Meeting the competitive challenge

A new architecture for lean transformation

By Dennis F.X. Mathaisel, Timothy P. Cathcart, Dennis J. Stamm, and Mario F. Agripino[1]

Customers demand a high degree of responsiveness that can result only from manufacturing agility. Unpredictability in the marketplace, resulting difficulties in forecasting, and demands for reduced lead-times and inventories place increased responsibility on manufacturing systems and supply chains. Manufacturers must confront these challenges with an aggressive but affordable transformation plan for the complete enterprise that entails changes in manufacturing processes, material support, financial accounting systems, supplier relationships, organizational hierarchies, and management mindset.

The industrial space needs to be transformed to function at increased levels of efficiency through business philosophies and production techniques such as lean and cellular manufacturing. The integration of people, machines, and simplified control and manufacturing processes optimizes floor space and reduces costs, material scrap, staffing requirements, lead-times, rework, and flow times. But lean engineering and cellular manufacturing, particularly in large organizations, are complex tasks that require a critical balance be maintained in four major areas during all stages of transformation:

~ The lean and cellular strategy
~ An infrastructure that supports a lean or cellular operation
~ Change management -- the symbiotic relationship involving people to establish ownership of lean goals and management's responsibility to provide additional education and training
~ Continuing to meet customer demand during the transformation

These interrelated areas are key to a transformation effort that also requires an architecture that portrays the overall flow of the action phases necessary to initiate, sustain, and continuously refine the enterprise transformation.

Lean enterprise architecture

The following definitions -- from published works by Massachusetts Institute of Technology professor Deborah Nightingale, famed professor and engineer Eberhardt Rechtin, and the Institute for Electrical and Electronics Engineers -- will help put lean enterprise architecture (LEA) in context with traditional lean transformation approaches.

- A lean enterprise is an integrated entity that efficiently creates value for its multiple stakeholders by employing lean principles and practices.
- Systems engineering is an interdisciplinary approach to enable the realization of successful systems.
- Enterprise engineering is the collection of tools and methods that can be used to design and maintain continually an integrated state of the enterprise.
- Systems engineering methods are the logical systematic set of processes selectively used to accomplish systems engineering tasks.
- Systems architecture is the arrangement of elements and subsystems and the allocation of functions to meet systems requirements.
- Systems architecting is the art and science of creating and building complex systems.
- Organizational architecting is the application of systems architecting to organizations.

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[1] This report is a condensed version of a paper under review in the *International Journal of Productivity and Performance Management* and a related paper published in *Defense Procurement Analysis* [Mathaisel 2003].

- An architecture framework describes basic concepts, descriptions, and the related models (views) to provide a standard for enterprise engineering.

Using these definitions, the lean enterprise architecture is defined as an architectural framework for enterprise re-engineering to design, develop, produce, construct, integrate, validate, and implement a lean enterprise using systems engineering methods. The design process incorporates lean attributes and values as baseline requirements for creating the enterprise. This approach is a structured systems engineering method for a lean enterprise transformation as opposed to the standard incremental lean methodology that uses a design-build and the cell-by-cell paradigm.

The traditional design-build approach attempts to capture the low-hanging fruit by first getting out waste in existing systems using techniques such as value stream mapping and kaizen events. The process continues until all cells are balanced and integrated so that the system is pull-based -- that is, based on pulling the requirements from the customer rather than pushing the requirements onto the customer. The process is slow, unfocused, resource-intensive, and creates many organizational disruptions and stresses during the transformation process. It is usually during this phase that transformation failure occurs.

LEA, on the other hand, uses a multiphase approach structured on the transformation life cycle phases and is developed from an enterprise perspective, paying particular attention to strategic issues, internal and external relations with all key stakeholders, and structural issues that must be addressed before and during a significant change initiative.

Manufacturing transformation

A successful transformation requires that manufacturers have an integrated set of activities that execute their strategic vision, program concepts, acquisition strategy, schedule, communications plan, and implementation strategy. LEA, presented in Figure 1, is structured to organize these activities for the transformation of the enterprise from a current state to a desired future condition. LEA uses a phased approach structured on the life cycle of the transformation. It portrays the flow of phases necessary to initiate, sustain, and refine continuously an enterprise transformation based on lean principles and systems engineering methods.

The top of the illustration in Figure 1 represents the life cycle of the transformation. The bottom represents the architecture that is used to create the life cycle, comprising three phases. Each phase creates the conditions to progress successfully through the transformation's life cycle, which is described in Figure 2. There are three essential steps that accompany each phase of LEA:

Phase 1: Transformation strategic planning. This phase specifies the actions associated with the decision to adopt the lean paradigm. Best practices continue to demonstrate the benefits of a strategic plan to focus the effort and energy of an organization toward the achievement of common goals, objectives, and performance metrics. Thus, the first step in a transformation acquisition is to develop a strategic plan. The plan should encompass the three crucial change elements of the transformation process: infrastructure, lean operations, and personnel change management. Phase 1 must also include the development of a high-level enterprise concept of operations that specifies the operating philosophy and forces discussion and planning to determine how the manufacturing processes will operate on a day-to-day basis.

Phase 2: Transformation acquisition and integration. This phase creates the environment for a successful change and requires the development of a requirements package, an acquisition plan, an integration plan, and a change management and communication plan.

The *requirements package* consists of a statement of objectives/work for the transformation, its scope and specifications, a contract data requirements list with acceptance criteria, and a delivery schedule. The package addresses the need for urgent cultural transformation and identifies the need for information technology integration. The package should also include a requirement to demonstrate and defend the expected return on investment of the transformation against established performance metrics.

An *acquisition plan* outlines the strategy for managing the acquisition elements of the transformation. Contracting methods can include turnkey, program manager, design/purchase/construct, design/construction management, or some variation of these common methods. Selection of the contracting method is influenced by the experience and availability of internal resources. Selection of a program manager or a turnkey transformation contractor should include early and continuous involvement of suppliers, including engineering services, equipment providers, IT system suppliers, integrators, consulting services, and contractors. Supplier selection should place emphasis on past performance, performance-based requirements, oral presentations, cost-benefit analysis, capital spending scheduling, and full and open competition and briefings. The plan must also identify the risks associated with the transformation and develop a mitigation strategy to overcome them.

An *integration plan* helps establish the appropriate lines of communication – vertically for stakeholders directly involved in the implementation of the transformation and horizontally to consider the impact of other productivity enhancement initiatives. The plan should anticipate how the transformation will affect and be affected by other initiatives. It may require a collaborative software tool to enhance communications and review decision making and actions taken throughout the affected organizations. The integrated process and product development approach is a proven tool that can help you achieve transformation goals by focusing on the integration and application of critical activities early in the acquisition process. Two key pillars of the approach are the integrated master plan and integrated master schedule. Together, these management tools provide the integrated plan of events and activities, the schedule in which these will occur, and the resources that will be used to execute them.

The heart of change management is communication, but that communication is effective only when it is focused in an overall *change management plan*. Therefore, the scope should extend across all areas of change management, including strategy, training, and supporting management systems. Success depends largely on how effectively management communicates with those affected by the transformation. This communication must address what's happening, why it's happening, and how it's happening. More importantly, each individual and organization affected by the transformation must understand how the transformation impacts him or her. These plans should include the development and maintenance of a Web site containing briefings, presentations, contact lists, milestones, mission statements, organizational goals, streaming video shows, and collaborative tools.

Phase 3: Transformation implementation. Transformation implementation is built on a strong centralized vision, continuous improvement, and progress measurement. Successful implementation also requires leadership, innovation, and organization. That basic leadership and organizational framework occurs when the necessary personnel are versed in program management, the best lean or cellular manufacturing processes, financial management, acquisition, source/vendor selection, administrative/office support, and other functions to help integrate company and general contractor personnel efforts. A good implementation plan is one of monitoring schedules, performance metrics, and engineering changes; managing risks, costs, and vendor selection; prioritizing payback initiatives and resources; and fostering a sense of urgency in task completion.

Role of systems engineering

LEA is an enterprisewide structure rooted in lean principles and systems engineering. Enterprise transformation engineering builds on the tools and methods of enterprise engineering to organize all of the tasks needed to design, implement, and operate enterprise transformation changes using lean systems engineering practices to integrate the operational enterprise. Enterprise transformation engineering uses an architecture framework to describe enterprise design and implementation solutions. Architecture frameworks provide a standard for enterprise engineering. There are four basic enterprise engineering frameworks:

- Computer-integrated manufacturing open system architecture
- Generalized reference architecture and methodology
- GRAI laboratory model
- Purdue enterprise reference architecture

Of these four, the generalized reference architecture and methodology framework was selected and adapted as the enterprise transformation engineering framework for lean enterprise architecture (Figure 3). The framework is an ISO standard that facilitates the unification of several disciplines in the change process to allow their combined use in the design process. The framework provides a description of all elements required in enterprise engineering and integration. It is structured using an enterprise life cycle perspective that compliments and integrates with LEA transformation life cycle phases. Lean and cellular transformation practices are incorporated into the framework as design requirements for the future state enterprise. Systems engineering and enterprise engineering methods coupled with the framework are used to design, develop, test, evaluate, integrate, and implement the lean enterprise transformation.

The five basic tasks in the framework shown in Figure 3 are described below:

For the **conceptual design task**, the strategic position of the enterprise is evaluated for competitive capability, organizational structure, and the processes. Current business strategies and market research are used to define future state enterprise architecture performance requirements. Feasibility studies, formal business case analysis, and return-on-investment projections are used to select a conceptual architecture for the enterprise from various configuration alternatives. The conceptual enterprise architecture defines a concept of operations for future state enterprise performance, organizational and value chain structures, technology, human resources, facilities, products, and operational requirements. The architecture defines operational interfaces and performance requirements to meet enterprise business strategy, vision, and mission objectives.

During p**reliminary and detailed design**, the conceptual architecture is evaluated and synthesized into functional and operational architectures. The functional architecture is developed during the preliminary design to describe enterprise functional and performance requirements. The operational architecture is developed during the detailed design task to describe the enterprise organizational structures and their individual configurations (technology, human resources, facilities, products, etc.). Systems engineering methods are used to design and develop these architectures using integrated product teams. Each level of the architecture captures a stage in the design process as more detail evolves. The teams perform systems engineering analysis from previous architecture definitions and use trade studies to select architectural components. The architecture forces the teams to maintain a total enterprise solution that properly aligns processes and organizational components. This approach provides an enterprise engineering method to meet organizational requirements. During the design tasks, facility and production system cells are designed in accordance with lean principles.

During **implementation**, the operational architecture is produced and implemented with structured project management methods and is used to develop the enterprise transformation plan. Facility and production system cells are constructed and modified in accordance with lean practices. Specialized equipment and selected IT networks are procured, installed, integrated, tested, and certified. Work force training is conducted for new enterprise operations. Depending on risk, implementation can be either incremental or a one-time event. It requires significant integration of people, technology, facilities, and operational processes. During this phase, be careful to prevent disruption to current operations while simultaneously implementing enterprise changes. Implementation must consider both internal and external architecture interfaces.

The **operation** of the transformed facilities and production system cells should ensure the continued strong centralized vision, transformation improvement goals, and progress measurement metrics that were designed in the earlier tasks of phases 1 and 2. The enterprise

architecture is only as good as the leadership, organization, and engineering frameworks that are the foundation of the architecture. Thus, transformation operation requires continuous leadership, innovation, monitoring, control, and management of engineering changes. Such changes require a complete risk, impact, and cost assessment to either the production system or the entire enterprise. Any operations that undergo transformation operate best when all personnel are versed in the best current commercial lean or cellular manufacturing principles and practices.

Putting it all together

Figure 4 shows how LEA and the concepts of enterprise transformation engineering work together to ensure successful enterprise transformation. Each phase in the architecture creates the conditions necessary to put into effect the life cycle of the transformation. The middle, gray region of Figure 4 is the framework for enterprise transformation engineering. This combination of lean enterprise and systems engineering methodologies portrays the overall flow of the action necessary to initiate, transform, sustain, and continuously refine an enterprise.

LEA was developed from an enterprise perspective, paying particular attention to strategic issues, internal and external relations with all key stakeholders, and structural issues that must be addressed before and during a significant change initiative. This architecture is intended to have a fast clock speed with ongoing action monitoring and corrective action activities. The intent is to provide a general framework to assist any enterprise in making the lean transition.

LEA is less resource-intensive and disruptive to the organization than traditional cell-by-cell transition. The work force is the critical stakeholder and helps define the system requirements and design selection. The enterprise development process is essentially the same process used for the development and implementation of new systems. The new enterprise will be designed, developed, prototyped, constructed, integrated, validated, and implemented by the stakeholders and contractors in an integrated product team environment.

For further reading

Agripino, Mario; Cathcart, Timothy; and Dennis F.X. Mathaisel, "A Lean Sustainment Enterprise Model for Military Systems," *Acquisition Review Quarterly*, Fall 2002

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Rechtin, Eberhardt, *Systems Architecting of Organizations*, CRC Press, 1999

Rechtin, Eberhardt and Mark Maier, *The Art of Systems Architecting*, CRC Press, 2000

Dennis Mathaisel, Ph.D., is professor of management science at Babson College and was formerly a research scientist at the Massachusetts Institute of Technology. He is a lean sustainment/lean manufacturing expert, and his research interests focus on the sustainment of complex and aging systems and new techniques for the optimization of air transportation systems.

Tim Cathcart received a B.S. from Southern Illinois University and is an advanced studies program fellow at the Massachusetts Institute of Technology. He has been employed at the Naval Undersea Warfare Center in Newport, R.I., for 20 years. Cathcart was a researcher and program coordinator for MIT's Lean Sustainment Initiative.

Dennis Stamm is director of manufacturing services for Lockwood Greene Engineers Inc. and a founding principal of Innovative Business Strategies LLC, a provider of business life cycle consulting. Stamm is a senior member of IIE and a regular columnist for *Industrial Engineer*. He has more than 25 years of experience in industrial engineering, production management, and lean manufacturing consulting.

Mario Agripino holds a B.S. from Charter Oak State College and is an advanced studies program fellow at the Massachusetts Institute of Technology. He has been employed at the Naval Undersea Warfare Center in Newport, R.I., for 21 years. Agripino was a researcher for MIT's Lean Sustainment Initiative.