Transitioning to a Lean Enterprise:

A Guide for Leaders

Volume I

Executive Overview

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WELCOME TO THE LEAN JOURNEY

This Transition-To-Lean Guide is intended to help your Enterprise Leadership navigate your Enterprise's challenging journey into the promising world of "Lean." You have opened this guide because, in some fashion, you have come to realize that your Enterprise must undertake a fundamental transformation in how it sees the world, what it values, and the principles that will become its guiding lights if it is to prosper — or even survive — in this new era of "clock-speed" competition. However you may have been introduced to "Lean," you have undertaken to benefit from its implementation.

Take Heart! Others have blazed some of the trails that you will now traverse. They have left helpful guideposts that come from their experience and knowledge.

Be Resolute! This journey is not for the weak of conviction. It will require extraordinary commitment, perseverance, and hard work.

Be Brave! Not all the roads have been paved smooth for you. Much is still being learned, and you will undoubtedly add to the existing wealth of knowledge with your own learning and experimentation as you apply the foundational principles of "Lean thinking."

Be Filled with Hope! Enterprises before you that have adopted these "Lean" principles and practices are transforming themselves into efficient and relentless developers and producers of some of the finest products in the world! You can join them!

Think of this Guide as a "Roadmap," because it recognizes

that this is a journey;
that it has a starting point and a destination in mind;
that there are many different ways that the final destination can be reached,
that regardless of the route chosen there are milestones through which everyone must pass at some point; and
that each Enterprise must ultimately choose the route that best serves its own circumstances.

A warning: this journey never ends! Each destination you reach becomes the starting point for the next journey. This is the true essence of "Continuous Improvement" and a fundamental principle of "Lean thinking." Be prepared for a never-ending journey.

Also, realize that if your Enterprise is to reach its destination in the foreseeable future, you must *lead the way*. This is not a march that you can delegate "to the troops" nor observe from afar. There is difficult, hands-on, intensely personal work to be accomplished. Can it be done without you? Possibly — but why would you, as the Enterprise Leader, leave such a critical act as the fundamental transformation of the culture, beliefs, and practices of your Enterprise to someone else?

INTRODUCTION TO
VOLUME I: EXECUTIVE OVERVIEW

Background

The Lean Aerospace Initiative (LAI) is a collaborative effort among major elements of the United States Air Force, leading companies within the aerospace defense industry, and the Massachusetts Institute of Technology. LAI was formed to identify and implement Lean principles and practices throughout the military aerospace systems' acquisition, development, and production processes.

Early in its existence, LAI brought together an Integrated Product Team (IPT) comprising government, industry, and academic representatives to develop a tool that could logically and effectively integrate the consortium's extensive research findings in Lean principles and practices. That tool evolved as the Lean Enterprise Model (LEM), which was released to all consortium members at the end of LAI's first three-year phase in 1996. During LAI's second three-year phase, the LEM's database was expanded to include both MIT and non-MIT research and was made available to LAI consortium members in a Web version.

In providing a powerful taxonomy of Lean principles and practices, the LEM addressed the issue of the "whats" of Lean, but did not attempt to address the "hows" of implementation. While much had been documented about the implementation of specific Lean practices, especially on the factory floor, little had been developed regarding the greater issue of Lean implementation as a holistic process — especially at the Enterprise level. Enterprise, in this context, refers to every element of the organization, extending forward to the Customer and reaching back into its supply chain. In response to a clear need to provide this "how" guidance, the LAI executive board challenged the LEM IPT to expand its efforts to develop a product to address the issue of broad and extensive Enterprise implementation.

In response to this challenge, this "Transitioning to a Lean Enterprise: A Guide for Leaders" has been developed. The heart of this Guide is the Transition-To-Lean (TTL) Roadmap, which describes a logical sequence of several *Primary Activities* and the *Major Tasks* required to complete each of these *Primary Activities*. There is an extensive set of background material for each *Major Task* that expands upon the **issues**, **tensions**, and **barriers** that are likely to be confronted at each task stage. This material also describes the **enablers**, **tools**, **related references**, and **case studies** that can be accessed to promote successful completion of each task.

Transition-To-Lean Guide

This Enterprise TTL Guide comprises three volumes that provide a set of materials allowing the user to understand and navigate through the Roadmap at increasingly deeper levels of detail.

Volume I: Executive Overview invites the Enterprise Leader and Lean Change Agents to understand the compelling "whats and whys" of Lean. It offers a history of the evolution of Lean thinking and principles, and introduces the concept of the top-level Transition-to-Lean Roadmap as an overarching guide to transforming an organization into a Lean-thinking and behaving organization. This "Top-Level" view of the Roadmap consists of six Primary Activities and the Major Tasks that must be addressed within each Primary Activity. These tasks flow in a logical, sequential process that evolve into natural "cycles" of both short and long-term activities as the Continuous Improvement process progresses.

Volume II: Transition-to-Lean Roadmap provides the next level of description and detail in understanding the nature and scope of the tasks required to complete each of the primary activities that make up the dynamic roadmap.

Finally, **Volume III: Roadmap Explorations** provides an in-depth exposition — using a common template — of each of the twenty-two tasks identified within the roadmap addressing

the primary issues,
the tensions likely to emerge,
the barriers that will be encountered, and
the enablers that can be applied to overcome these barriers.

This template, titled the "six tensions," reminds Guide users that it is imperative to address continually the questions of **"Who, What, Where, When, Why, and How"** involved in any transformation undertaking. Where appropriate, the Guide suggests and describes tools that can help in navigating successfully through the task at hand. For those interested in exploring a particular issue more fully, we identify relevant references for the several task areas.

Guide's Perspective

It is important to understand that this Guide is for all of the leaders vital to the modern-day "Extended Enterprise." These leaders — "Stakeholder Leaders" — are found within each of the array of constituencies that together define this new competitive entity. Their individual and collective success depends upon their ability to further, simultaneously, their individual goals and those of the "Enterprise" that binds them together. Without this collaborative behavior, these "Stakeholder Leaders" will fail to optimize their collective capacity and capability.

In this Guide for Leaders, then, we use this terminology of "Stakeholder Leaders" to reinforce the reality that 'leadership" can and must be found along at least two dimensions in the "organizational" framework of the Enterprise. Leadership must be demonstrated by the organizational leaders of each of the constituencies that are crucial to the Extended Enterprise, including company management, union management (if present), supplier management, and even customer management. While each of these leaders has different responsibilities, different perspectives, and a different array of goals and objectives, they must, to be successful as a group, collectively develop at least one subset of common goals and objectives around which they can work together and which can simultaneously support the pursuit of their individual unshared goals.

We reserve the singular reference of "Enterprise Leader" to the senior manager of the company who is at the center of the "Extended Enterprise," but generally we use the term "Senior Managers" to refer to the key personnel who support any of the "Stakeholder Leaders." This general reference acknowledges that leadership must also be demonstrated by the "change agents" within each of these groups who provide guidance, direction, and encouragement for change wherever they exist within the organizational layering of their respective constituencies. We direct this "Transition-To-Lean Roadmap and Guide," then, to every one of this diverse set of "Leaders" — because we have found that they encounter many of the same issues, barriers, enablers, and challenges in managing and leading change. This applies whether they are acting at the managerial level, within the bowels of the organization, or at the boundaries of the alliances that make up this extended association. While each of their situations may differ in the details or terminology, the principles and overarching practices that define the essence of Lean thinking are — at their root — one and the same.

We also have observed that "leadership" in the Lean transformation process can emanate from and/or be sustained within any part of the organization. Company management, unions, a major supplier, or even the customer can play an initial or sustaining role. What is most important is not where the transformation begins nor who sustains it, but that with Enterprise leadership the critical mass of involvement and commitment necessary to change the culture of the Enterprise into one where Lean thinking and behavior are the norm in times of stability and crisis can be achieved. For an Enterprise to make the successful journey of transitioning to Lean the creative and dedicated leadership of many different participants will be required. We hope this Guide is useful as a common map for all the pilgrims on this quest.

Looking Ahead

Every day brings new discoveries and insights into more effective ways for eliminating waste and reducing the cycle time from customer want to customer satisfaction. While the basic principles of Lean thinking are simple, transforming that thinking into behavior — and especially action — within differing circumstances that result in consistent Lean performance is complex and far from fully understood. Fortunately, the cadre of Lean believers has grown substantially over the past several years; their collective experiences provide substantial evidence and lessons from which to advance the Lean process everywhere.

With this in mind, this Guide is meant to be just that: a guide, not a dictate. Every journey has its own unique circumstances, demanding individual choices and decisions that ultimately set it apart from any other journey ever attempted. If you are the change agent and/or the transformation leader, your decisions and circumstances will ultimately shape the journey and determine its degree of success or frustration.

Finally, this Guide does not purport to provide every answer to the demanding problem of Lean transformation in complex organizations. It does, however, aggregate in a structured framework much of what has been learned by recent Lean pioneers and practitioners. As important, it looks ahead at the Lean journey and helps the transformation agent ask the relevant questions that must be addressed to minimize the surprises, setbacks, and barriers that will inevitably appear. This guide can help you understand the terrain, prepare you for some of the previously discovered obstacles, arm you with the tools needed to reach your destination with greater ease, and help you shape the creation of your own memorable and rewarding journey. You have but one obligation in return: to add to the wealth of knowledge that you find in this guide by capturing and sharing your own discoveries, your own tool developments, your hard-earned insights and findings. Other pilgrims are not far behind. Let the journey begin!

THE "WHAT AND WHY" OF LEAN

LEAN IS ABOUT BEHAVIOR

First and foremost, it is important to understand that "Lean" is not merely a set of practices usually found on the factory floor, but rather a fundamental change in how the people within an organization think and what they value, thus transforming how they behave. Positive results are achieved from the supporting practices that follow once a common set of beliefs and principles are understood and adopted.

A "Lean" organization understands and believes in the fundamental virtue of its basic Lean principles. Within that Lean organization, everyone is focused on identifying and eliminating sources of waste and inefficiency. They look at the world through the eyes of their customer and seek to fulfill customer expectations. They value only what the customer values. They anticipate change and learn how to be responsive to make change their ally. They understand the concept of flow, the power of sharing information, and the criticality of relationships.

Because Lean is about beliefs and behavior, it is applicable beyond the factory floor to encompass the entire Enterprise. Its benefits pervade the organization. Employees who adopt a focus on eliminating waste, and who see the world through their customers' eyes, can improve whatever "flows" and whatever is "produced" in terms of cycle time, quality, and efficiency.

Unfortunately, too many have been introduced to a very narrow perspective of "Lean." Often viewed as a collection of practices with names such as "*Kaizen*," "*poka-yoke*," and "*kanban*," "Lean" has also been relegated to being appropriate mainly "on the factory floor." As a result, the true transformational power of adopting "Lean" has often been lost, with organizations desiring to improve realizing only a fraction of its potential.

The true transformational power of Lean lies in its inherent ability to unlock the potential of the ***entire*** organization: It can transform everyone and everything that an Enterprise does. In fact, when totally adopted, Lean cannot help but extend its transformational power both upstream to the supply base as well as downstream to customers!

The following pages offer a detailed cataloging of the benefits and characteristics of Lean, designed to help you understand Lean more concretely. But even though this Guide provides considerable detail on practical actions you can undertake in implementing Lean in your organization, you must never lose sight of this basic truth: above all, Lean is about how an organization thinks and behaves. This belief is what

leads to applying the correct Lean practices and sustaining the dynamic, continuous improvement process.

This guide for Transitioning to a Lean Enterprise is designed to be used at the Enterprise level to achieve an integrated implementation of Lean principles and practices.

BENEFITS OF LEAN

What benefits can a company expect to realize if it transitions from a mass-production mentality to one based on Lean principles and practices? Benefits accrue both in factory operations and in areas beyond the production floor. Companies that have attempted to convert their factory operations to Lean, without simultaneously adopting Lean principles and practices throughout the entire organization, have not realized Lean's full potential. In fact, many such companies have viewed their Lean transformation as a failure. Companies that have enjoyed the greatest success in transitioning to Lean are those that take a holistic approach and view the transformation as a fundamental restructuring of the Enterprise, including its organizational structure, business and information systems, workforce policies, incentive systems, and relationships with customers and suppliers.

Benefits in Factory Operations

Factories that convert to Lean production typically achieve the following results.

- There is a dramatic improvement in responsiveness to customers. Shipments are rarely late; the number of defects reaching customers drops significantly, and overall customer satisfaction is much greater — thereby increasing market share.
- Most of the factory-floor chaos is eliminated. Rather than aisles clogged with batch production orders waiting for processing at banks of identical machines grouped together, individual parts and assemblies move smoothly within the Lean factory's synchronized manufacturing cells, never stopping until processing and inspection are completed. Production flow times are reduced by 80 percent to 90 percent. Workstations are well organized and neat; no idle parts or carts clutter the workspace. No expeditors are needed to push through late production orders by brute force. Storage racks for work-in-process are largely eliminated. Material handling is simplified, often with manual methods replacing automation. Re-work stations are gone. Scrap is significantly reduced, and the factory floor is much cleaner.
- Labor productivity is double or triple that of the past.
- Production control systems and their associated information systems are greatly simplified.

- Shipments from certified suppliers arrive shortly before needed, are organized in the correct sequence, and move directly to the point of use with no need for incoming inspection. Warehouse space for purchased parts and materials is reduced by 80 percent to 90 percent in most cases.
- Completed orders are shipped immediately to customers upon completion of the last stage in the internal value chain, rather than accumulating in large warehouses. Orders are shipped to customers in small quantities (often single units) rather than in large lots.
- The total floor space needed in Lean factories is typically 55 percent to 65 percent of that needed in mass-production factories for the same level of production.
- Inventory levels at all stages (raw materials, in-process, and finished goods) are dramatically lower, often by greater than 90 percent.

To support these claims, the book *Lean Thinking* (Womack and Jones 1996, p. 27) reports the following improvements from converting to Lean:

	INITIAL LEAN CONVERSION	CONTINUOUS IMPROVEMENT
· LABOR PRODUCTIVITY	Double	Double again
· PRODUCTION THROUGHPUT TIMES	90% reduction	50% reduction
· INVENTORIES (THROUGHOUT)	90% reduction	50% reduction
· ERRORS REACHING CUSTOMERS	50% reduction	50% reduction
· SCRAP	50% reduction	50% reduction
· TIME TO MARKET, NEW PRODUCT	50% reduction	50% reduction

Values in the "Initial Lean Conversion" column are the results that can be expected from the initial conversion effort. Values in the "Continuous Improvement" column are the further improvements that can be expected from continuous improvement efforts within two to three years. Improvements can be expected to continue indefinitely, but at a declining rate. (These values represent rough averages in the companies studied by Womack and Jones; they have not been validated and are obviously not precise.)

Benefits Beyond Production Operations

We would be missing a great opportunity were we to confine our application of Lean principles and practices to the factory floor. Lean thinking can and should be applied to all functions in the enterprise. Consider, for example, the Lean principle of "one piece flow." Here is how this principle should be implemented across several enterprise functions.

PRODUCTION	Parts and assemblies never stop moving until order is shipped
PRODUCT DESIGN	Design never stops moving forward until it is in production
BUSINESS PROCESSES	Paperwork (or electronic equivalent) never stops moving until processing is completed

Similarly, the same Lean principles associated with material flow and processing should be applied to information flow and processing: minimize material/information flow times; minimize material/information content; shorten and straighten material/information flow to the maximum extent possible, and so on.

Using still another analogy from Lean production, the monolithic office should be converted to "cellular offices," just as the monolithic factory is modularized into smaller production cells. Office equipment should be "right sized" (for example, huge, centrally located, monolithic printing presses should be replaced with smaller presses dispersed among the cellular offices.)

While there are no reported studies that quantify all the benefits of Lean beyond production, the following general outcomes logically can be expected.

- The "voice of the customer" becomes the primary driving force in the enterprise. This has an impact on product quality, organizational structure, production processes, policies, and overall behavior.
- New product development time is greatly reduced. Customers, suppliers, and enterprise specialists are involved in product design from the outset.
- Relationships with suppliers have been revolutionized. Adversarial posturing has been replaced by win-win cooperative practices. Target costing results in continuously lower prices for purchased items, with equitable sharing of savings.
- Responsiveness to changing market conditions is enhanced. Production rates can be adjusted much more rapidly to meet fluctuating market demand. New products are introduced rapidly, with minimal disruption.

- The organizational structure shifts from a vertical to a horizontal focus, aligning value-adding activities with the customer value stream. Decision-making is decentralized, contributing to enterprise responsiveness. The organization is "flattened," greatly reducing "overhead."
- The workforce is empowered. Integrated product/process teams function as self-managed work units, reducing the cost and clumsiness of supervision. The workforce is multi-skilled, contributing greatly to the flexibility and responsiveness of the Enterprise. Employees perform inspection and maintenance, and also determine work methods and workplace arrangement taking on tasks once the purview of highly paid specialists. These specialists are now freed to focus on the overall Enterprise.
- Improved operating margins and increased flexibility provide enhanced business opportunities in existing or new markets.

Specific Benefits in Aerospace

Between 1996 and 1999, LAI consortium members made several site visits to facilities of LAI sponsor-companies to observe progress toward implementing Lean principles and practices. The site visit report's "Executive Summary" speaks to the potential benefits of Lean implementation in aerospace by posing two questions:

> "What if an aerospace company and its key suppliers had mastered the application of Lean practices to the point where they approached Toyota as a practitioner of the art?"
>
> "What if all of the best results the team saw on various LAI site visits were achieved in every operation throughout a single aerospace enterprise?"

According to those who participated in the site visits, Enterprises that met these two "criteria" would be able to achieve tremendous improvements in product development and production:

Product Development

- Cycle time down 50%
- Product development man-hours down 50%
- Software development cost down 50%
- Prototypes made without tools
- No physical mockups
- Engineering changes after release reduced by 50%
- ECP paperwork virtually eliminated
- CDRLs down 80%

Production

- Assembly touch hours down 49%
- Nonconformance costs down 70%
- Assembly support labor down 80%
- Inventory reduced by 90%
- Assembly cycle time down 47%
- Engineering changes reduced by 60%
- Fabrication costs reduced 50%
- Part lead-time down 69%
- DPMO down 90%

Such an enterprise could develop a new aircraft in four to six years (versus today's twelve- to fifteen-year standard) at half the current development cost. It would also be able to deliver aircraft and missiles with a production lead-time of less than one year and at half the current production costs. That Enterprise does not exist today, but the achievement does not appear to be out of reach for an Enterprise with the right motivation. Every element of this level of performance has been demonstrated at one or another of the LAI companies visited; what is needed is the leadership to implement them all.

COSTS OF LEAN

The remarkable improvements resulting from converting to the Lean paradigm cannot be achieved without a considerable investment. The primary investment required, however, is the *time* of the entire management team and workforce.

Experience has shown that Lean conversion does not typically require extensive capital investments. Lean is not necessarily high technology, but rather reduces the need for sophisticated, complex approaches to production management and information systems.

Lean does require a considerable investment in education and training. There may also be the costs of acquiring new tooling to reduce set-up times. Replacing large "monument" machines with several smaller machines to serve the same function will also require capital expenditures, as will "mistake-proofing" manufacturing equipment and processes. Similarly, there may be some expenditures in information technology to increase information flow across the Enterprise (e.g., integrated CAD/CAM systems).

Typically, the savings from reduced inventory levels alone are greater than all the costs of converting to Lean. Freed-up floor space becomes available for future expansion, or may be rented or sold. Shortened product development lead times also result in reduced resource requirements.

On balance, implementing Lean actually *reduces* capital investment and other resources over the long run.

OVERARCHING STRATEGIC CONCEPTS OF LEAN

Six core *strategic* concepts of the Lean paradigm capture the principal nature of Lean.

- Customer Value and Value Stream
- Waste Minimization and Continuous Improvement
- Flow and Pull
- Near Perfect Product Quality
- Horizontal Organizational Focus
- Relationships Based on Mutual Trust and Commitment

These six concepts clearly distinguish Lean from mass production. The manner in which these concepts are addressed in Lean organizations is fundamentally different from the approach in traditional organizations, as discussed in the following sub-sections.

Customer Value and Value Stream

The starting point for Lean thinking is "value" as defined by the end customer. Defining value requires thinking from the customer's perspective and working inward to the company's capabilities and core processes.

Ultimately, value is defined in terms of specific products and services having specific capabilities/functionalities, offered at specific prices to specific customers, to be delivered defect-free at specific times. Value must be viewed in terms of the *entire customer experience*. The goal is to streamline the entire experience, thereby delighting the customer with a complete solution (Gunneson 1997).

Once customer value is defined, the Enterprise must determine specifically how that value can be created and delivered in the most efficient and cost-effective manner. A "value stream" is an end-to-end, linked set of actions, processes, and functions necessary to transform inputs (information, raw materials, labor, energy, etc.) into a finished product delivered to the customer. The value stream includes service after the sale. Customers "pull" value from the value stream.

Waste Minimization and Continuous Improvement

Defining the value stream as indicated above provides a basis for performing an in-depth analysis of each individual action in that value stream. Each action is classified into one of the following categories:

(1) It is an action that unambiguously creates value.
(2) It is an action that creates no value but is unavoidable given the current capabilities within the company.
(3) It is an action that creates no value and can be eliminated immediately.

Actions in categories (1) and (2) are analyzed further in an effort to improve the actions as much as possible and eliminate unnecessary resource expenditures.

This process never ends. The organization implements a formal Continuous Improvement process that relentlessly seeks to reduce waste of all kinds and continually improve the product and service delivered to the customer. Consequently, Lean Enterprises realize ongoing reductions in response cycle times, production times, costs, required production space, and errors. The workforce is heavily involved in the Continuous Improvement process and is the primary source of ideas and initiatives that generate improvements. This applies to the entire organization, not just production operations.

Flow and Pull

Once wasteful actions along the value stream are eliminated to the maximum extent possible at a given time, the next Lean principle is put into practice: making the remaining value-creating steps "flow." Here the primary challenge is to discard the "batch-and-queue" mentality prevalent in mass production and implement small-lot production, with batch sizes of a single unit as the ultimate goal. Flow is best achieved by discarding traditional functional organizational structures, to be replaced with integrated product/process teams organized along the value stream (see the "Horizontal Organization" discussion below). It is important to note that the concept of "flow" and small batch size applies not only on the factory floor but throughout the organization (e.g., the flow associated with administrative procedures).

"Customer pull" is an important conceptual breakthrough in the creation of the Lean paradigm. Customers pulling value from the value stream (rather than the Enterprise pushing products onto customers) results in subsequent pulling actions that cascade up the value chain, stage by stage, through the Enterprise and all the way to the supply chain.

Near-Perfect Product Quality

A Lean production system operates like a fine-tuned watch, with each element highly dependent upon other elements with which it interacts. Since there are no buffers, any part delivered from one work unit to another must meet specifications. Defects cannot be tolerated. Consequently, much effort is expended in designing processes that turn out near-perfect (within tolerances) parts every time. Also, there are no re-work stations to compensate for defective production. If a defective part is produced, it must be detected immediately (not passed to the next workstation) and the situation resulting in the defect must be determined and corrected before production is resumed. This same tight adherence to very high quality standards carries through fabrication, assembly, and final product completion.

While these principles are expressed in terms of production systems, they should also be implemented and rigorously enforced in all areas of the Enterprise. TQM programs have demonstrated the benefits of implementing high quality standards pervasively throughout the Enterprise.

Horizontal Organization Focus

The traditional organizational structure (a "silo" with the various units representing the functions of a mass production organization) is incompatible with the value stream flow. Its design supports long production runs of standardized parts in large batches but does not support one-piece flow and just-in-time (pull) production.

Companies that have successfully transitioned to the Lean paradigm have found that Integrated Product/Process Design (IPPD) teams organized as self-managed work teams to be an effective structure. In this structure, work teams focus horizontally on a linked set of activities along the value stream, rather than reporting up a chain of command through many layers. IPPD teams include members from engineering design, production operations, industrial engineering, quality assurance, purchasing (supply chain management), human resources, suppliers, and most important, the customer.

In addition to using IPPD, many of these same companies are structuring their organizations around other core processes, shedding their traditional organizational silos.

Relationships Based on Mutual Trust and Commitment

In the mass-production world, many relationships are adversarial. For example, it is common to engage a large number of suppliers who compete against each other for the firm's business. Suppliers are rarely engaged in product development. Relationships tend to be short-lived, one year at a time. The Enterprise maintains a large staff of incoming inspectors to catch defects. Similarly, relationships with the workforce are often adversarial, especially if it is unionized.

In Lean Enterprises, win-win arrangements are the norm, as are long-term relationships with a few suppliers. Qualified suppliers are involved in product development. Target costing is used to achieve continual reductions in costs, with the savings shared. The supplier ensures the quality of the supplies delivered; no incoming inspection is necessary.

It is desirable in most cases to establish labor-management partnerships that stress win-win arrangements. The workforce is multi-skilled and supports continuous improvement efforts. Provisions are made for mutual sharing of benefits that accrue from the implementation of Lean practices and continuous improvement activities.

Decision authority is decentralized. Decisions are made at the point of knowledge, application, and need. People are empowered to make appropriate decisions at the point of work.

Increasingly, Lean Enterprises operate in a "virtual" mode. Non-core functions are outsourced. Temporary strategic partnerships, formed (often with direct competitors) to capitalize on a particular opportunity, are disbanded when the opportunity is exhausted. Enterprises operating in this manner must learn to share data, knowledge, and expertise considered highly proprietary in the mass-production mindset.

Two recent developments are having a dramatic impact on the manner in which companies may interact with customers, suppliers, partners, and other potential stakeholders. Electronic commerce (e-commerce) is changing the manner in which enterprises deal with suppliers. The cycle time for ordering, shipping, receiving, and paying for supplies has been reduced from weeks to days (or, in some cases, even to hours). Equally dramatic change is unfolding in business-to-business (B2B) interactions, both in terms of their nature and speed. Strategic partnerships can be formed very rapidly in response to business opportunities that may be available only briefly. To play in this fast-paced game, enterprises must become much more "forward-focused," ever ready to move swiftly and deftly into the fray.

It is interesting to note that Enterprises that have transitioned to the Lean paradigm are much better prepared to capitalize on the new capabilities offered by the Internet than are companies that continue to operate with a mass-production mentality. The horizontal organizational orientation facilitates the agility and responsiveness required for the new mode of enterprise functioning.

In short, the "brave new world" is upon us. New approaches, new assumptions, new structures, and new mental models are required to guide us through the largely uncharted waters of the future. There is no alternative. The mass production mental model is passé.

CHARACTERISTICS OF A LEAN ENTERPRISE

The general nature of a "Lean Enterprise" is still being formulated as we enter the 21st century. Indeed, there is much confusion and inconsistency in terminology used to characterize the concepts of "lean", "agile", and so on. Some argue (Gunneson 1997) that "agile" is the ultimate end state, with "lean" an intermediate state between "mass" and "agile." We do not subscribe to this view. The view of "Lean" in this Guide encompasses the characteristics that some authors assign to "agile," and includes additional elements. The principal difference is that some authors view "Lean" as applicable only at the production level. Our view, however, is that "Lean" is applicable throughout the Enterprise. We have attempted to be as precise as possible with our terminology to avoid adding to the existing confusion.

Webster's Dictionary offers several definitions of "enterprise." The most pertinent for our purposes is as follows:.

Enterprise – a unit of economic organization or activity; especially a business organization.

Similarly, *Webster's* offers this definition of "lean":

Lean – *thin, spare; containing little or no fat; . . . suggests a sinewy frame without any superfluous flesh.*

Combining elements of these definitions provides this useful definition of "Lean Enterprise":

Lean Enterprise – *a business organization that delivers value to its stakeholders, with little or no superfluous consumption of resources (materials, human, capital, time, physical plant, equipment, information, energy).*

Lean companies are more alert, agile, and responsive than their heftier cohorts. In a dynamic, global, and competitive business environment, companies must not only achieve a high state of agility and responsiveness, but must continuously and relentlessly search for ways to reduce consumption of all required resources while delivering superb value to their customers and other stakeholders.

We will explore the characteristics of a "Lean Enterprise" across these dimensions:

- Strategy
- Customer Focus
- Organizational Structure
- Incentives and Performance Scorecards
- Lean Management
- Workforce Issues
- Enterprise Business Systems
- Organizational Learning

Strategy

- Factors associated with Lean principles and practices are incorporated explicitly into the Enterprises's strategic planning process: customer response cycles; customer satisfaction; rationalized supply chain; flexibility and adaptability; service after the sale; strategic use of information/communication technologies.
- The business need for Lean has been clearly determined, articulated, and conveyed throughout the organization.

- Strategic business goals, along with Lean enterprise metrics, are conveyed to all levels of the organization.
- Flexible strategies and relationships exist with suppliers and even with direct competitors, allowing rapid formation and disbanding of partnerships as opportunities arise.
- Competitive benchmarking is performed regularly relative to delivery of customer value.

Customer Focus

- Everyone in the Enterprise is focused continuously on the goal of delivering best life cycle value to the customer.
- The primary driving force is the "voice of the customer," with tangible evidence of this found in every corner of the Enterprise.
- Each individual understands his or her personal impact on customer value, and how he or she adds values to the Enterprise.
- The company has an ongoing customer research program that gathers information on what constitutes "success" for the end customer and how well the organization is performing relative to customer expectations and competitor performance.
- Customer value streams are mapped and optimized to ensure that all resource deployment decisions are directed to the primary goal of delivering superb customer value.
- Integrated Product and Process Development (IPPD) teams include customers, suppliers, marketing, purchasing, human resources, business systems, and manufacturing. These teams are organized horizontally along the customer value stream, thereby ensuring concurrency and collaborative input to product and process design decisions. The IPPD teams may be geographically distributed, functioning as "virtual" teams.

Organizational Structure

- Ideally, the Lean Enterprise has evolved into an agile, rapidly reconfigurable, customer-focused, supplier-integrated, "virtual" organization.
- The horizontal axis dominates the organizational structure, with IPPD teams aligned along the customer value stream; there is a minimum number of management levels; and decision authority is at the point of action. Large, bloated, "indirect" staff functions are mostly gone, and any remaining staff is redeployed to value-adding activities in the horizontally oriented structure.
- A majority of the resources previously concentrated in the functional "silos" of the vertical organization are now redeployed and integrated into the IPPD teams and other core processes. A relatively small contingent of managers in each functional (core process) area may remain centrally located at the Enterprise level to enforce necessary standards across multiple product

families and to facilitate professional development and career-path planning for the various specialty employees now dispersed among the process teams.

- Team-based management is implemented in all areas of the Enterprise, following a comprehensive education and training program. The workforce consists of multi-skilled workers, organized in properly sized work cells to optimize one-piece flow and accommodate fluctuations in market demand. This concept applies to support functions as well as to production.
- All work activities, both direct and indirect, are organized to support the optimization of multiple customer value streams.
- Customers and suppliers are involved in all phases of the product life cycle, from concept development through product delivery and support.
- Cross-functional interdisciplinary teams support and continuously improve all core processes in the Enterprise.

Incentives and Performance Visibility

- Value-added metrics are determined and deployed, since all performance is evaluated against customer value and world-class performance. Any activity that does not measure up is improved or outsourced.
- Metrics that portray process performance relative to the value stream are communicated to appropriate levels and made visible. Visible scorecards are posted in all areas so that employees can see immediately the impact of their performance on the Lean metrics, and how their own rewards are a function of their performance against those metrics.
- An integrated set of metrics are designed and deployed to reflect performance outcomes central to the primary goals of the Lean Enterprise: (1) delivering superb value to the customer and other stakeholders; (2) maintaining the capability to respond rapidly to changes in the global business environment; (3) continuously eliminating non-value-adding activities; (4) continuously upgrading workforce skills and knowledge in preparation for future challenges and opportunities. These metrics should distinguish between *output* (enabling), such as hours of training, and *outcome* (results), such as ROI, market share, and so on.
- Incentives are designed to reward both individual and team performance that contributes to the achievement of the primary goals of the Lean Enterprise, as stated above. An equitable arrangement is in place for the mutual sharing among all stakeholders of benefits gleaned from overall Enterprise performance and from continuous improvement activities.
- Employee compensation accounts for the degree to which multi-functional skills and knowledge have been acquired and demonstrated.
- Both individual and team performance appraisals are based upon contributions to the achievement of strategic business goals and operating results.

Lean Management

- The Enterprise Leader and Senior Managers have a deep knowledge and understanding of Lean principles, practices, and behaviors, not only as applied in production operations, but throughout the entire Enterprise. The leadership is visibly involved in promoting Lean initiatives and in evaluating the results of these initiatives. The leadership ensures the provision of required resources.
- The Enterprise Leader involves the Stakeholder Leaders in the formulation, implementation, and review of Lean initiatives. Special attention is paid to the relationship between management and the workforce.
- Enterprise Leaders optimize the value across all Enterprise stakeholders: customers, employees, suppliers, stockholders, and the community.
- A shared vision of the Lean enterprise is created and communicated to the entire organization.
- The Lean transformation involves leaders at all levels, who nurture the change process and remove barriers to implementation.
- Relationships based on mutual trust and commitment are developed with customers, suppliers, and the workforce.
- Management spends most of its time developing employees to the point that they can organize and manage their own work and improve the capability of the organization to respond to the market faster than before, with solutions of higher market value.
- Employees are empowered to make their own work decisions. Employees are given general directions, resources, and guidance, and then expected to run their processes and strive for continuous improvement through the implementation of creative solutions.
- Lean principles, practices, and behavior are "business as usual" ("This is the way we do business; this is the way we operate.") within the Enterprise.

Workforce Issues

- The workforce is multi-skilled. Ideally, every employee is capable of performing every task within his or her work unit. This is necessary to ensure that the throughput rates of work units may be adjusted dynamically in response to changes in market demand.
- There is a heavy emphasis on continuous education, training, and skill building.
- Risk taking, leadership, and innovation are encouraged and rewarded at all levels.
- Employees are involved actively in planning and goal setting for their own work units. They perform their own inspection, maintenance, and workplace design, once handled by professional/technical staff.
- Employees are considered critical to problem-solving, cycle-time reduction, and continuous improvement.

Enterprise Business Processes and Systems

- "Flow" is optimized across the processes. All non-value-added activities and resources are eliminated.
- Processes, because they are flexible and dynamic, can be adapted to changing markets, customer expectations, and competitive pressures.
- Process teams continuously redesign and streamline all business processes to reduce cycle times, while improving quality and customer service.
- Processes are networked and interlinked to facilitate concurrency, speed, and handoffs, and to minimize inter-process gaps and disconnects.
- Process designers are capable of continuously renewing processes to accommodate rapidly shifting strategies and capitalize on unanticipated opportunities.
- Databases are integrated, interactive, and seamless, providing consistent information to all elements of the extended enterprise.
- Employees share information that is available at the precise time and place that decisions need to be made.
- Information flows seamlessly across all processes of the extended Enterprise.
- Information is shared without regard for geographic distance or corporate boundaries.
- Information is created and maintained in a "Lean" fashion: entered once into common databases in an open architecture.

Organizational Learning

- "Organizational learning" is fostered to enhance the creation, capture and rapid diffusion of knowledge.
- The enterprise captures lessons learned and incorporates the derived general principles in its decision rules, design guides, and other appropriate elements.
- Knowledge is retained in electronic knowledge bases managed by a Chief Knowledge Officer (CKO), as well as in documented processes, training materials, individual employees, and teams.
- The Enterprise knowledge bases provide input to a family of reusable simulation models that can be retrieved and executed in various configurations. These models are the basis for optimizing the many processes across the Enterprise and for assessing the likely outcomes of a wide variety of "what-if" questions asked by executives during the strategic planning process and by managers during normal business operations.

THE ESSENTIAL ROLE OF THE ENTERPRISE LEADER

It is a major undertaking to transform a manufacturing Enterprise from a mass-production orientation to one based upon Lean principles and practices. It will likely be the most comprehensive change initiative ever undertaken, and will touch every person and position in the organization. The Enterprise Leader *must* lead a change initiative of this magnitude and scope. The success of the transition effort depends strongly upon the personal involvement, understanding, and leadership of the Enterprise Leader. This is not a task that can be delegated.

Art Byrne, president and CEO of Wiremold Company (a firm that has made the transition to Lean), makes the following statements in this regard:

> "... The single most effective action in converting an organization to lean practices is for the CEO to lead the initial improvement activities himself …"
>
> "... Big changes require leaps of faith in which the CEO must say '*just do it*', even when 'it' seems contrary to common sense."

Mike Rother, reporting on several Lean transition efforts in the book *Becoming Lean* (edited by Jeffrey Liker), concludes: "The notion that you can drive change to lean from the bottom is 'pure bunk'."

Keith Allman, General Manager of Donnelly Mirrows, adds the following comment (reported in *Becoming Lean*): "The transition to lean must be driven by knowledgeable and committed managers who understand it in their gut."

The Enterprise Leader can be greatly assisted by the formation of a Stakeholder Leaders group designed to represent the interests of all stakeholders. In the Introduction, we identified Stakeholder Leaders as the highest-level people in the extended Enterprise, representing company and union management, suppliers, and customers.

In summary, the role of the Enterprise Leader is to:

- Develop and communicate a vision for Lean
- Create an environment for change and transformation across the Enterprise
- Develop Enterprise-level goals and metrics that encourage and promote Lean
- Identify and support Change Agents
- Promote leadership and risk taking at all levels
- Empower teams and individuals
- Commit and train resources
- Nurture the transformation process
- Remove barriers

and, *most important,*

- **Lead the Enterprise transformation**

THE HISTORY OF LEAN

INTRODUCTION

As we enter the 21st century, manufacturing enterprises around the world find themselves at the beginning of a major paradigm shift. The term "Lean" is widely used as a label for the newly emerging framework for guiding industrial enterprises, one that is different in fundamental ways from the traditional mass-production model.

The Toyota Motor Company is widely recognized for developing and successfully implementing many of the concepts that underlie the Lean framework. From these initial concepts and philosophy, an array of researchers, universities, companies, and industries have created an expanded vision of the values, behaviors, and practices within Enterprises that constitute a new and emerging expression of what it means to be "Lean." No company, not even Toyota, has completely implemented this expanding version of Lean. This will probably always be the case, since the framework itself is continuously evolving, including enhancements from non-automotive and non-Japanese firms as well.

Many manufacturing firms in many different countries and in many different industries have attempted to implement some elements of the Lean framework. Successes to date make us optimistic that a high degree of Lean implementation is, indeed, achievable. It is important to recognize that the scope of the Lean framework extends beyond the production floor to encompass the entire Enterprise. Indeed, the scope even extends beyond the Enterprise proper to include customers, strategic partners, and suppliers, thus constituting an "Extended Lean Enterprise."

This overview of Lean history provides a high-level summary of the paradigm shift underway and emphasizes the critical role of the Enterprise Leader and other senior managers in guiding the organization through a difficult and potentially hazardous transition, but, most importantly, further contrasts the fundamental differences between traditional mass-production and lean companies.

THE LEGACY OF MASS PRODUCTION

The emergence of mass production, beginning more than a century ago, is among the greatest achievements in human history. Replacing craft production (one-of-a-kind products crafted by hand), mass production dramatically lowered manufacturing costs and time for most products in all types of industries. Over the course of the 20th century, the mass-production approach spread throughout much of the world, dramatically raising living standards for most of humankind. America's mastery of mass-production techniques was a major factor in achieving victories in both of this century's major "hot" wars and the "cold" war.

If mass production is so great, why are we now being urged to replace it with a different production paradigm? The simple answer is that "nothing is forever"; virtually every human artifact is made obsolete by something better. Mass production supplanted craft production following several *technological breakthroughs*: interchangeability of parts, widespread availability of electrical power, internal combustion engine, advances in metallurgy, and so on. The conversion from mass to Lean production, however, was due more to *conceptual breakthroughs*: pull vs. push, even flow, level scheduling, rapid set-up changes, and so on. It is also important to note that the move from craft production to mass production was driven by the emergence of mass markets, which simply could not be satisfied using craft production. In the same way, Lean is being driven by markets that demand great variety, near-perfect quality, reliable service, and responsiveness, all at ever-lower costs.

To appreciate fully the paradigm shift now underway, it is important to characterize objectively the underlying construct of mass-production systems. This will facilitate our understanding of the inherent flaws of mass production and their unintended negative consequences throughout the Enterprise.

The Business Climate in 1900

At the dawn of the 20th century, the Industrial Revolution had transformed societies throughout Europe and in North America. The factory had replaced the farm as the predominant workplace. Technological advancements were creating more and more products and services. New companies emerged by the tens of thousands. Products — the demand for which had skyrocketed — became more complex and more difficult to manufacture. Customers were relatively unsophisticated and non-discerning. Standardized products of average quality were just fine.

Companies grew rapidly in size, requiring complex coordination and thus creating inefficiencies. Company executives struggled with how best to organize their rapidly growing companies and manage their employees. When they looked around for organizational models to emulate, the most obvious were those of the military and the church — both highly hierarchical and emphasizing command and control. This style of

organization, though criticized today, was a significant improvement over work systems dominated by favoritism and fragmented operations.

Ford's Contribution to Mass Production

The Ford Motor Company, under Henry Ford's leadership, is widely credited with catalyzing and defining the mass-production era due to its remarkable successes during the first quarter of the 20th century (see Hounshell 1984, pp. 217-301, for a detailed account of these accomplishments.) Henry Ford had two major insights that became the foundation upon which his version of mass production was built: first, he recognized that the automobile (only about 10 years old in 1900) was one of the most important developments in human history, and that practically every family should be able to own one; second, he realized that the best approach to building and selling automobiles at a price that every family could afford was to produce a single model with essentially no options, thus concentrating on continuously refining the product. Thus was born the legendary Model T.

Ford was among the first industrialists to recognize that price is related to volume. He reasoned further that a low price could best be achieved by building his single model. The need to minimize fixed capital per unit of production led to the Ford system of mass production.

The Model T was designed to be rugged (to withstand the primitive roads of the day), easy to manufacture, and easy for the owner to maintain. It was first sold to the public in 1908 at a price of $850. By 1916, the price had dropped to $360, and sales reached more than half a million that year. To achieve this remarkably low selling price required many innovations and production breakthroughs. Perhaps the most significant was the moving assembly line.

Ford's strategy to produce only the Model T, and the drive to achieve the lowest possible cost, led to the extensive use of single-purpose, dedicated machine tools and production processes. One machine, for example, drilled forty-five holes at once in the sides of the engine block (Hounshell 1984, p. 233), and the spindles were non-adjustable. This same approach of using single-purpose machine tools was extended to all areas of fabrication and to many areas of assembly. These specialized machines performed only one function, often for only one product design.

Ford's approach led to greatly lowered production costs due to economies of scale (see Pine 1993, pp. 14-21). The system depended upon the entire operation running smoothly at near its design capacity. If anything went wrong (with the equipment, the workers, suppliers, etc.), unit costs would increase. Thus, buffers were deployed throughout the factory and the entire supply chain. The need for close control led to steeply hierarchical organizations, technical specialists, and professional managers.

Ford also pursued vertical integration to its ultimate limit. His goal was to produce everything that went into his automobiles. He owned rubber plants, tire factories, iron ore mines, steel plants, and so on.

Ford's success with this approach was remarkable. By 1921, the company had captured 55 percent of the U.S. automobile market. But by 1927, Ford's market share had dropped to under 15 percent. By then, it had mass produced 15 million Model Ts. Meanwhile, an upstart company named General Motors perceived a shift in the buying patterns of the American consumer. A "car for the masses" (as Henry Ford called the Model T) no longer satisfied buyers with increasing wealth and a desire for new features and styling. GM's Chevrolet Division introduced the annual model change. Meanwhile, Ford was locked into its rigid, inflexible system of manufacturing a single model, year after year.

Chevrolet's factories were designed to accommodate annual changeovers by using more general purpose and flexible production equipment. Chevrolet also pursued decentralization, utilizing a large number of suppliers and thus adding to its ability to change models quickly.

Ford attempted to answer the Chevrolet challenge, but found it tremendously difficult to make the transition. While it eventually stabilized into a competitive company, Ford never regained its dominant position in the automotive market. A new era of "flexible" mass production (governed by new rules) began to emerge. As we shall see in the next section, however, "flexible" mass production was still *mass* production.

As Mass Customization (Pine 1993, pp. 21-25) points out, this American system of mass production (Fordism modified by GM) "became virtually the only production system practiced by large U.S. manufacturers." Large service providers such as insurance companies, banks, and others emulated the fundamental principles of mass production, which became the prevailing paradigm not only of production, but also of management.

> "... Its precepts encompass the entire firm and all its many functions across the value chain."

This general framework spread quickly beyond the United States to become the predominant production paradigm throughout the industrialized nations of the world. Developing nations also attempted to establish this framework.

Clarification of the Term "Mass Production"

The term "mass production" has been used in several different ways over the past century. For many people, "mass production" is synonymous with assembly-line production of high-volume, standardized products. As we shall see, however, mass-production practices are more closely tied to *large-lot production* (even of low-volume, high-variety products) than to the total production volume.

Henry Ford is credited with perfecting the moving (continuous) assembly line, made possible by the interchangeability of parts and the simplicity of joining them together (Womack, Jones and Roos 1990, p. 27). Alfred Sloan at General Motors was the mastermind behind "... the organization and management system he needed to manage effectively the total system of factories, engineering operations, and marketing systems that mass production called for" (*ibid*., p. 40). Sloan's approach introduced decentralized divisions managed strictly and objectively by detailed numerical reports from a small corporate headquarters. Also under Sloan, the principle of a "division of labor" was extended to professional ranks, prompting the emergence of professional specialists such as marketing, accounting, purchasing, finance, engineering, personnel, and others.

Under the Ford/Sloan approach, the organization of manufacturing firms evolved into a steeply vertical hierarchy. All work activities, including professional effort, became more and more narrow and specialized, giving birth to the "silo" mentality that still pervades today's organizations.

Factory workers became interchangeable parts of the overall production system. (This interchangeability was highly functional at the time, with a workforce comprised largely of immigrants and workers moving from agriculture to the factories.) Tasks were extremely narrow and highly repetitive. No thinking was required nor judgment allowed. An array of narrowly skilled, indirect workers emerged: quality inspectors, maintenance specialists, industrial engineers, and so on. Workers were under constant pressure to complete their tasks faster and faster, using work methods designed by others. A broad array of job descriptions emerged, along with restrictions regarding workers performing tasks outside their job descriptions.

After much struggle, a strong labor union movement emerged and prospered in this environment. Union-management contracts emerged that gave unions a greater voice in job assignments and promotions, with greater emphasis upon seniority.

The status of the mass production movement in the United States in the mid-1950s is summarized by Womack, Jones, and Roos (1990, p. 43):

> "Take Ford's factory practices, add Sloan's marketing and management techniques, and mix in organized labor's new role in controlling job assignments and work tasks, and you have mass production in its final mature form."

That characterization applies not only to companies that manufacture high-volume, low-variety products, but also to many companies that manufacture low-volume, high-variety products. These companies adopted many of the same practices described above, including steep vertical hierarchies, narrowly defined jobs in functional groupings, rigid labor rules, and so on.

Another practice that essentially all manufacturers adopted is that of "large lot production." Even low-volume manufacturers, such as those producing aircraft engines, tended to create production orders for relatively large lot sizes, believing that they were

minimizing costs under the principle of economy of scale. This practice resulted in the "batch-and-queue" approach to production organization (see below). Large-lot production is perhaps the single most distinguishing fundamental feature of mass production. Indeed, Mr. Shigeo Shingo, in differentiating the Toyota production system from mass production, states:

> "The Toyota production system is the antithesis of large-lot production, *not* mass production." (Shingo 1989, p. 84)

Consequently, the term "mass production" is used here to describe all organizations, regardless of their volume/variety profile, that exhibit the general characteristics described in this section. It is noted that many non-unionized firms exhibit these characteristics, including rigidly defined job descriptions, a large number of job classifications, seniority-based job assignments, and so on. Even many non-manufacturing firms exhibit these general characteristics.

Consequences of Equipment Inflexibility

Production equipment introduced in the early 20th century was inflexible. Changing equipment for the manufacture of different parts required considerable time. Consequently, parts were produced in large batches at each of several sequential machine centers.

Typically, 5 to 10 percent of parts processed at any machine center failed to meet specifications. When detected, defective parts were re-worked or scrapped. Those that were undetected were incorporated into assemblies, some of which failed final test. These assemblies were sent to re-work stations for rectification. Those defectives not detected in final test were incorporated into finished products shipped to customers, who then became the ultimate recipients of poor quality.

Relations with Suppliers

Parts purchased from suppliers were ordered in large batches and typically required several weeks or months of lead-time. When delivered, 5 to 10 percent of purchased parts failed to meet specifications. Incoming inspection was mandatory. Adversarial relations with suppliers were common. Multiple suppliers were engaged as a means of obtaining competitive prices and having alternative sources. Large purchasing departments were required to place and track purchase orders. Large warehouses were required for storing purchased parts and materials. Large quality inspection staffs were required for incoming inspection and to deal with rejected parts.

Relations with Customers and Distributors

Relations with customers were indifferent. Customers typically ordered from a catalog of standard products, with only small variations permitted as options. Products designed internally were manufactured in high volume and "pushed" onto the customer base. Consequently, large warehouses were required to store finished products. Commonly, a multi-tiered distribution system required substantial storage space, product shipment, and handling. Relations with distributors were often adversarial. Demand fluctuations were amplified upstream through the distribution channel, causing large false fluctuations in production rates and general instability at the factory.

Push Production System

A system of coordination, today called "push production," was devised in an attempt to manage an entire manufacturing enterprise in a rational manner. The system began with an estimate of future demand for each end product, derived using a variety of forecasting methods devised for this purpose. Detailed bills of material for each end item provided a basis for determining how many of each part (in all the end products) needed to be manufactured or purchased. Allowances were made for anticipated defective parts and for lead times of manufactured (in-house) or purchased parts. The projected parts requirements were laid out over some planning horizon. Process plans for producing each part determined the routings through the factory. Often, production orders for large batches of various parts would compete for the same processing equipment at the same time, leading to delays and making detailed scheduling of equipment necessary. In-process buffers grew large. In this manner, production orders were "pushed" through the factory — hence the name "push production system."

Factories Organized, Designed, and Managed for Batch and Queue

In the business environment that existed in mass-production companies, it was natural and logical for companies to strive for long production runs of highly standardized products. Engineering design groups operated within this context. Factories and processing equipment were designed for long production runs, large batch sizes, and 5 to 10 percent defective production at each stage. Changeovers at machine centers were expensive and time-consuming. Consequently, each workstation was highly specialized, performing only a few operations. A large batch of machined parts requiring 150 operations typically progressed through 25 to 40 workstations. Hundreds of batches (production orders) would typically be moving through the factory simultaneously, each requiring service on a large number of the machine centers. Processing times were highly variable. Machine breakdowns and malfunctions were common. The inevitable consequence was long queues of production orders waiting to be processed at each machine center. Factory layouts had to provide space for batches in the queues, and as much as 40 percent of the floor area was used for this purpose. Quality-control inspectors

were assigned to each machine center and re-work stations were incorporated as a necessary element in the factory plan.

The chaos resulting from this type of production environment gave birth to a new "production management" function. To deal with all the complexity inherent in mass production, it became necessary to develop means of projecting ahead, determining requirements for each item in complex bills of material on a day-by-day basis, level-loading the many machine centers to their capacity limitations, and determining economic order quantities for both manufactured and purchased items. This complex system depended heavily upon accurate bills of materials, inventory records, and standard processing times. In actual practice, these records were notoriously inaccurate and out of date, even after they were computerized. Armies of expeditors were employed to chase late production orders, especially at the end of the month when monthly shipment quotas were in jeopardy. These actions simply compounded the confusion and added to the growing list of non-value-added activity.

Batch-and-Queue Mentality Pervades the Enterprise

The batch-and-queue mentality that emanated from the mass-production paradigm carried beyond the production function into all other functions of the enterprise. Subconsciously, batch-and-queue became the overarching organizing principle of all mass-production organizations. Support functions became a reflection of the factory floor. Just as there were very long flow times for production orders moving through the factory, there were correspondingly long flow times for batches of paperwork moving through various administrative processes. (Even service organizations such as banks and insurance companies operated in basically the same fashion.)

With the batch-and-queue mentality, it was logical to organize the enterprise along functional lines, thus creating the pervasive silo structures with steeply vertical hierarchical chains of command. There was little incentive to avoid the "walls" that naturally arose between functions. Each function might seek to optimize its own performance, but there was no mechanism to encourage total system optimization. Financial and performance measurement systems designed with the batch-and-queue mentality perpetuated the fragmentation of the enterprise.

Blind Acceptance

The vast majority of the manufacturing world conformed to this *modus operandi*. The complexities, clumsiness, and inefficiencies of the mass-production paradigm went largely unchallenged for almost a century. Because the improvements realized from mass production were so vastly greater than prior craft production, the negative consequences were accepted as "the way things are." Long flow times were accepted as unavoidable, as were outrageously high inventories (raw materials, work-in-process, and finished goods), factory aisles clogged with queues of production orders, defects (that often moved

forward), re-work stations, and frequent late shipping of customer orders. Shipments from suppliers were expected to arrive in large batches, frequently late, and with 5 to 10 percent defective units.

Even large backlogs were viewed as "good": to management, they indicated healthy business conditions; to employees, they represented job security.

University textbooks and sequences of university courses outlined complex methods for dealing with the intricacies of mass production. Millions of dollars and thousands of person-years of graduate student time were invested in developing rigorous, complex algorithms and other methods for addressing the complexities.

The computerization of these awkward systems only introduced chaos into the system at a faster rate; it did nothing to address the fundamental weaknesses of batch-and-queue.

ESSENTIALS OF LEAN PRODUCTION

Fundamental paradigm shifts are infrequent. Such a shift began a century ago, when mass production replaced craft production as the overarching organizing strategy of manufacturing firms. With all its inherent disadvantages, mass production was far superior to craft production in terms of delivering large quantities of useful products at reasonable prices. Nevertheless, it is clear from the discussion above that mass production's many fundamental flaws would eventually lead to the emergence of a new paradigm.

Origins of Lean Production

As noted earlier, the Toyota Motor Company is credited with initiating the next production paradigm shift, originally referred to as the "Toyota Production System" (TPS). With later refinements and modifications (many by non-Toyota people and companies), this has come to be known as "Lean production."

Toyota developed its TPS because the company had to find a way to compete, given the conditions faced in the late 1940s and 1950s. Three key factors influenced Toyota's strategy: market conditions, capital availability, and labor-management relations. (Scarce land availability is sometimes cited as an additional driving force.)

The Japanese domestic market for automobiles was small after World War II, but the country needed a wide range of vehicles. Toyota could not use U.S. auto manufacturers as role models, since those companies were organized and managed to produce only a few types of cars in very large quantities. "Our problem was how to cut

costs while producing small numbers of many types of cars" (Ohno 1988, p. 1). (Toyota was also determined to produce good quality vehicles.) This fundamental need became the overriding driving force that led to the development of a revolutionary production system.

The scarcity of capital in post-war Japan also heavily influenced the development of Toyota's production system by severely limiting Toyota's ability to invest in Western-style production technologies. However, this limitation probably turned out to be a blessing in disguise, since investment in the huge, monolithic production machines commonly used in the West would have been inconsistent with the highly flexible, quick-change equipment needed for manufacturing low volumes of many vehicle models.

Labor-management relations in post-war Japan played an important role in the development of the Toyota Production System. *Alternatives to Lean Production* (Berggren 1992, pp. 23-25) present a cogent overview of the developments, which established the structure of Japanese labor-management relations. Efforts to form national unions (e.g., of autoworkers) similar to those in the United States were defeated. Rather, company unions were formed that generally do not represent workforce interests as vigorously as do U.S. and European unions.

Berggren goes on to outline the consequences of the Japanese style of union. The primary impact on the development of the TPS was the free hand companies obtained in matters of shop-floor organization and workforce supervision and utilization. This eventually permitted the introduction of cross-trained workers in production cells, and the shifting of some functions (such as quality assurance, maintenance, and methods improvements) to the workers. Continuous improvement activities also resulted. In return, Japanese workers gained greater job security (at least among "core" employees) and continue to be treated more as equals with management than in the typical American factory.

Some of the fundamental elements of the Toyota Production System actually originated prior to WWII. A brief review of the company's history, taken largely from *Toyota Production System* (Ohno 1988, pp. 75-92), will assist in understanding the background. (The section below follows the Japanese practice of listing family name first.)

The Toyoda Spinning and Weaving Company was founded by Toyoda Sakichi prior to 1900 (see Ohno for more details). One of his outstanding achievements was the development of an automatic loom that would stop immediately if any one of the many warp threads broke or if the weft thread ran out. This device prevented the production of defective materials, obviously a "waste," even though the machine was running unattended. Toyoda Sakichi's overriding concern for eliminating waste carried forward many years later into automobile manufacturing. This approach to using automated machines that would shut themselves off when something goes wrong became known as autonomation, or "automation with a human touch."

Toyoda Sakichi visited the United States in 1910, when the automobile industry was in its infancy. He was fascinated by Ford's Model T and recognized that a new era was beginning. Upon his return to Japan, he instructed his son, Toyoda Kiichiro, to prepare to enter the automobile industry.

Many years were required to develop a sufficient foundation to enter vehicle manufacturing. Toyoda Kiichiro toured the United States and Europe in 1930, devoting considerable attention to the automobile industry. In 1933, Toyoda Kiichiro announced the goal of producing cars for the general public. According to Ohno (p. 91), Toyoda Kiichiro said:

> "We shall learn production techniques from the American method of mass production. But we will not copy it as is. We shall use our own research and creativity to develop a production method that fits our own country's situation."

Ohno Taiichi joined the Toyoda Spinning and Weaving Company in 1932. He worked closely with Toyoda Kiichiro and his son, Toyoda Eiji, over four decades. Ohno believes that the original concept of "just-in-time" originated with Toyoda Kiichiro sometime around 1933, when it was announced that the company would enter automotive manufacturing. The new company, Toyota Motor Company, was founded on September 1, 1933.

Ohno emphasizes strongly that the two pillars of the Toyota Production System (eventually called "Lean production" in the West) are "just-in-time" and "autonomation" (automation with a human touch). Note that both of these concepts originated before 1935, one with the founder of Toyoda and the other with his son.

Toyota produced a small number of automobiles and many trucks for the Japanese war effort. Several more years were required after World War II for the company to become a major automobile manufacturer. It built upon the two pillars of autonomation and just-in-time to develop a unique production system.

Ohno Taiichi transferred from Toyoda Spinning and Weaving to Toyota Motor Company in 1943 and led the effort to implement and refine the Toyota Production System over the next four decades.

Focusing on Customer Value

Ohno's book *Toyota Production System* (pp. 85-86) relates some of the insights of Toyoda Kiichiro in the late 1930s. "Toyoda Kiichiro recognized that the market always demands reasonably priced products." "A consumer automatically derives pleasure from buying something at a lower price." "Good marketing and skillful advertising might allow us to deceive buyers for a while — but not for long. As people learn the value of domestic cars, they will buy only if the price is commensurate." "Low prices are fine —

but if they mean poor materials, poor quality, and eventually unusable products, nothing is achieved."

It is evident that Toyota was keenly attuned to customer value even before World War II. As with other major developments at Toyota, the concept of customer value evolved over several decades. Ultimately, Toyota dared to bring the customer into the product-definition process at the beginning to elicit from customers what they would *value* in Toyota products and services. The concept of "customer-defined value" became the linchpin of Toyota's new approach. Once customer value had been defined, it became necessary to determine specifically how this value could be created and delivered in the most efficient and cost-effective manner. This eventually evolved in the West into the "Customer Value Stream" concept, where the customer literally "pulls" value from a value stream that consists of all the actions necessary to deliver value.

Toyota recognized the futility of trying to deliver customer value using mass-production methods. The Toyota approach required a highly responsive, flexible system that could deliver the specific product and service desired by the customer almost instantaneously, with essentially zero defects, at a competitive price. The system had to produce small quantities of many types of vehicles for the Japanese environment. Quality had to be very high and costs had to be reduced continuously. Clearly, the entire approach to manufacturing goods had to be re-examined from scratch. The batch-and-queue mentality was woefully inadequate.

Pull Production System

In retrospect, the basic tenets of the Toyota system seem deceptively simple. Toyota's production engineers, managers, workers, and team leaders continued to view the system "from the other direction." Each stage in the value stream was regarded as the "customer" of the preceding stage. The system responded only to actual (not forecasted) demands from customers and never produced anything "ahead of time." The customer (the following stage) "pulled" the needed items from its predecessor stage. This process cascaded back upstream, all the way through the factory, product design, and support functions to the company's suppliers and even to the suppliers' suppliers. Thus was born the "pull" system of production, also known as just-in-time (JIT).

Implementation of a pull system has an immediate and significant impact on factory design. To achieve the responsiveness required necessitates the ability to process production orders of very small quantities, ideally achieving a batch size of one unit. A pull system requires that work flows smoothly on demand, with no interruption or delays, which in turn requires processing equipment and tooling that can be converted almost instantaneously from producing one part to another part. The basic design of processing equipment and tooling had to be completely rethought. Huge presses that were ideal for producing large batch sizes of a particular part, for example, were no longer appropriate for a pull system. Several smaller presses dispersed among the work centers served the

needs better. Similarly, it was more effective in a pull system to have several small paint booths imbedded in production lines than to employ one huge, monolithic paint booth.

A significant feature of a pure pull system is that it operates without buffers. In its relentless drive to eliminate all forms of waste, the system places great emphasis on eliminating inventories of all types. Thus, work units are not permitted to "produce ahead," but to produce only when a downstream unit "places an order."

Impact on Concept of Quality

A pull system requires that production operations result in essentially zero defects. Re-work stations and backflow to correct production errors are intolerable. Consequently, enormous up-front effort is required to make production operations "mistake-proof." Products usually need to be redesigned with an eye toward error-free manufacturability. Processes also need to be redesigned (concurrently with product redesign) with built in automatic checks, use of physical limits, and so on.

The quality standards for each operation must be ensured before parts are passed to the next operation. The entire line is stopped in the event of a defect. The reason for the defect is determined and the condition causing it is eliminated. While this may seem extreme, the fundamental principle is that the pain associated with a production error should be so great that the enterprise will go to all necessary lengths to correct the condition that caused the error. This is one of several Lean principles that may at first seem counter-intuitive.

Equipment malfunctions are also intolerable, as they would interrupt the smooth flow required in a pull system. Consequently, an intensive preventive maintenance program is implemented, making extensive use of imbedded sensors to detect bearing wear, vibrations, and so forth — so that the likely causes of potential breakdowns are detected and corrected before they occur.

Impact on Shop Floor Design

A pull system requires the capability of making every part every day, sometimes in batch sizes of one. To achieve this, Toyota managers and engineers determined that their monolithic factory should be modified to a series of smaller, flexible production cells. A modularized factory is more compatible with the requirements of a pull production system. The production cells are designed to achieve "one-piece flow," — that is, once a part enters production, it is not put down until its processing has been completed. This includes handing the part off from one workstation to the next within the production cell. Queues between workstations are not permitted.

To achieve one-piece flow, the work content for each operation must be standardized and the operations must be assigned to the various workstations such that

balanced workloads are achieved. The flow rate through any production cell is determined by the pace at which the customer (the next stage in the value chain) "buys" the product. This pace is called "takt time."

Recognizing that takt time changes frequently in accordance with market pull, the flexible production cells are designed to be scalable to accommodate variable production rates. This requires the ability to perform dynamic reconfigurations of the workloads among workstations within the cells.

Workforce levels in the cells are also changed up or down dynamically, so that the workers remaining in a cell are always working at the same pace, no matter the production rate. Workers taken out of a cell are assigned to other productive work (e.g., maintenance or training) until they are again needed in the cell. This underscores the need for cross-trained workers.

It is obvious that production cell design and redesign is a challenging task that never ends. Continuous improvement initiatives are required to fine-tune cell operations to achieve ever greater efficiencies. Toyota takes pride in its ability to "reconfigure a production cell over lunch." Perhaps this ability will emerge as a critical success factor and performance metric for 21st century manufacturing firms.

Note that one-piece flow in small production cells leads to immediate quality feedback from workers on adjacent processes. Production errors/defects are caught immediately rather than being passed down the line. The cause can be determined and corrected before a large number of defects accumulate.

Impact on Production Management and Control

The complex, elaborate production management systems (detailed scheduling, inventory control, MRP, etc.) required in mass-production environments can be dramatically simplified in a Lean production environment. Simple "kanban" systems (cards that visually signal the upstream stage to produce another unit) link the various stages of the value stream and no part is made until a request is received from the downstream customer. (This discipline is imposed even if it idles machines and workers part of the time — another counter-intuitive principle of the Lean paradigm.) Day to day scheduling can typically be run off of visual control boards located throughout the factory. These visual control boards also display order status and equipment status, so that every employee can see the information and take appropriate action when needed. It is important to note, however, that some of the higher-level production management modules are still needed in a Lean environment.

The factory information systems that support the production management function can also be greatly simplified. Production orders are pulled along between workstations automatically, responding to the kanban system. Formerly complex

information flows are largely eliminated, the physical product and information about it having been combined into a single entity.

Impact on the Workforce

A pull production system has a dramatic impact upon the nature of the workforce. The various workstations within a cell require a variety of skills and capabilities. Often, the equipment is designed so that one operator can manage multiple workstations simultaneously. It is desirable that every operator be able to operate every workstation in the cell. This leads to the need for a multi-skilled workforce with very few job classifications — a sharp contrast to the nature of the workforce in mass-production factories, where an individual worker repeatedly performs a single, narrow task. In a pull system, operators are no longer tied to a particular machine. Frequent job rotation is practiced as a means of maintaining broad skills and evenly distributing the total work content among the cell operators. This also reduces boredom and the dangers inherent in repetitive operations at a particular workstation. It is common to find visual work instructions displayed that portray the standard method for performing each task, inspection procedure, and so forth.

Operators in a production cell typically function under the principles of "team based management." Many operational decisions are delegated to teams. Considerable time is devoted to "problem-solving" and to searching for better ways to complete work. Operators perform many of the roles formerly done by industrial engineers, manufacturing engineers, maintenance specialists, quality control inspectors, and others. Supervisors become coaches and facilitators, and sometimes fill in at workstations. Incentives are modified to encourage team achievements. Results of the work team are displayed in visual scorecards. Team cohesion is stressed.

The underlying logic of team-based management is captured nicely in the book *Lean Thinking* (Womack and Jones 1996, p. 215). "Workers," they note, "should be focused horizontally on a linked set of activities along the value stream and perform many of the indirect tasks associated with managing their work, including quality assurance, machine maintenance, tool changes, development of standard work, and continuous improvement." This is in contrast to workers reporting "up the chain of command" through many layers of a steeply vertical hierarchy.

The large staffs of professional engineers, technicians, quality experts, and others who once performed these tasks, while still available to the workers for guidance and technical assistance, are now free to devote much more of their time and technical skills to the design and optimization of the manufacturing enterprise as a *total system*.

The roles of many middle managers change dramatically in a Lean environment. In fact, the organizational structure can be flattened significantly, leaving fewer layers and fewer indirect support staff, since many of these functions have been designed out of the system or have been dispersed in the new horizontally focused structure.

Were Some of the "Genes" of Lean Inherited from Ford and Taylor?

Some have argued that Lean production is simply an extension of "Fordism" and "Taylorism." Babson (Nunez and Babson 1998, p. 28), for example, states, "It can be argued that this focus on time management and continuous-flow production simply restates the original recipe for mass production, as authored by Henry Ford, Frederick Taylor, and others in the opening decades of the twentieth century. This continuity is suggested all the more emphatically by the current emphasis on 'standardized work', an apparent echo of Taylor's stress on seeking the 'one best way' to perform a task."

Babson is certainly correct in recognizing that the specific elements he mentions (i.e., time management, continuous-flow, and standardized work) were developed and implemented long before Toyota developed its production system. Indeed, Toyota clearly incorporated these earlier elements into its emerging system. Other elements of the Toyota system (e.g., just-in-time, pull, cross-trained work teams, scalable production rates, etc.), however, were features unique to the new system.

The Toyota system also includes several features based upon "Taylorist principles" (Berggren 1992, pp. 22-34). Nevertheless, Berggren draws this overall conclusion regarding the Toyota system: "The individual features were often not unique in themselves, but in their entirety they became a new production matrix."

Ohno Taiichi, principal architect of the Toyota Production System, also gives great credit to Ford for many of the concepts imbedded in Lean production. In *Toyota Production System* (pp. 93-109), Ohno advances the argument that Ford was heading in the right direction (i.e., toward Lean), but that his successors "did not make production flow as Ford intended. They ended up with the concept, 'the larger the lot size, the better'." Finally, Ohno says, "... I have long doubted that the mass-production system practiced in America and around the world today, even in Japan, was Ford's true intention."

It can be argued that the concept of "just-in-time" was the one fundamental element of Toyota's production system that did not evolve from earlier systems. This was one of those rare insights that come from perceiving a situation in a fundamentally new way. JIT led to the development of several other secondary elements, such as very short set ups, small batch production, level scheduling, and so on. These developments often occurred over several years and after much trial and error. The Toyota Production System that we see today in its totality did not appear suddenly as a full-fledged system, but rather was the result of years of effort, experimentation, and refinement.

Most new systems rarely evolve out of "whole new cloth." They are usually refinements, modifications, and/or extensions of certain elements of previously existing systems. New thinking comes from seeing old things in new ways.

Lean was a case of seeing the basics of automotive manufacturing in a fundamentally new way. Lean, as it has evolved, constitutes a new framework of thinking with new organizing principles. In its totality, it is clearly different and distinctive from previous manufacturing systems such as craft production and mass production.

One can look back and see certain principles and practices in other production systems which, if extended to their logical conclusion, might have yielded some of the features found in Lean. There has been speculation that one can identify certain "genes" in Fordism that might have led, but did not lead, to Lean. Actually, it does not matter whether these "Lean genes" existed within Fordism; if they ever existed, they were long gone by the 1940s and 1950s, when Toyota was rapidly developing its new system of production.

Continuing Refinements at Toyota

As Toyota gains experience with its Toyota Production System, both in its domestic plants and in its transplants in other countries, the company continues to make modifications and refinements. Some of the lessons learned in its transplants are being fed back to the company's home base in Japan.

The book *Knowledge-Driven Work* (Cutcher-Gershenfeld *et al.* 1998, pp. 14-15) provides a concrete example. Toyota has modified its "guiding principles" based upon experiences in its various operations around the world. The new draft reflects a more globally decentralized and culturally sensitive corporate stance.

Guiding Principles at Toyota

1. Be a company of the world.
2. Serve the greater good of people everywhere by devoting careful attention to safety and to the environment.
3. Assert leadership in technology and in customer satisfaction.
4. Become a contributing member of the community in every nation.
5. Foster a corporate culture that honors individuality while promoting teamwork.
6. Pursue continuing growth through efficient, global management.
7. Build a lasting relationship with business partners around the world.

The book *After Lean Production* (Kochan *et al.* 1997, pp. 45-60) provides further examples of lessons that Toyota has learned as it has expanded globally. The lessons are grouped under the several headings: "Management of Production"; "Work Organization and Skills Development"; "Remuneration Systems"; "Labor-Management Relations and Enterprise Governance"; and "Employment Systems and Job Security." Modifications are described in each of these categories. An example is given here that involves Toyota

backing off of one of its fundamental tenets — no buffers. The case study pertains to three plants in Japan.

> "Long assembly lines were broken up, so that three or four main lines were divided into eleven to twelve mini-lines, and, when possible, some tasks were transferred to sublines. An allowance of three to five cars was provided before and after the mini-lines to serve as buffers."
>
> "The buffers before and after the mini-lines have reduced the psychological pressure on workers not to halt operations of the lines."

Undoubtedly, many further modifications and refinements of the Toyota Production System will be made in the years ahead. Some will be initiated in Japan, while a growing number will likely be initiated in Toyota operations in other countries. Toyota has always excelled at rapidly adopting and diffusing lessons learned throughout the company, no matter their origin.

ORIGINAL CORE CHARACTERISTICS OF LEAN PRODUCTION

As companies in various industries have attempted to implement the principles and practices of Lean production, they have encountered a common set of fundamental requirements. Specifically, the Lean production paradigm is critically dependent upon the following precepts.

- Equipment and tooling can be "right-sized" and made readily movable and re-configurable.
- Set-up times can be reduced to almost zero.
- Workers can be cross-trained and be able to perform every task in the production cell.
- The entire value stream can function with near zero level safety stock.
- Equipment can be made to be very reliable.
- Defects can be essentially eliminated.
- Product Design Teams can translate *customer value* to design specifications and then to detailed designs that are manufacturable with near zero defects.
- Target costing is feasible and attainable.
- Overall customer demand can be made relatively level, or at least very predictable.
- Reduction/elimination of most overhead and waste will save more than the costs of achieving level flows.
- The Integrated Product/Process Team approach to organization is superior to functional organization.
- Shutting down the production line (in response to a defect) is more effective in the long run than allowing defects to move forward or having re-work stations.

- Human actions (moving materials, loading machines, etc.) are often superior to automation and mechanization, thus facilitating the need to achieve scalability of production cells in response to varying demand rates.
- Operations personnel are capable of performing such functions as inspection, equipment changeover, maintenance, methods improvements, etc.
- Focusing on inappropriate performance measures (e.g., machine utilization and worker idle time) leads to policies and practices that are significantly sub-optimal at the total enterprise level.
- Expediting and fire-fighting are symptoms of an inferior production system design and can essentially be eliminated through the introduction of Lean thinking and Lean practices.
- High levels of inventory (raw materials, WIP, finished goods) are unnecessary and undesirable and can essentially be eliminated through the implementation of *flow*, *pull*, and *level scheduling*.

Companies that have had success in converting to Lean have driven their production systems to reflect the characteristics that flow from these precepts. These can be regarded as "performance requirements" of Lean production system design. While not applicable to every situation, this set can serve as a first "checklist" of Lean requirements.

CONTINUING EVOLUTION OF LEAN THINKING

Western companies were slow to comprehend the fundamental principles underlying the Toyota Production System. Thousands of U.S. and European manufacturing managers and engineers participated in "study tours" of Japan during the late 1970s and throughout the 1990s. Toyota was among the favorite Japanese firms to visit. Most of the visitors returned to their companies believing that they had discovered the "secret" of Japanese production systems. Numerous books were written on the subject. Attempts were made to implement individual practices, such as quality circles and just-in-time. Few of these attempts were successful.

It was only when Toyota's total production and management system was described in books written by the leaders of Toyota's own transformation that Western companies began to comprehend how the system worked (see Ohno 1988, Shingo 1989, and Monden 1998 for examples of such publications). Another factor that greatly accelerated the adoption of the Toyota system was the move by several Japanese automotive companies to establish vehicle manufacturing facilities in the United States and Europe.

A research group — the International Motor Vehicle Program (IMVP) — was established at MIT during the late 1980s to perform an in-depth study of automotive manufacturing worldwide. One of the outputs of this program's effort was *The Machine that Changed the World* (Womack, Jones, and Roos 1990), a book that set out to describe the comprehensive production and management system that Toyota had developed over four decades.

Two of the authors, Womack and Jones, worked as consultants to numerous U.S. and European companies that had begun to implement Lean principles and practices during the late 1980s and through the mid-1990s. These experiences were documented in their book *Lean Thinking* (Womack and Jones 1996). After working with many companies, the authors/consultants began to see a generic framework for successfully implementing Lean in Western companies. This amounted to a restatement of the Lean framework as practiced by Toyota, designed to be more compatible with Western practices and management approaches. Womack and Jones (*ibid.*, pp. 16-26) perceived that there are five general principles of Lean thinking.

> *Value* — The starting point for Lean thinking is "value" as defined by the end customer. Value is defined in terms of specific products and services having specific capabilities offered at specific prices to specific customers.

Value Stream — A "value stream" is the set of all specific end-to-end, linked actions, processes, and functions necessary to transform raw materials into a finished product in the hands of the customer. Service after the sale is included in the value stream. Mapping the value stream for each product provides a basis for performing an in-depth analysis of each of the individual actions in the value stream. Each action is classified into one of the following categories: (1) it unambiguously creates value, (2) it creates no value but is unavoidable given the current capabilities within the company, and (3) it creates no value and can be eliminated immediately. Actions in categories (1) and (2) are analyzed further through the use of value engineering, in an effort to improve the action as much as possible, eliminating unnecessary expenditures of resources.

Flow — Once the wasteful actions along the value stream have been eliminated to the maximum extent possible, the next step according to Lean principles is to make the remaining, value-creating steps "flow." The primary challenge is to discard the batch-and-queue mentality prevalent in mass production and install small-lot production. The ultimate goal is to implement batch sizes of a single unit. Flow is best achieved by discarding traditional functional organizations, replacing them with integrated product teams organized along the value stream.

Pull — Conceptually, the customer "pulls" the product from the enterprise rather than the enterprise pushing the product onto the customer. This "pulling" action cascades up the value stream, stage by stage, all the way to the supply chain. A production system organized in this manner is said to be a "just-in-time" (JIT) system. Establishing a JIT system involves the use of "kanbans" and a system of total quality that roots out all defective work. JIT is supported by production smoothing, standardization of operations, reduction in setup times, single piece flow and rearrangement of production operations into work cells.

Perfection — Companies that have implemented the principles and practices of Lean find that there is no end to the process of reducing waste of all kinds and continually improving the product and service delivered to the customer. Consequently, there are on-going reductions in response cycle times, production time, required production space, costs, and errors.

The book *Lean Thinking* has had a major impact in transforming production operations to a Lean framework in a wide variety of firms. As more and more companies gain experience with the Lean approach, further refinements to the framework will be discovered, implemented, and diffused.

FROM LEAN PRODUCTION TO LEAN ENTERPRISE

Clearly, a "Lean" production system is far different from a mass production system. The differences are manifested not only in how the systems operate, but also in how the people working in those systems behave. This is true not only in the production function, but also throughout the Lean Enterprise. How is Lean thinking being elevated to the Enterprise level?

Work Flow and Work Design Beyond the Factory Floor

The fundamental principles and practices of Lean are applicable to all areas of the Enterprise. The Lean practice "one-piece flow" is just as applicable to administrative paperwork flowing through an office as it is to parts flowing on the factory floor. The concern with minimizing the inventory of custodial supplies should be just as great as the concern over the supply of raw materials. The concept of detecting defects immediately when they occur is applicable to administrative work, or to engineering design. Defects should simply not be passed to the next workstation. Similarly, there should be equal concern about optimizing the flow of information and the flow of materials. In short, applying Lean principles and practices beyond the factory floor is essential if there is to be a true minimization of waste throughout the Enterprise.

Organizational Structure

The entire organizational arrangement of the Lean Enterprise must be made compatible with the needs of the customer value stream. To focus all Enterprise endeavors toward the ultimate goal of maximizing value delivered to the customer, it is necessary to organize and deploy all Enterprise resources and actions toward that end.

The existing organizational structure is likely an outgrowth of the mass-production mentality. It may have a "silo" orientation, with the various units defined according to the traditional functions of a mass production organization: marketing, product design and development, production, procurement, finance/accounting, quality assurance, maintenance, and a number of other support units. Arranged in a hierarchical structure, these silo units impede efficient communication, coordination, responsiveness, and overall system optimization. The various units operate in an almost autonomous fashion.

The traditional organizational structure is incompatible with the value stream flow. Its design supports long production runs of standardized parts in batches with long flow times; it does not support one-piece flow and just-in-time (pull) production. It is structured to minimize machine and worker idle time, but at the expense of very high

inventory levels, long flow times, cluttered shop floors, and high scrap/obsolescence rates; it is not structured for minimizing response time and maximizing flexibility. Its hierarchical and rigid structure results in extreme specialization of job functions and a large number of job classifications; it is incompatible with the team approach of Lean production, in which workers perform many tasks and have few job classifications.

Companies that have successfully transitioned to the Lean paradigm have found an effective structure in Integrated Product/Process Teams (IPPT) organized as self-managed work teams. A dedicated team for each product family includes expertise from marketing, engineering design, purchasing, tooling, manufacturing, industrial engineering, quality assurance, customer relations, suppliers, and customers.

Rather than reporting up a chain of command through many layers, work teams should be focused horizontally on a linked set of activities along the value stream. Such a structure facilitates ongoing efforts to minimize waste via continuous improvement initiatives. Organized in this manner, the work teams are in a position to perform many of the "indirect tasks" associated with managing their work, including workspace layout, quality assurance, maintenance, setup change-overs, rebalancing work loads, and continuous improvement. Such an arrangement greatly reduces non-value-adding functions, increases efficiency and flexibility, and enhances the workers' value to the Enterprise.

It is interesting to note that the hierarchical structure is the organizational equivalent of batch-and-queue, whereas the horizontal team structure is analogous to one-piece flow (no handoffs, immediate quality feedback).

Incentives and Reward Structure

Human nature is such that people will always respond to whatever incentives and rewards are in place. If we want "Lean behavior," then we must reward such behavior and not reward non-Lean behavior. All too often, incentives are not aligned with the end results sought. (Looking at this issue from the other direction, it is just as important to remove disincentives.) As the organization is re-aligned into work teams, close attention must be paid to both individual *and* group incentives.

Incentives should be linked to the metrics through the use of visual scorecards. People need to be able to see immediately the impact of their performance on the Lean metrics, and their rewards need to reflect this relationship. The scorecard should include both financial and non-financial measures, which in turn should be traceable to the ultimate objective of creating maximum value for the customer.

Adapting Structure and Systems

Extensive modifications will probably be required in the various systems, structures, and policies of the organization to bring them into compliance with the Lean transformation vision. The following are examples of the structures, systems and policies that may require modification.

Structures
- Form of organization (internal)
- Process of interface approach to externalities (labor relations, suppliers, customers, regulators, etc.)
- Standardization vs. empowerment (e.g., in software, the organization wants to standardize the platforms, while some individuals want their own types of software that differ from the standard.)

Systems
- Information/communication systems (hardware, software support, management control systems, engineering information systems, technology)
- Financial and accounting
- Human resources (focus on rewards, hire/fire, training/development, promotion)

Policies
- Decision authority
- Employment continuity
- Human resource policies
- Etc.

Legacy systems, structures, and policies evolved under a mass-production mindset, and many are inconsistent — even contradictory with the Lean paradigm. Consider, for example, the information/communication system. Because of the high degree of planning, coordination, and corrective action required in mass-production systems, the attendant information systems are extremely complex. The Lean paradigm eliminates the need for many of these information processing requirements.

Lean principles should be followed in the redesign of the information system. Just as material flows should be optimized, straightened, and shortened in Lean production, so should the information flows deployed throughout the Enterprise. Waste should be eliminated wherever it occurs in the information system.

Similarly, with Lean principles and practices in place, the complexity of all resource planning/deployment systems (scheduling, MRP, ERP, etc.) can be reduced significantly. Likewise, the financial, accounting, human resource systems, and all core business systems should be redesigned following Lean principles and practices.

Many of the policies of the Enterprise will need to be brought into compliance with the Lean paradigm. For example, decision authority typically moves closer to the

point of implementation in a Lean environment. Traditional middle managers may view this as an erosion of their authority. Policies regarding job classifications will likely be modified, causing concerns among the workforce and the union (if any).

All business systems should be modified following Lean principles. For example, a "Lean" accounting system is needed. Activity-Based Costing is only a start. What is really needed is value stream/product-based costing that includes product development, marketing, production, and supplier costs associated with specific products. Many traditional functions (e.g., purchasing) are eliminated or reduced, with the appropriate functional activities integrated directly into the value stream. In this way, costs can be assigned directly to specific products rather than allocated as overhead.

Similarly, other enterprise functions such as sales, order-entry, human resources, and all production management sub-systems should be redesigned to conform to Lean principles and to properly support Lean production.

The Critical Role of Education and Training

By far, the most important element in any organizational transformation initiative is that of education and training. These are especially critical in transitioning an organization from a mass-production paradigm to a Lean-production paradigm.

A successful Lean transformation initiative will likely require the most extensive changes a company will ever have encountered. There will be a significant impact on every employee and every position. Successful transition to Lean will require a deep understanding of Lean principles and practices. Extensive education and training will be required at all levels. The focus of these efforts must be on changing mental models, beliefs, behaviors, and attitudes throughout the workforce.

ACHIEVING AN EXTENDED LEAN ENTERPRISE

A Lean transformation is not complete until it reaches beyond the immediate company to include customers and suppliers in the overall Lean system design. Only in this way can the complete value stream be structured and optimized in accordance with Lean principles and practices.

Here are the major tasks to be accomplished with regard to the supply chain.

- Develop long-term supplier relations, moving toward cooperation and away from confrontation.
- Reduce the number of suppliers.
- Teach and implement target costing.

- Agree on how savings will be divided.
- Establish continually increasing quality standards and expectations.
- Eliminate incoming inspection; certify suppliers.
- Have suppliers teach *their* suppliers.

Similarly, it will likely be necessary to coach customers in Lean thinking — for instance, that the Lean Enterprise wants to deliver orders to customers in a steady, continuous stream rather than in large batches, and will deliver certified quality products directly to the customer's point of use at the most appropriate time. Most customers will, at first, be apprehensive about this type of behavior, since they are accustomed to late deliveries of large batches, numerous defects, and so on — all the norm under the mass-production system.

LABOR-MANAGEMENT RELATIONS

As Lean practices and principles have been introduced into companies, there has been a range of reactions from organized labor. The book *North American Auto Unions in Crisis: Lean Production as Contested Terrain* (Green and Yanarella 1996) provides considerable detail on the various responses to Lean within the auto industry in North America. *Confronting Change: Auto Labor and Lean Production in North America* (Nunez and Babson 1998) addresses the same general issues and provides broad coverage of auto industry issues in Mexico as well as in the United States and Canada.

In recent years, the International Association of Machinists (IAM) union has been actively promoting a progressive and enlightened approach — "High Performance Work Organization" (HPWO) — to labor-management relations that attempts to achieve a win-win outcome for both parties. (The terms "high performance work organization" and "high performance work teams" have been used in a more generic way in many publications. Here the terms are used in specific reference to the approach being promoted by the IAM.) The IAM has developed a field manual for building and implementing an HPWO. Details are available from the IAM. The overview that follows summarizes a presentation made by Mr. Don Kennedy, director of IAM's HPWO Department, at a conference on "Enhancing the Effectiveness of Our National Workforce," held in Washington, D.C. on January 19-20, 2000. The conference was co-sponsored by LAI.

HPWO Principles, Practices, and Terminology

- Underlying the High Performance Work Organization (HPWO) model developed by the IAM is a commitment to an overall workplace change strategy centered on:
  - Grow the business
  - Cost the activities (activity-based costing)
  - Improve the work

- We now have a global marketplace — different than we've ever faced before. In this context, "it is a never-ending change process. To be effective, we have to have a process and an approach."
- The necessary components for an HPWO include:
  - Full partnership
  - Shared decision-making
  - Continuous learning and skill-building. Every employee is a knowledge worker. Technology integration — labor and management identify the technology needed and the strategy needed.
  - Co-determine the definition of quality
  - Share technical and financial information. Make information available to a far greater extent than we did before.
  - Joint determination of costs — traditional costing system doesn't give us good information about the way people do work. ABC gives more accurate information, and powerful non-financial information as well.
  - A collective bargaining agreement
  - Leadership (both labor and management) motivates employees to accept partnership.
  - A jointly developed strategic business plan: What business are we in? How can we grow? How can we keep the good jobs here?

(The IAM then outlines a ten-step process for launching a HPWO.)

The keys to success are understanding and attention to the following:

- Compelling business reason for change to survive and grow. Communicate to all employees.
- Commitment to change by management and labor
- Labor-management role changes
- Readiness of workplace culture
- Time to accomplish the plan — long-term view and one step at a time

The plan presented above is an example of new labor-management arrangements. Whatever approach is used, the success of a Lean transformation in an Enterprise will require the active participation of all stakeholders, especially the workforce.

MAJOR CHALLENGES

Achieving a successful Lean transformation is a formidable task. Many major challenges will be encountered. Some of the more important ones are listed below.

Awareness and Understanding of Lean

- Lean concepts are relatively new, and so are neither widely known nor understood.
- Some Lean concepts are counter-intuitive, that is, diametrically opposed to traditional wisdom.
- Methodologies for attaining Lean are not yet mature.
- There is a shortage of "Lean gurus."
- Lean requires a deep understanding that comes only from repeated application of its principles.
- "Whole-hog" acceptance and implementation of Lean is usually advocated (although many managers will want to start with pilot projects).
- Lean is often confused with re-engineering, TQM, and other movements and initiatives.
- Lean initiatives face management and worker cynicism about fads.
- Leaps of faith are sometimes required to implement Lean.

Deeply Engrained Mass-Production Mentality

The mass-production mentality is characterized by the typical performance measures seen in mass production factories:

- Minimize machine idle time
- Minimize worker idle time
- Minimize stock outs
- Minimize labor costs

When employees are incentivized to achieve these performance measures, the following consequences are seen:

- Long production runs of standardized parts in batches; long flow times
- Very high levels of inventory (raw materials, WIP, finished products)
- High number of defects; high scrap/obsolescence rates
- Extensive re-work areas
- Crowded factory floor; long queues of production orders waiting at machine centers
- Self-induced fluctuations in "demand" at all levels

The negative impact of mass-production thinking extends beyond the factory floor and encompasses the total Enterprise. Many of the consequences of mass production mentality were highlighted above in the section titled "From Lean Production to Lean Enterprise."

Management Resistance

Until there is a deep understanding of Lean principles and practices, organizations can expect considerable resistance from managers, especially those in middle management. The reasons include the following:

- With Lean, there is a perceived loss of power, prestige, and authority.
- Lean represents a major paradigm shift that runs counter to decades of conventional wisdom.
- Lean's team-based management concept is threatening.
- Managers are uncomfortable with the removal of safety nets (safety stocks, padded forecasts, excess capacity, etc.) that comes with Lean.

Employee Concerns

Similarly, many employees will feel uncomfortable and threatened by the Lean paradigm.

- Many feel threatened when transitioned out of the old way of organizing work, which is highly departmentalized, limited in scope, and with everything "in its place."
- By its very nature, Lean emphasizes dramatic and continuing reductions in labor content; employees are asked to seek continually means of reducing their own work content.
- Job security may be threatened.
- Employees fear work intensification and unlimited demands for performance.
- Employees fear forced overtime.
- With fewer job classifications, employees may perceive diminished career path opportunities.
- Employees fear an increased risk of injury in an environment where there is little tolerance for work injuries.
- Employees fear a new rigidity of standardized work, with the pressure of ever-shorter work cycles.
- Workers fear increased pressures due to the removal of buffers.
- With the company/employee contract changing, employees are asking: What is the meaning of "loyalty" in this brave new world of Lean? A major challenge is to find a way to overcome large disparities (real and perceived) between worker and company/manager benefits from the conversion to Lean.

TOP LEVEL TRANSITION-TO-LEAN ROADMAP FOLDOUTS

The conceptual framework that follows — the "Transition-to-Lean Roadmap" — is aimed at assisting firms in their efforts to transform into Lean Enterprises. The framework portrays the overall "flow" of action steps necessary to initiate, sustain, and continuously refine an *Enterprise transformation* based upon Lean principles and practices. This particular Transition-to-Lean Roadmap was developed from an *Enterprise perspective*, with particular attention paid to strategic issues, internal and external relations with all key stakeholders, and structural issues that must be addressed during a significant change initiative.

The figure in the first fold-out shows a high-level schematic representation of the Transition-to-Lean Roadmap. Several principles and concepts guided its creation.

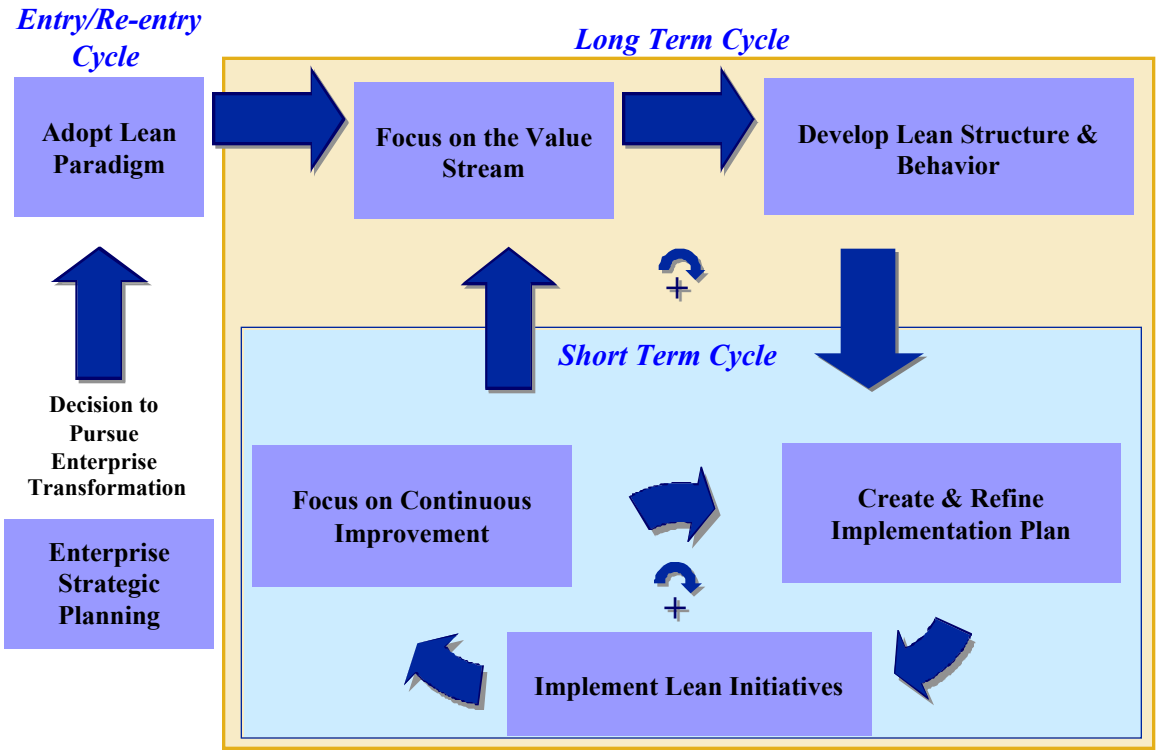
- Top Management must lead the transition.
- Since Lean principles and practices are fundamentally different from those of mass production, Senior Leaders must open their minds to new concepts that may seem counter-intuitive and even contradictory to common sense.
- Until Senior Leadership understands, embraces, and commits to a full conversion to Lean, any initiative will have little chance of succeeding.

The figure on the left side of the second fold-out includes all the "bullets", or major tasks, associated with each block of the Roadmap. On the right side of the second fold-out, we show the Roadmap as it will look when Lean behavior has become deeply embedded in the culture of the enterprise.

Volume II of this Guide, "Transition-to-Lean Roadmaps," elaborates on each of the elements shown in the Roadmap. Volume II provides a separate double-page foldout for each element, containing further details regarding specific tasks and actions that must be undertaken to accomplish the goals of that element. Collectively, the foldouts in Volume II portray a quick "snapshot" of the overall Transition-to-Lean process that has been derived. The text accompanying the foldouts provides further detail and elaboration.

Enterprise Level Roadmap

The Entry/Re-entry, Long and Short Cycles



TRANSITION-TO-LEAN ROADMAP: ENTERPRISE LEVEL

The Enterprise Level Transition-to-Lean Roadmap provides a general framework for assisting companies in their transition to Lean. It portrays an overall "flow" of action steps that can initiate, sustain, and continuously refine the transformation of an Enterprise based upon Lean principles and practices.

The Roadmap comprises three "cycles." First is the *Entry/Reentry Cycle*, which specifies the actions associated with the decision to adopt the Lean paradigm. This cycle is closely linked to the Enterprise Strategic Planning cycle.

The second cycle is called the *Long Term Cycle*, in which the environment and conditions necessary for a successful Lean transformation are created. The organization is then prepared for launching into detailed planning and implementation.

The third cycle is the Short Term Cycle, in which detailed implementation is planned, executed, and monitored. This cycle has a fast clock speed, with ongoing action-monitoring-corrective action phases. The Long Term Cycle is re-entered periodically to capitalize on lessons learned during implementation and to accommodate changes occurring in the dynamic external environment.

TRANSITION-TO-LEAN ROADMAP: ENTERPRISE LEVEL

ADOPT LEAN PARADIGM

Implementing the Lean paradigm requires revisiting every assumption, practice, and process associated with customer interactions, product design, production, quality assurance, human resources, work supervision, organizational structure, business systems, and supplier relations. We must learn to do business, behave, and see value in fundamentally different ways.

FOCUS ON THE VALUE STREAM

A primary concept of Lean thinking is that all actions and resources of a firm should be focused on *creating value*. Any action or resource expenditure that does not contribute directly to the goal of creating value is *waste* and should be eliminated to the greatest extent possible. Value stream definitions and analysis will identify the highest leverage areas that should be pursued in the Lean transformation.

DEVELOP LEAN STRUCTURE AND BEHAVIOR

Both the *structure* and *behavior* of Lean organizations are significantly different from those of mass-production organizations. This segment of the Roadmap deals with creating the mental model and conditions necessary for the implementation of Lean principles and practices.

Incentives, structures, systems, and policies of the Enterprise must be aligned with the desired behavior.

CREATE & REFINE IMPLEMENTATION PLAN

Moving to the Short Term Cycle, we now must identify and prioritize those Lean initiatives that collectively constitute the Enterprise Level Plan for achieving the desired transformation. Resources must be committed to the plan. An extensive program of education and training will be required.

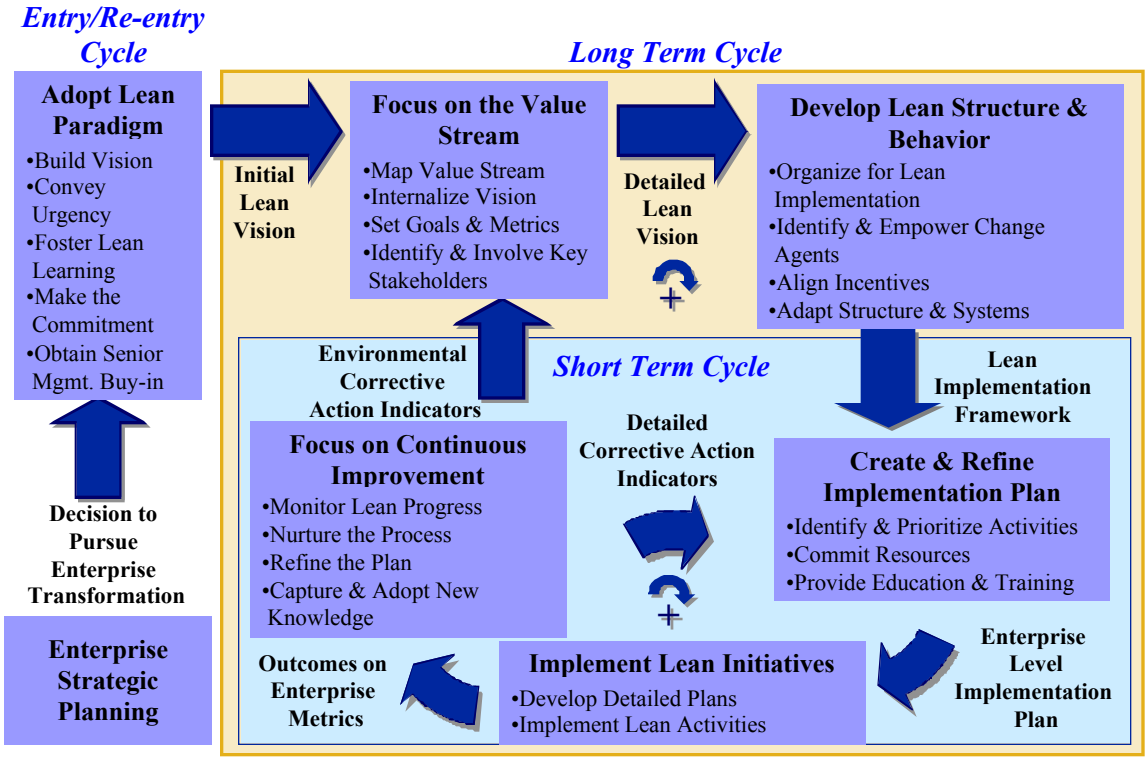
IMPLEMENT LEAN INITIATIVES

It is here that the changes in practices and procedures are actually implemented. As a flow-down from the Enterprise Level Plan, we now define the specific actions, programs, and projects that will be executed within each organizational area and determine how they will be integrated at the system level. These detailed action plans are executed, monitored, and modified as required.

FOCUS ON CONTINUOUS IMPROVEMENT

As progress is made on the detailed action plans, the results of the changes are measured and assessed. Corrective actions are part of the continuous improvement process. Opportunities for further improvements are identified. Detailed corrective actions become input for the "Create & Refine Implementation Program" segment, to be incorporated into the next iteration of the Enterprise Level Plan. Corrective action indicators of more fundamental change drive the need to revisit the Long Term Cycle for further modifications to the structure and behavior of the enterprise.

Enterprise Level Roadmap



BRINGING IT ALL TOGETHER: THE COMPLETE ROADMAP

The complete Enterprise Level Transition to Lean Roadmap is reconstructed here. It illustrates a general "flow" of actions, decisions, and initiatives that an organization may follow in pursuit of its own Lean transformation.

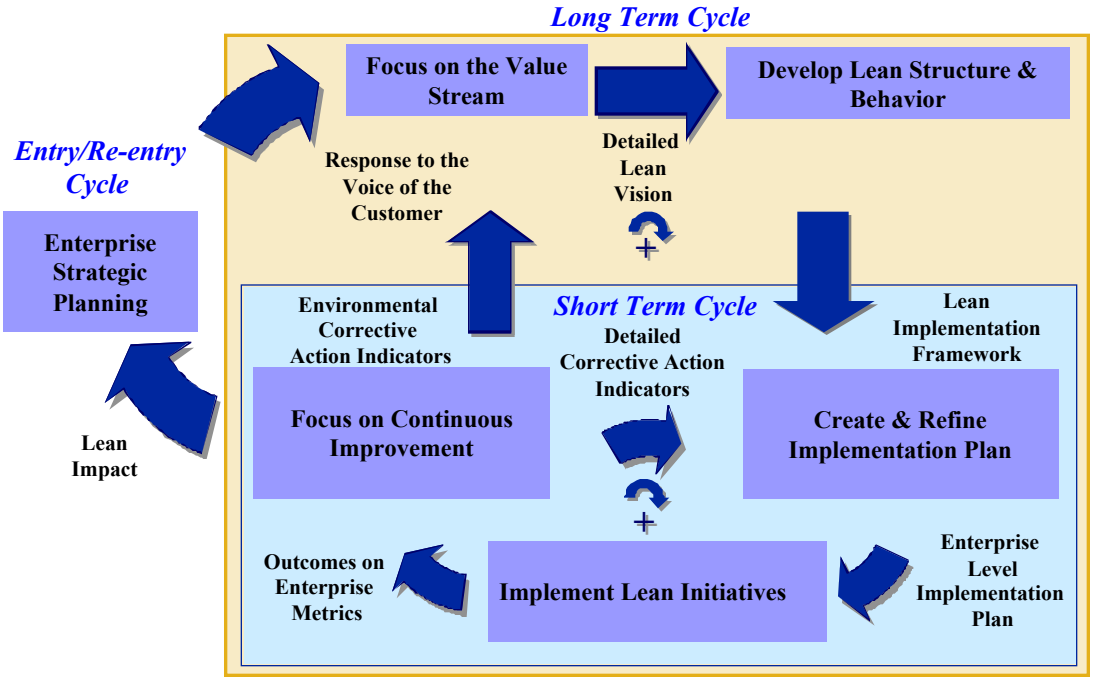
Every company has its own particular starting point and circumstances that will dictate how it approaches its Lean transition. The amount of time and effort required to accomplish the various segments may vary considerably from company to company.

The most formidable obstacles on the road to Lean are likely to be people-related rather than technology-related. In fact, Lean is mostly about people and processes. That is why this Roadmap places great emphasis on preparing the organization for change by focusing on organizational and people issues that need to be addressed prior to launching lower level initiatives.

Eventually, the *Entry* zone of the Roadmap goes away. The ultimate goal is to embed Lean principles, practices and behavior to such an extent that they become "business as usual" (see next diagram.)

Enterprise Level Roadmap

The On-going Lean Enterprise



THE ON-GOING LEAN ENTERPRISE

Once there is a "critical mass" of Lean behavior in the enterprise, Lean becomes a "way of life", the way we do things. This final Roadmap diagram eliminates the segment called "Adopt Lean Paradigm", since this segment has now been accomplished. Lean has become the fundamental, collective mental mindset of the Enterprise. However, it is important that *new* Enterprise leaders and senior managers individually enter the Adopt Lean Paradigm block, so that they understand and enthusiastically embrace the Lean paradigm.

The Roadmap now includes a feedback loop from the Short Term Cycle back to "Enterprise Strategic Planning," now called the Reentry Cycle. This illustrates the important concept of capitalizing on "lessons learned" that are being accumulated in the Enterprise Knowledge Base on an on-going basis, and acknowledging that ultimately the Lean transformation will become an integral part of the Enterprise's success strategy. Also, the significant impact that Lean implementation is now having on total Enterprise performance can be reflected in future strategic opportunities and plans.

Enterprise Strategic Planning and Lean are now linked explicitly to the on-going process of continually fine-tuning the way the Enterprise delivers value to its customers.

REFERENCE MATERIAL

There is a substantial body of material available that explores various elements of the subject of Lean. In the following two sections, we have identified materials that we believe would be most useful to Enterprise Leaders serious about lean transformation. In the first section, we have listed a set of available materials that we consider as essential for anyone wishing to acquire a substantive understanding of the subject of Lean. In the second section, we recommend additional materials that provide greater depth of understanding especially regarding specific facets of lean.

ESSENTIAL READING

Kochan, T., R. Lansbury, and J. MacDuffie, *After Lean Production* (Ithaca: ILR Press, 1997)

Kotter, J., *Leading Change* (Boston: Harvard Business School Press, 1996)

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