuous improvement initiatives often result in isolated islands of success, failing to spur sustained enterprise-wide change and transformation. Despite some modest benefits mostly at the tactical and operational levels, scaling these methods up to address strategic issues essentially breaks down under the weight of thorny organizational complexity at the intersection of policies, business models, technologies, culture, and behavioral rules. It is found in government organizations, for example, that identification of the root causes of strategic performance gaps is often very difficult because of the sheer complexity of government organizations and processes, and also because of varying views of what strategic gaps are and what constitutes success in closing such gaps. In general, the available LSS CPI concepts and approaches fall short of being capable to be scaled up to address the structural and behavioral complexities characterizing today's large-scale enterprises.

Third, there appears to be a general assumption, evidenced from current transformation efforts, that deploying LSS CPI initiatives through extensive training, certification and implementation activities would ensure enterprise transformation. The expectation seems to be that an aggressive LSS CPI effort would produce self-sufficiency in terms of the development of internal enterprise LSS CPI capabilities within a relatively short period of time, which would then ensure sustainable enterprise change over the longer haul. This, however, remains a dubious proposition. It is highly unlikely for an organization to transform itself unless the individuals within the organization themselves are first transformed. For example, providing LSS CPI services could equip the enterprise's personnel with new skills and capabilities, but whether they will, as a consequence, start thinking and acting differently as transformed "change agents" remains far from certain. Although existing research is not encouraging on this point, LAI's approach outlined in this paper can help provide guidance to the member organizations on ways of maximizing the effectiveness of their LSS CPI training and implementation activities in order to produce effective "change agents" rather than delivering mechanical learning.

Fourth, the lack of an effective enterprise transformation management structure and engagement process – that is, the absence of a centrally-coordinated and integrated approach with active and synchronized leadership engagement at multiple levels -- is often a serious source of failure in both public and private sector enterprises. Enterprises are often observed to pursue basically a top-down change process within individual vertical organizational silos, with little coordination across them. Moreover, various initiatives within the respective organizational silos often move at different speeds, employ a different mix of methods to address similar problems, attack varying sets of priorities, differ in terms of their scale and scope, and employ a duplicative process of developing and using training curricula that may not be well-tailored to different types of problems being faced at different management levels and problem contexts.

Finally, the adopted transformation strategy may be rigidly implemented in a top-down fashion, leaving little room for guided change or bottom-up emergent change. Sometimes adoption of the "gardener" metaphor may be more effective in enabling emergent change across the enterprise, within the context of an organized enterprise-wide transformation effort.

Conceptual Reasons

The practical reasons just cited support the various conceptual reasons in favor of taking a *Holistic Enterprise Systems Thinking approach*. At the conceptual level, today's modern enterprises are seen as purposeful complex adaptive systems, where a deeper causal understanding of their structure and dynamics is essential for prescribing effective solutions to improve their performance and help engineer their transformation. The basic idea here is akin to arguing that it is necessary to master the fundamentals of aerodynamics -- in terms of the underlying physics, mathematics and engineering principles -- in order to design and engineer airplanes.

Thus, at the basic conceptual level, LAI's *Holistic Enterprise Systems Thinking* approach encompasses general principles and frameworks through synthesis of major recent developments in a number of interrelated fields – such as organizational science, information and decision sciences, theory of complex systems and networks, engineering sciences, system-of-systems thinking, computational enterprise modeling and simulation – that are brought together and integrated to address the transformational challenges of today's large-scale complex enterprises. These developments, taken together, provide new strategic insights into the structure and dynamics of large-scale complex social and technical systems and their co-evolution over time. When integrated with Lean Thinking and related continuous process improvement methods, *Holistic Enterprise Systems Thinking* provides a powerful new way of looking at, understanding, and transforming today's large-scale enterprises.

Holistic Enterprise Systems Thinking represents an important step forward toward evolving an integrative new field that can be defined as **complex enterprise systems science, engineering and management**, at the intersection of socio-technical systems science, engineering, and management. The science "leg" of the new "stool" leads to a new systematic knowledge base and improved understanding of enterprise dynamics through integrative, multi-disciplinary, research. The "engineering" leg of the stool makes use of the scientific knowledge base that is generated to define, design and evaluate new enterprise architectures. The "management" leg of the stool provides the change management leadership, organizational, and implementation capabilities to achieve enterprise transformation.

How does LAI's approach differ from the various continuous process improvement methods, such as Lean Thinking, Six Sigma, Total Quality Management (TQM), Theory of constraints (TOC), and Business Process Reengineering?

Figure 3.0 presents a high-level comparative overview of LAI'S *Holistic Enterprise Systems Thinking* approach and the various LSS CPI methods -- Lean Thinking, Six Sigma and related continuous process improvement approaches such as Total Quality Management (TQM), Theory of Constraints (TOC), and Business Process Reengineering (BPR).

Three major points, in particular, are worth making, based on this comparative overview.

First, *LAI's Holistic Enterprise Systems Thinking approach builds upon and extends Lean Thinking by evolving general principles governing enterprise dynamics through the fusion of basic lean concepts and theory-based principles brought together and integrated from multiple disciplines.* The time is ripe for such a synthesis, particularly since there has been a virtual explosion of new ideas and methods in recent years. LAI's *Holistic Enterprise Systems Thinking* approach capitalizes on these rich new developments. The resulting synthesis would provide a sound conceptual basis for thinking about and transforming modern enterprises, while making full use of hallmark lean concepts.

An important benefit of *Holistic Enterprise Systems Thinking* would be to provide a unified scientific understanding of the causal dynamics of enterprises, offering a generic *descriptive* as well as *explanatory* model of enterprises. This would ensure a more rigorous scientific rationale on which to decide what would merit consideration as *normative* principles and practices that would be worthy of adoption, with a greater assurance that they are research-validated and stem from a deeper causal understanding of enterprises. Otherwise, enterprise leaders would essentially fall back to the clearly less desirable option of adopting certain principles and practices because they are deemed a "list of good things to do." This, however, is unlikely to produce either tangible or lasting benefits. More importantly, *Holistic Enterprise Systems Thinking* strives to develop a stronger scientific basis for *enterprise architecture modeling* and for *enterprise architecture design (enterprise architecting)* to help design and execute sound enterprise transformation strategies and processes.

Another important benefit of *Holistic Enterprise Systems Thinking* would be the ability to explore a number of contingent conditions facing enterprises, for example including both fairly stable and quite turbulent external environments within which enterprises may find themselves as they strive to search for strategically more advantageous locations across the enterprise competitive landscape. This is critical since it opens up whole new ways of thinking about enterprise change and transformation needs and strategies. Lean Thinking has evolved essentially in a relatively stable environment. However, many enterprises face transformation challenges in highly fluid, fast-changing and often hyper-turbulent market and technological environments. How Lean Thinking can be adapted to address a myriad of questions facing enterprises in relatively unstable, discontinuous or fast-changing external environments remains an open question that can be addressed through *Holistic Enterprise Systems Thinking.*

Pointing out certain limitations of Lean Thinking – largely as an artifact of its evolutionary history -- and striving for a new and more complete synthesis of the available knowledge base on enterprise dynamics should not be taken as an argument against Lean Thinking. What makes Lean Thinking still compelling – alone among the various continuous improvement methods -- is that it provides a basic philosophy, set of principles, management system, and a way of doing business where all elements come together as a system. In fact, its classification with the various process improvement methods as "continuous process improvement methods" does some injustice to Lean Thinking. Lean Thinking is not a set of tools or a list of things to do but a unified way of thinking about and managing complex enterprises. The various elements of Lean Thinking have been discovered and documented over a fairly long period of time and this discovery process still continues. All that can be known about Lean Thinking is still not yet

complete. The search goes on. Looking back, it can be recalled that the original architects of the Toyota Production System (TPS) deliberately refrained from making known the company's practices for some time. Lean Thinking did not emerge full-grown from some textbook theory of organizations but as the result of considerable experimentation and a variety of evolutionary paths over time.

At one level, Lean Thinking provides a *descriptive* model of a production system, documenting and revealing a set of principles, practices and methods that, working together in a mutually-reinforcing manner, are observed to result in successful enterprise performance. The early *Standard Lean Model* version of Lean Thinking, with its genesis in the Toyota Production System, focused primarily on factory floor operations and only gradually expanded its scope to encompass the supplier network. The *Standard Lean Model* represented a customer-focused, pull-based, small-lot production system designed to provide a variety of low-cost and high-quality products to meet diverse customer needs in a highly fragmented domestic market. The factory workflow process was designed to ensure continuous flow pulled by customer demand and enabled by just-in-time production, which, in turn, was made possible by creating virtually defect free products and processes, with respect for people squarely at the center of the entire system. Relentless pursuit of continuous improvement placed central emphasis on elimination of waste, by making optimal use of the capabilities of people, which ensured not only greater efficiency but also delivery of superior products to the customer.

Pull-based single piece flow through the factory has been a basic lean manufacturing practice – the traditional core of lean thinking. Materials and information *flow*, from one station to the next, but defects *do not flow* by design, since defects represent rework and a major source of waste. In this sense, striving for perfect quality – which makes continuous flow possible – has been integral to lean production. Further, continuous improvement of the continuous flow process itself has fueled *faster speed*, a critical feature of the *Standard Lean Model* not always widely recognized.

The current *Lean Enterprise Model* version of Lean Thinking, based primarily on research at MIT, broadens the scope of lean principles and practices from the factory floor production operations to the entire enterprise and expands the central thrust of the *Standard Lean Model* from the elimination of waste to the creation of value for multiple enterprise stakeholders. The *Lean Enterprise Model* stresses a number of core principles -- focus on the customer, eliminate waste with the goal of creating value, emphasize continuous knowledge-driven enterprise change, and foster organizational learning and capability-building. Other, complementary, principles, as well, have been offered, such as the following: create lean value by doing the job right and by doing the right job; deliver value only after identifying stakeholder value and constructing robust value propositions; fully realize lean value only by adopting an enterprise perspective; and, address the interdependencies across enterprise levels to increase lean value.

In the final analysis, Lean Thinking clearly provides an irrefutable "existence proof" (i.e., Toyota) that the adoption of lean concepts and principles -- as a way of thinking, not as a checklist of things to do -- can in fact work and produce significant performance improvement benefits. Lean Thinking – embodied earlier in the *Standard Lean Model* version and currently in the *Lean Enterprise Model* version – provides important precepts that many enterprises would find helpful. Obviously, each enterprise must develop its own way of doing business, and Lean Thinking is not offered as a solution to every enterprise's particular set of circumstances or

problems. Still, *Holistic Enterprise Systems Thinking* would augment and expand Lean Thinking in fruitful directions and, in the process, achieve a new synthesis of knowledge about the DNA of enterprises that should prove generally indispensable for sound transformation actions.

Second, *Lean Thinking provides an overarching conceptual and pragmatic umbrella for the various change initiatives, which share similar objectives, have common roots, and generally comprise highly complementary approaches, while the differences among them are dwarfed by the complementary strengths they bring to each other. This is why these methods are rapidly merging into an integrated set of approaches for bringing about continuous process improvement, by building upon their respective complementary strengths; the mix of the "continuous process improvement" toolset may vary, but they are often referred to as Lean Six Sigma (LSS) continuous process improvement (CPI) methods.* When the various pieces are assembled and deployed in combination, they can help produce tangible change. However, taken either separately or together, the various continuous process improvement methods, with the possible exception of Lean Thinking and highly qualified exception of Six Sigma, do not generally rise above essentially tactical or operational methods for achieving enterprise performance improvement. In contrast, *Holistic Enterprise Systems Thinking* offers not only a critical strategic perspective but also and integrated strategic, tactical and operational roadmap for designing and achieving enterprise transformation.

Total Quality Management (TQM), which became highly popular in the 1980s, shares common origins with Lean Thinking. They both seek continuous quality improvement to meet customer expectations (e.g., in terms of product performance, reliability, durability, and utility). Statistical process control (SPC), quality engineering for robust design, quality circles and similar methods and practices were adopted by Toyota -- the source of Lean Thinking – and by other Japanese companies, in the 1950s.

Six Sigma and Lean Thinking, as well, are highly complementary. Six Sigma represents a further refinement of TQM through the application of probability theory to Statistical Process Control. First introduced in the mid-1980s at Motorola, Six Sigma was later adopted by General Electric and a growing number of other companies and organizations. Both Lean Thinking and Six Sigma stress focusing on the customer, reducing variation, continuous improvement, collaborative relationships, and data-driven management. They both place importance on improving the capabilities of people.

Lean Thinking and Six Sigma further complement each other in other important ways. Among these, clearly the most important is the fact that Lean Thinking stresses *continuous flow* by tightly integrating all processes in the extended enterprise value stream, as well as placing a heavy emphasis on *striving for perfect quality*, in order to achieve the advantages of *speed.* By design, materials and information *flow* through the value stream from the upstream processes to the downstream processes, but defects do not, since defects represent rework and, therefore, constitute a significant source of waste. Meanwhile, Six Sigma stresses the achievement of higher *quality* (i.e., reaching a performance level of 99.99966 percent perfection, which means 3.4 defects per million opportunities) through elimination of all sources of process variation. Thus, Six Sigma directly complements Lean Thinking through its central emphasis on virtually defect-free products and processes, without which it would be impossible to achieve continuous flow and enjoy the benefits of speed, two critical benefits of Lean Thinking.

Theory of Constraints (TOC) was introduced in the 1980s to focus attention on throughput on the factory floor, to identify and remove bottlenecks constraining performance in production operations. TOC can be implemented as an integral part of Lean Thinking principles and practices, which is equally focused on achieving continuous flow and fostering better and faster learning by people. For instance, TOC methods and techniques can clearly help enhance value stream mapping and analysis. Among the various continuous process improvement methods, TOC in particular takes an explicit systems approach to enterprise performance improvement, viewing enterprises as interdependent systems containing leverage points that can be exploited to improve overall performance.

Finally, Business Process Reengineering (BPR), introduced in the early 1990s, pursues radical "clean-sheet" rethinking and redesign of enterprise business processes to bring about dramatic performance improvements to help enhance customer satisfaction and achieve greater productivity. Clearly, BPR can also be directly incorporated into Lean Thinking, for example as part of the value stream mapping and analysis process to realign or radically redesign existing

Change Model / Key Attributes	**Holistic Enterprise Systems Thinking (HEST)**	**Lean Thinking (LT)**	**Six Sigma (SS)**	**Total Quality Management (TQM)**	**Theory of Constraints (TOC)**	**Business Process Reengineering (BPR)**
Defining characteristics, core concepts & principles	• Holistic systems perspective (structure, dynamics, behavior, performance) • Enterprises viewed as complex adaptive purposeful systems of networked organizations • Enterprise architecture as a central organizing concept • Foster culture of organizational learning, innovation & discontinuous change	• Long-term thinking • Customer focus • Mutually-reinforcing set of concepts, principles & practices for eliminating waste, achieving continuous flow & striving for perfect quality • Evolving a culture of organizational learning • Pursuing continuous improvement	• Customer focus • Structured set of practices, methods & tools for reducing all sources of variation in enterprise processes • Disciplined problem solving approach to process improvement • Data-driven process management toolset	• Evolving system of practices, tools & methods for improving quality • Integrated approach to increasing customer satisfaction • Improving productivity & performance through continuous improvement	• Framework for improving throughput • Viewing business operations as interdependent chains of activities • Leveraging system bottlenecks (constraints)	• Customer-centric radical redesign & change of enterprise business processes for dramatic improvement • Process-centric view of enterprises; emphasis on processes, not functions • Pragmatic; learning and improvisation
Goals, objectives, expected outcomes	• Create value for multiple enterprise stakeholders • Design and evolve high-performance enterprises (efficient, sustainable, flexible, adaptive) • Achieve successful enterprise transformation optimizing internal and external fit	• Create value for multiple stakeholders, focusing on the customer • Build sustainable competitive advantage	• Increase customer satisfaction by fostering a customer-focused culture • Create economic wealth (higher profitability & shareholder value)	• Meet customer expectations • Satisfy latent customer needs by introducing innovative new products • Enhance enterprise performance (profitability, shareholder value)	• Improve system performance (e.g., net profits) • Foster continuous learning	• Improve enterprise performance (cost, quality, service, speed) • Optimize value added work • Reinvent the company (organization) for the customer
Focus	• End-to-end networked enterprise system (enterprise ecology; system-of-systems) • Integrated multi-level (strategic, tactical & operational) change & transformation process	• Enterprise: Stakeholder value exchanges; enterprise value stream • Business unit: Core & enabling processes • Factory floor: Workflow processes	• Discrete enterprise operations focus (functions, processes) • Specific improvement projects	• Enterprise processes (production operations, functions) • Product quality (performance, reliability, durability, aesthetics, utility)	• Production system (business unit, factory floor workflow processes) • Weakest links in production system (bottlenecks)	• Discrete enterprise business processes (process = end-to-end work) • Business unit; organization; individual facilities
Strategy, methods, tools	• Enterprise transformation framework for defining context & strategy • Enterprise architecture	• Enterprise: Value stream mapping and analysis • Business unit:	• Six sigma improvement strategy focusing on key processes critical to customer satisfaction	• Committed leadership; closer customer relationships; employee training &	• Stabilize system, identify & remove system bottlenecks to speed up flow	• "Clean-sheet" radical process redesign (mobilization, diagnosis, redesign, transition)

	design (define current architecture, define future architecture options, evaluate options & tradeoffs, select best option) • Enterprise transformation roadmap & integrated multi-level transformation management structure • Computational enterprise modeling & simulation • Advanced techniques & methods (e.g., multi-objective optimization, real options) • Evolutionary systemic as well as fundamental improvement	Pursue structured lean implementation process -- Define *value* to customer; identify product *value stream*; achieve continuous *flow* of value-adding steps; *pull* value-adding activities throughout the production system; strive for *perfection* • Factory floor: Implement standard lean practices (e.g., production leveling, takt time, standard work, single piece flow, cellular manufacturing, pull-based just-in-time production, multi-skilled workforce, quality circles) • Continuous & systemic improvement	• DMAIC approach to prioritized improvement projects (Define, Measure, Analyze, Improve, Control) • Process-specific incremental or radical improvement	empowerment; process improvement; use measurement • Statistical process control (SPC); quality circles; quality engineering • Incremental improvement	• Employ "Drum-buffer-rope" method to ensure continuous flow • Foster better & faster learning • Incremental improvement	• Exploit technology – enable new ways of working • Formulate & implement change roadmap • Implement "chunks" (releases) in waves (lab, pilot, rollout) • Radical process change
History	Particularly over the last decade; grounded in a cumulative body of knowledge in recent decades and with roots reaching back to Lean Thinking & embracing other process improvement initiatives	Since late 1940s	Since mid-1980s	Since early 1980s	Since mid-1980s	Since early 1990s

FIGURE 3.0 – SUMMARY COMPARATIVE OVERVIEW OF MAJOR SYSTEMIC ENTERPRISE CHANGE MODELS

enterprise processes to achieve not just incremental but significant performance improvements. By extension, it can be readily seen that Six Sigma methods can help strengthen BPR, through the development of reliable as well as efficient business processes. Also, TOC methods and techniques can help with the diagnosis and redesign of processes to remove bottlenecks. TQM can help support all of the methods by stressing quality improvement for evolving both efficient and effective enterprises.

Thus, Six Sigma, TQM, TOC and BPR can help deepen and enhance basic lean practices and methods, contributing to reduced process variation, improved flow, better quality, and a more efficient processes. Similarly, elements of Lean Thinking can bring a more systematic logic to Six Sigma, TQM and BPR and deepen their impact by providing a value stream perspective.

At the same time, there are certain differences among these methods that are worth highlighting briefly, by focusing on Lean Thinking and Six Sigma. Lean Thinking provides an overall, internally-consistent, set of concepts and principles guiding specific improvement initiatives primarily at the tactical and operational levels, focusing on value stream mapping and analysis. By contrast, Six Sigma, despite efforts in recent years to cast it into an overall integrative management system, largely represents a generic problem-solving approach that can be employed to implement discrete *project-specific* improvement initiatives. These *project-specific* initiatives -- driven by their respective cost-benefit criteria and respectively pursued by multiple teams led by Black Belts or Master Black Belts – typically represent a collection of localized improvement efforts. Six Sigma lacks a unifying conceptual framework driving the various improvement efforts, to ensure that they do not become isolated cases resulting in "islands of success." Thus, a central – still open -- question facing Six Sigma is whether or how the various improvement initiatives fit into a coherent enterprise-wide transformational framework and whether these localized improvements in fact scale-up to bring about enterprise-wide change.

There is another important difference between Lean Thinking and Six Sigma. Lean Thinking concentrates on *elimination of waste*, as well as on *striving for perfect quality*, to achieve continuous flow. By contrast, Six Sigma basically concentrates on *reducing all sources of variation*; this helps to eliminate waste stemming from the presence of variability. But unlike Lean Thinking, Six Sigma does not attack all sources of waste. Also, the concept of flow does not play as prominent a role in Six Sigma; it is only recently that Six Sigma practices have acquired the concept of the value stream, a key idea in Lean Thinking. Finally, while Six Sigma puts central emphasis on reducing variation to improve quality, Lean Thinking employs a wider array of tools and practices to ensure higher quality.

Third, while the various LSS CPI methods place heavy emphasis on process improvement, they lack a conceptual framework driving enterprise transformation. Enterprise transformation is fundamentally different from achieving incremental improvement. A simple example or two might help to make the point. It can be seen without too much effort that pursuing continuous process improvement here and there would be unlikely to produce lasting changes if this is done without a firm causal understanding of the complex interactions and interdependencies characterizing an enterprise. Enterprise complexity presents not only a serious constraint to achieving transformation but also increases potential system vulnerability to multiple modes of

failure. *Holistic Enterprise Systems Thinking* can provide the needed concepts and techniques for both simplifying and managing complexity.

Similarly, without understanding complex enterprise-environment interactions, it is relatively easy to see why pursuing incremental process improvements in a rapidly changing and turbulent external enterprise landscape could be a futile exercise. When the enterprise is out-of-step with the pace of change in the external environment, or when the external environment is characterized by past-paced market shifts and disruptive technological change, enterprise transformation would more likely require not incremental change but discontinuous change, requiring fundamental change in terms of the enterprise's concept, structure and behavior. However, under fairly stable external market and technological conditions, seeking continuous improvement by using these methods, in some combination, may be the right choice, leading to tangible organizational change and improvement over time. *Holistic Enterprise Systems Thinking* would help avoid such potential strategic traps by offering knowledge-based thinking, conceptual frameworks and computational methods that can be used to chart the right course for enterprise transformation.

How do these approaches -- LAI's approach and the various process improvement methods -- fit together in striving to change and transform enterprises?

Figure 4.0 shows how LAI's Holistic Enterprise Systems Thinking and the various continuous process improvement methods fit together in pursuing planned enterprise change and transformation. Figure 4.0 considers the scale of application of these methods, showing at what scale within an enterprise they can be best applied, as well as how they can complement each other at different scales of application. How these methods fit together is examined by asking a number of questions, which are differentiated by scale of application. Why do enterprises feel an imperative for change and transformation? What outcomes do they expect to achieve as a result of the transformation process? What approaches or methods can be employed to achieve these end results? How, in fact, can these methods be used, individually or in some combination, to achieve the expected results?

The driving reasons for enterprise transformation and expected outcomes, indicated at different enterprise scales, are illustrative only, to frame the answers – what methods to use, at what scale, in what combination? The enterprise scales, as well, are mainly illustrative and serve the purpose of characterizing enterprises at various levels of complexity. A given enterprise – be it a relatively small and medium size enterprise (SME), business unit or division of a larger enterprise, or a multi-divisional large-scale complex enterprise -- can adopt this multiscale definition and use it in thinking about and planning its own change and transformation:

- *Strategic* – encompassing the enterprise's basic purpose and value creation objectives, business model, stakeholder alignment, governance, organizational structure, decision rights, policies and behavioral rules, key business directions and priorities (e.g., new product development, product differentiation, cost-based competition), technology development and acquisition choices, creation of core capabilities, establishing business alliances, major investment decisions, and managing key external relationships.
- *Tactical* – encompassing the design, development and management of business processes and functions as well as enabling infrastructure systems and capabilities, enterprise

integration and coordination mechanisms, and performance of the enterprise's core mission (e.g., engineering and development, production; acquisition of new weapon systems, sustainment and readiness of capabilities to support the warfighter).

- *Operational* – encompassing the design and management of the enterprise's workflow processes, concentrating on effective synchronization of workflow throughout the enterprise's value stream (encompassing the supplier network), continuous improvement of business processes (e.g., to eliminate waste, increase efficiency, improve quality, shorten flow times), and delivering superior products and services that the customers value and that directly support the enterprise's strategic and tactical goals and objectives.

Examining the key transformation-related questions at different enterprise scales leads to a number of important conclusions concerning what methods to use at what scale, as well as how to use these methods and in what combination to use them at different scales of application. A useful insight in trying to answer these questions is that even if complexity is not necessarily greater at the higher scales, complexity is different *in kind* at different scales in terms of its nature, content and dimensions. A strong implication of this is that specific methods that seem to work well at a particular scale of the enterprise do not necessarily scale up for equally effective application at a higher scale.

Two major conclusions can be summarized as follows:

First, the various continuous process improvement methods, considered both separately and together as highly complementary approaches, cluster mostly around the operational and tactical levels, but fail to fill an important void at the strategic level.

At the *operational level*, lean principles, methods and practices can be used to implement a five-phased process to build lean operations (i.e., create stability, achieve continuous flow, develop standardized work, build pull-based production). The objective would be to evolve a pull-based just-in-time production system with continuous flow, enabled by constant striving for perfect quality and elimination of waste. This can be accomplished by applying standard lean techniques & practices (e.g., standardized work, visual controls, 5S (sort, stabilize, shine, standardize, sustain), five-whys (problem solving), error proofing, total productive maintenance (TPM), single piece flow, cellular manufacturing, leveled production, point-of-use storage (POUS)) and by stressing teamwork and the development of a multi-skilled workforce. Value stream mapping can be used for continuous process improvement. At the same time, TQM can be used to achieve continuous quality improvement (products, processes), while Six Sigma (SS) can be employed to help reduce process variation and improve quality, focusing on customer-critical processes. At the same time, TOC can be utilized to help identify and eliminate production bottlenecks impeding flow. Finally, BPR can be used to redesign processes to improve efficiency and flow.

At the *tactical* level, as well, lean principles and methods can be used to achieve customer-focused continuous process improvement (i.e., specify customer value; identify the value stream; make value flow continuously; let customers pull value; pursue perfection; use value stream mapping for continuous improvement). TQM can be implemented to achieve continuous quality improvement (e.g., robust design, quality circles). The Six Sigma methodology (i.e., Define, Measure, Analyze, Improve, Control (DMAIC)) can be employed to reduce variation in customer-critical core processes. Six Sigma can also be used as an integral part of value stream

Explanation / Scale of Application		WHY		WHAT	HOW-TO
		Driving Reason (Motivation for seeking enterprise change and transformation)	**Desired Outcome** (What is the outcome that is sought or expected)	(What approaches or methods to use, and where best to use them)	(How to use these approaches or methods, and in what combination to use them, to achieve enterprise change and transformation)
SCALE OF APPLICATION OF APPROACHES	**Strategic** (Enterprise-level)	• Actual or potential loss of competitive advantage (e.g., market share) • Growing customer dissatisfaction • Poor financial performance • Imperative for greater affordability (e.g., acquisition cost, lifecycle support) • Deteriorating combat support (e.g., long acquisition cycles, high cost of maintenance, declining readiness levels • Seeking new growth opportunities	• Ensure sustained competitive advantage (e.g., larger market share, lower costs, greater product differentiation, innovative products) • Deliver greater value to multiple stakeholders (e.g., improved customer satisfaction, greater profitability & wealth, higher return to shareholders) • Achieve greater lifecycle affordability & performance of products and systems • Achieve higher readiness levels • Foster a culture of organizational learning and innovation	• *Holistic Enterprise Systems Thinking (HEST)* to design and execute enterprise transformation (architecture-based, knowledge-driven, total enterprise focus, integrated multilevel deployment of change strategies, higher situational awareness via computational enterprise modeling and simulation) • *Lean Thinking (LT)* to align stakeholder value expectations and improve business processes • *Six Sigma (SS)* to reduce process variation & improve quality	• Apply *enterprise transformation framework* to define *transformation concept plan*: context, time, outcome, scope, culture, strategy, process, infrastructure, methods and tools, training and education, management, evaluation • Employ *enterprise transformation roadmap* to operationalize the concept plan: define action blocks & relationships; apply *enterprise architecture design (enterprise architecting)* principles and practices (define current enterprise architecture; define future architecture solution options; evaluate options; select best architecture solution) • Execute architecture-based enterprise transformation roadmap (integrated strategic, tactical, operational implementation process, with leadership engagement at all levels) ➢ Use *Lean Thinking* to align stakeholder value expectations and improve business processes ➢ Use Six Sigma (SS) to reduce variation in customer-critical processes • Monitor & evaluate enterprise transformation progress using enterprise transformation self-assessment tool
	Tactical (Business unit, program)	• Declining sales & financial performance • Poor efficiency (productivity) • Cost overruns, schedule delays (e.g., development programs) • Deteriorating fleet readiness levels (e.g., low fully-mission-capable levels for weapon systems, such as the F-16 fleet, due to maintenance or supply)	• Improved performance (cost, schedule, quality) • Reduced time-to-market; shorter cycle time • Higher efficiency and flexibility in responding to customer needs	• Lean Thinking (LT) • Standard Lean Model (SLM) • Total Quality Management (TQM) • Six Sigma (SS) • Theory of Constraints (TOC) • Business Process Reengineering (BPR)	• Apply *Lean Thinking (LT)* to achieve customer-focused continuous process improvement – specify customer value, identify the value stream, make value flow continuously, let customers pull value, pursue perfection; use value stream mapping for continuous improvement • Implement TQM to achieve continuous quality improvement (e.g., robust design, quality circles) • Employ Six Sigma (SS) -- Define, Measure, Analyze, Improve, Control (DMAIC) -- to reduce variation in customer-critical core processes; use SS as an integral part of value stream mapping • Use TOC, in conjunction with Lean Thinking, to identify & eliminate production bottlenecks and to improve flow • Apply BPR, in combination with Lean Thinking, to redesign business processes

	Operational (Plant, business processes, factory floor workflow)	• High cost of production • High cost of quality • Long lead times • Frequent customer complaints • Chronic supplier-related problems (e.g., parts shortages, poor quality, late deliveries) • High volume of backorders impacting fleet readiness levels • High degree of "cannibalization" (e.g., base, depot maintenance & repair facilities)	• Reduced waste • Higher quality • Improved throughput • Faster cycle time • Low backorders • Improved supplier performance	• Lean Thinking (LT) • Total Quality Management (TQM) • Six Sigma (SS) • Theory of Constraints (TOC) • Business Process Reengineering (BPR)	• Use lean principles, methods & practices to implement a five-phased process – create stability, achieve continuous flow, develop standardized work, build pull-based production – to evolve a pull-based just-in-time production system with continuous flow, enabled by constant striving for perfect quality and elimination of waste ➢ Apply standard lean techniques & practices (e.g., standardized work, visual controls, 5S (sort, stabilize, shine, standardize, sustain), five-whys (problem solving), error proofing, total productive maintenance (TPM), single piece flow, cellular manufacturing, leveled production, point-of-use storage (POUS), teamwork, multi-skilled workforce) ➢ Use value stream mapping to achieve continuous process improvement • Use TQM to achieve continuous quality improvement (products, processes) • Use Six Sigma (SS) to help reduce process variation & improve quality, focusing on customer-critical processes • Use TOC to help identify & eliminate production bottlenecks impeding flow • Use BPR to redesign processes to improve efficiency and flow

FIGURE 4.0 – SUMMARY VIEW OF HOW HOLISTIC ENTERPRISE SYSTEMS THINKING AND THE VARIOUS CONTINUOUS PROCESS IMPROVEMENT METHODS FIT TOGETHER, BY SCALE OF APPLICATION

mapping. Also, TOC can be used in conjunction with lean principles to identify and eliminate production bottlenecks impeding flow. Finally, BPR can be used to redesign processes to improve efficiency and flow.

At the *tactical* level, as well, lean principles and methods can be used to achieve customer-focused continuous process improvement (i.e., specify customer value; identify the value stream; make value flow continuously; let customers pull value; pursue perfection; use value stream mapping for continuous improvement). TQM can be implemented to achieve continuous quality improvement (e.g., robust design, quality circles). The Six Sigma methodology (i.e., Define, Measure, Analyze, Improve, Control (DMAIC)) can be employed to reduce variation in customer-critical core processes. Six Sigma can also be used as an integral part of value stream mapping. Also, TOC can be used in conjunction with lean principles to identify and eliminate bottlenecks in order to improve flow. Finally, BPR can be used to redesign and realign business processes to improve efficiency, flow and customer responsiveness.

Second, *with the possible exception of Lean Thinking and much more strongly qualified exception of Six Sigma, the various continuous process improvement methods generally do not scale up for application at the strategic level.* A straightforward explanation for this is that these methods – TQM, Six Sigma, TOC, BPR – generally do not purport to present conceptual frameworks providing a causal explanation of the nature, structure and dynamics of enterprises. They are also not informed by the considerable academic knowledge base on enterprises. The same can be said of Lean Thinking, as well; however, unlike these other methods, Lean Thinking has evolved from close observations of a real-life learning laboratory – Toyota and, more recently, a growing number of enterprises.

A simple thought experiment might help make the point more sharply. The starting point is that these methods have been respectively presented as the most effective solutions to real or imagined enterprise performance improvement problems. As a first principle, it would seem that in order for a proposed solution to be effective, it would be necessary and desirable to demonstrate first a deeper understanding of the enterprise as a system. Thus, the basic tenets driving these methods can be used to conduct a series of simple diagnostic tests to see how well they in fact point to any fundamental problems that specific enterprises might be facing. It would seem that these methods would pass a relatively low scientific threshold by being able to detect the presence of a variety of pathological symptoms – such as the presence of extensive waste, process variation, quality problems, production bottlenecks, or inefficient processes. But the mere identification of such symptoms is not the same as providing a deeper insight into any underlying systemic problems that individual enterprises may be experiencing, at the "system" level. The direct implication of this is that while the application of these methods may help produce certain benefits, mostly at the operational level, it would be a stretch to expect them to offer systemic solutions to deeper enterprise problems, especially at the strategic enterprise level.

In the final analysis, enterprise transformation is a complex process, requiring an understanding and management of a large number of interdependent change processes orchestrated at multiple levels over time. The various continuous process improvement methods discussed here generally do not provide much guidance on designing and managing complex enterprise transformation processes. The challenge of developing conceptual models of enterprise

transformation and the necessary toolset for accomplishing such transformation – basic principles, simulation-based modeling, heuristics, practices, methods and techniques – represents the next frontier. LAI's *Holistic Enterprise Systems Thinking* approach represents this new frontier.

SELECTED READINGS

Ackoff, Russell L. (1999). *Re-Creating the Corporation: A Design of Organizations for the 21st Century.* New York: Oxford University Press.

Assessment Panel of the Defense Acquisition Performance Assessment Project (January 2006). *Defense Acquisition Performance Report.* Washington, DC: A Report by the Assessment Panel for the Deputy Secretary of Defense (Lt. Gen. Ronald Kadish, USAF (Ret.), Panel Chairman; Dr. Gerald Abbott; Mr. Frank Cappuccio; Gen. Richard Hawley, USAF (Ret.); Gen. Paul Kern, USA (Ret.); Mr. Donald Kozlowzki).

Axelrod, Robert (1984). *The Evolution of Cooperation*. Basic Books, A Member of the Perseus Books Group.

Axelrod, Robert and Cohen, Michael D. (1999). *Harnessing Complexity: Organizational Implications of a Scientific Frontier.* New York: The Free Press.

Baldwin, Carliss Y. and Clark, Kim B. (2000). *Design Rules: The Power of Modularity.* Volume 1. Cambridge, MA: The MIT Press.

Baum, J. A.C. and Singh, J.V., *eds.* (1994). *Evolutionary Dynamics of Organizations*. New York: Oxford University Press.

Bernus, Peter, Nemes, Laszlo and Schmidt, Gunter., *eds.* (2003). *Handbook on Enterprise Architecture.* Berlin and Heidelberg, Germany: Springer-Verlag.

Boccaletti, S., Latora, V., Moreno, Chavez, M. and Hwang, D.-U. (2006). "Complex Networks: Structure and Dynamics," *Physics Reports*, 424, 175-308.

Bozdogan, Kirkor (May 31, 2006). "A Comparative Review of Lean Thinking, Six Sigma and Related Enterprise Process Improvement Initiatives". Cambridge, MA: Massachusetts Institute of Technology, Engineering Systems Division, Lean Aerospace Initiative, Working Paper, May 31, 2006 (available at http://lean.mit.edu/).

Chandler, Alfred D., Jr., Hagstrom, Peter and Solvell, Orjan, *eds*. (2003). *The Dynamic Firm: The Role of Technology, Strategy, Organization, and Regions.* New York: Oxford University Press (Published in 1998; Reprinted in 2003).

Cusumano, Michael A. and Nobeoka, Kentaro (1998). *Thinking Beyond Lean: How Multi-Project Management is Transforming Product Development at Toyota and Other Companies.* A Study Sponsored by the MIT International Motor Vehicle Program. New York: The Free Press.

Deming, W. Edwards (1982). *Out of the Crisis*. Cambridge, MA: Massachusetts Institute of Technology, Center for Advanced Egineering Study.

DiMaggio, Paul, ed. (2001). *The Twenty-First-Century Firm: Changing Economic Organization in International Perspective.* Princeton, NJ: Princeton University Press.

Dorogovtsev, S. N. and Mendes, J. F. F. (2002). "Evolution of Networks," *Advances in Physics*, Vol. 51, No. 4, 1079-1187.

Dyer, Jeffrey H. (2000). *Collaborative Advantage: Winning through Extended Enterprise Supplier Networks.* New York: Oxford University Press.

Fine, Charles H. (1998). *Clockspeed: Winning Industry Control in the Age of Temporary Advantage.* Reading, MA: Perseus Books.

Fujimoto, Takahiro (1999). *The Evolution of a Manufacturing System at Toyota.* New York: Oxford University Press.

Galbraith, Jay (1973). *Designing Complex Organizations.* Reading, MA: Addison-Wesley Publishing Company.

Galbraith, Jay R. (2002). *Designing Organizations: An Executive Guide to Strategy, Structure and Process.* New and Revised. San Francisco, CA: Jossey-Bass, A Wiley Company.

George, Michael L. (2002). *Lean Six Sigma: Combining Six Sigma Quality with Lean Speed.* New York: McGraw-Hill.

Goldratt, Eliyahu M. (1990). *Theory of Constraints.* Croton-on-Hudson, NY: North River Press, Inc.

Hammer, Michael and Champy, James (1993). *Reengineering the Corporation: A Manifesto for Business Revolution.* New York: HarperBusiness, a Division of HarperCollins Publishers.

Holland, John H. (1995). *Hidden Order: How Adaptation Builds Complexity.* Cambridge, MA: Perseus Books.

Holland, John H. (1992). *Adaptation in Natural and Artificial Systems.* Cambridge, MA: The MIT Press, First Edition Published in 1975 by The University of Michigan.

Kauffman, Stuart A. (1993). *The Origins of Order: Self-Organization and Selection in Evolution.* New York: Oxford University Press.

Liker, Jeffrey K. (2004). *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer.* New York: McGraw-Hill.

Lomi, Alessandro and Larsen, Erik R., *eds.* (2001). *Dynamics of Organizations: Computational Modeling and Organizational Theories.* Menlo Park, CA and Cambridge, MA: American Association for Artificial Intelligence (AAAI)/The MIT Press.

Maier, Mark W. and Rechtin, Eberhardt (2002). *The Art of Systems Architecting.* Second Edition. Boca Raton: CRC Press.

March, James G. and Simon, Herbert A., with the collaboration of Guetzkow, Harold (1993). *Organizations.* Cambridge, MA and Oxford, United Kingdom: Blackwell Publishers, First Published in 1958 by Wiley (USA).

Harry, Mikel and Schroeder, Richard (2000). *Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations.* New York: A Currency Book Published by Doubleday, a Division of Random House, Inc.

Lawrence, Paul and Lorsch, Jay (1967). *Organization and Environment*. Cambridge, MA: Harvard University Press.

Mintzberg, Henry (1979). *The Structuring of Organizations*. Englewood Cliffs, NJ: Prentice-Hall.

Murman, Earll M., *et al*. (2002). *Lean Enterprise Value: Insights from MIT's Lean Aerospace Initiative.* Houndmills, Basingstoke, Hampshire RG21 6XS, Great Britain: Palgrave.

Nadler, David A., Gerstein, Marc S., Shaw, Robert and Associates (1992). *Organizational Architecture: Designs for Changing Organizations.* San Francisco, CA: Jossey-Bass, A Wiley Company.

National Research Council, Committee on Network Science for Future Army Applications (2006). *Network Science.* Washington, DC: The National Academies Press.

National Research Council, Committee on Modeling and Simulation for Defense Transformation (2006). *Defense Modeling, Simulation, and Analysis: Meeting the Challenge.* Washington, DC: The National Academies Press.

Newman, M. E. J. (2003). "The Structure and Function of Complex Networks," *SIAM [Society for Industrial and Applied Mathematics] Review*, Vol. 45, No. 2, 167-256.

Ohno, Taiichi (1988). *Toyota Production System: Beyond Large-Scale Production.* Portland, OR: Productivity Press; for the original Japanese edition of this book refer to: Taiichi Ohno, *Toyota seisan hõshiki* (Tokyo: Diamond, Inc., 1978).

Pande, Peter S., Robert P. Neuman and Ronald R. Cavanagh (2000). *The Six Sigma Way.* New York: McGraw-Hill.

Sheffi, Yossi (2005). *The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage.* Cambridge, MA: The MIT Press.

Shiba, Shoji, Alan Graham and David Walden (1993). *A New American TQM: Four Practical Revolutions in Management.* Portland, OR: Productivity Press.

Simon, Herbert A. (1996). *The Sciences of the Artificial*. Cambridge, MA: The MIT Press, Third Edition.

U.S. Department of Defense (March 15, 2007). *Annual Report to the Congressional Defense Committees: Status of the Department of Defense's Business Transformation Efforts.*

Washington, DC: U.S. Department of Defense, Presented as per the "Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005" (P.L. 108-375).

Watts, Duncan J. (2003). *Six Degrees: The Science of a Connected Age.* New York: W.W. Norton & Company.

Womack, James P. and Daniel T. Jones (1996). *Lean Thinking*: *Banish Waste and Create Wealth in your Corporation*. New York: Simon & Schuster.

Womack, James P., Daniel T. Jones, and Daniel Roos (1990). *The Machine that Changed the World.* New York: Rawson Associates.