Supply and Operations Management Collection

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Leading and Managing Lean

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Abstract

Lean is a comprehensive, integral system consisting of four interdependent elements: leadership, culture, team, and practices and tools. This book examines these elements following a systematic, hierarchical orientation and explains their relevance for guiding lean initiatives. This book follows a framework beginning with the identification and establishment of strategic goals, followed with strategy development, and lastly tactical choices. This model framework is cognizant of a firm's relative internal strengths and weaknesses as well as external opportunities and threats. Each of the four integral lean system elements is explored in depth. The model framework offers a path to develop lean leaders with practical, actionable ideas suited for applications in all industries. Throughout the book, the evolution of the current body of lean knowledge is examined as well as lean's complementary initiative, Total Quality Management. A perspective which views lean as a customer-driven philosophy for organization-wide continuous improvement and waste elimination is maintained throughout the book. This second edition builds upon the first edition with additional lean content focused on technology, supply chain management, flexibility and agility constructs, and accounting. This offering is different from other lean books in three fundamental ways. First, it pursues a comprehensive lean model based on a sound framework. Second, it examines evolutionary lean timeline contributions. Third, it explores topics where future lean contributions will be found.

Keywords

agility, kaizen, lean, lean accounting, lean culture, lean history, lean leadership, lean supply chain management, lean system, lean team, lean tools, sustainability, total quality management, Toyota production system

Contents

Preface

Over the past two decades lean practices have evolved considerably. The focus of early lean practices in the 1980s was the elimination of non-value-added activities and resources. More recently, there has been recognition of the significant role people play in achieving lean objectives. Numerous forces, including a large number of global competitors and greater access to global markets; an increasing pace of knowledge, information, and technological advances; seemingly ever shortening product life cycles; as well the recent and continuing global financial hardships have placed a premium on lean practices.

This book promotes a framework of four necessary and interrelated lean system elements: leadership, culture, teamwork, as well as more familiar practices and tools that contribute to the attainment of lean objectives. Over the past 35 years there have been numerous articles and books written about lean by practitioners and academicians alike. Each of these focuses on a small subset of lean such as kaizen, practices, organizational culture, or lean tools. These articles and books examine lean in a variety of environments including manufacturing, service, administrative, health care, education, and others. Yet, none recognizes the importance of a systematic approach to lean and the significant contributions people must make to achieve lean objectives.

This book draws upon my 30 years of working with practitioners and academicians. It incorporates best practices learned from industry applications and theoretical writings. I have drawn much from my own experiences, as well as from authors of numerous disciplines who have shared their experiences. The intent is to offer a comprehensive explanation for all the necessary components of a lean system.

This book presents an organized approach to explaining the elements of a comprehensive lean system. The intended audience is wide, including practitioners in all fields as well as students in academia. Everyone should view himself or herself as a student with this book offering something to reflect upon.

Chapter 1 presents an explanation of the integral lean system elements, the phases that organizations typically go through in lean implementations, and offers a brief tracing of lean historical development. Chapters 2 through 5 each examine one of the respective lean system components, beginning with the most important, lean leadership, followed successively by lean culture, lean team, and then lean practices and tools. Chapter 6 examines total quality management, which is inseparable from any lean implementation. Chapters 7 through 10 examine content that is particularly relevant to the entire body of lean knowledge. Chapter 7 explores how technology is being applied to further the objectives of lean efforts. This exploration considers a variety of industries with numerous example applications and supporting data that demonstrates the benefits of technology. Chapter 8 takes an in-depth look at the application of lean concepts and practices and how these are being extended across the entire supply or value chain. This includes the three common supply chain elements of procurement, transformation, and distribution or logistics. Chapter 9 examines the management philosophies, constructs, or paradigms of "flexibility," "agility," and "lean." Taken as a whole, the preponderance of the research for the three constructs suggests that there are differences among them, yet there exists confusion and inconsistency associated with their use, which leads to difficulty in differentiating among them. Finally, Chapter 10 introduces an emerging concept, lean accounting. This chapter focuses on identifying various metrics that lean practitioners use to assess the firm's performance and on the accounting practices that underlie the determination of some of these metrics. The content of this chapter is not to suggest a better means of accounting, but rather to identify potential shortcomings of current accounting practices, which may lead to future improvement efforts.

It is the intent of this book to offer a fairly current and comprehensive examination of the current state of lean knowledge. A comprehensive lean model based on a sound framework is offered. A historical timeline of significant lean contributions is identified. The book ends with an extension of lean with a glimpse into its future. This book can serve as a core lean reference book if its intent is achieved.

I want to thank many people who have contributed to the development of this book. First, the Pawley Lean Institute at Oakland University

should be noted for offering me an additional incentive to pursue this undertaking. Its founder, Dennis Pawley, has made significant contributions to promoting an enhanced understanding of lean. Second, although too many to mention, I want to thank the numerous practitioners and academicians who have contributed to my current understanding of lean. Most important to me, however, is my family. Without their support, this book would not exist. To my wife Cindy and children Courtney, Robbie, and Charlie, I love you all.

Gene Fliedner

CHAPTER 1
Introduction

The underlying concept of *lean management* is a customer-driven philosophy for organizationwide continuous or ongoing improvement and waste elimination. Improvement and waste elimination efforts have often been referred to as *kaizen*. Kaizen roughly translates as good (*zen*) change (*kai*). Kaizen is a learning approach based largely on evaluating past experiences through questioning and observation. Following a lean management philosophy, all activities should eventually lead to enhancing customer value. If an activity does not enhance customer value, the activity should be eliminated.

Whether the setting is manufacturing, service, administration, health care, education, politics, or something else, it must be understood that lean management must possess a systems perspective. A survey of practitioners suggested that the single most important lean skill, knowledge, or expertise item is the possession of a systems view and thinking.[1] Over many years, this result has maintained its consistency in conversations with practitioners. Companies that have implemented successful lean programs have commonly taken into account the entire enterprise, ranging from suppliers to customers and everything in between.[2]

Lean must be viewed as a comprehensive system consisting of leadership, culture, team, and practices and tools. A *system* is simply a set of integrated parts sharing a clearly defined goal. In a system, if changes are made to optimal values for only a few elements, the system will not likely come close to achieving all the benefits that are available through a fully coordinated move and may even have negative payoffs.[3] A firm must implement lean as part of a systematic and comprehensive transformation of production and operation procedures. If only a select few of the system elements reach optimal levels, then the full benefits of change might be diminished.

Lean management must be viewed as an integral system of four, *interdependent* elements: leadership, culture, team, and practices and tools. Each of these necessary components affects the effectiveness of the other components. For example, lean leaders must be able to rely upon a supportive organizational culture. Lean leaders are responsible for creating that culture. In order for a transformation process to produce and to eliminate waste, it takes an immediate response from every functional discipline, accounting, finance, purchasing, and so on, when opportunities or issues arise. It takes a coordinated effort of a team to achieve goals. Respect for team, people, and their ideas for improvement are a necessary component of lean management.

In the survey of practitioners, the second-most important ranking lean system element was "human relations skills," which was identified as consisting of leadership, change management, and team problem solving.[4] This was followed by real-world knowledge and experiences, lean culture, and then lean practices and tools among many others.

The remainder of this chapter explores lean management and its historical development. First, a phased approach to effective lean management is described. This is followed with a brief exploration of the four lean elements. These four integral elements are explored in more depth in Chapters 2 through 5. The chapter ends with a historical exploration of lean and some of the most significant contributions to the lean body of knowledge.

Lean Management Phases

Effective lean management possesses a systematic, disciplined, as well as a hierarchical orientation. Lean management consists of planning phases, which first establish goals (or objectives), followed by strategies, and then tactics in chronological order. Long-term goals must be established first as these give guidance for strategic choices. Strategies are the means for achieving the goals. Strategic choices have a long-term (longer than one year) duration, involve significant risks (strategic, financial, compliance or regulatory, reputational, safety, and others), and are guided in their development by higher-level management, but in a participatory manner, which includes lower management. In turn, tactics or operational choices possess a shorter-term (less than one year) duration, involve less risk as these decisions may be revisited (e.g., a decision regarding the extent of inventory for an item may be reconsidered next week or month), and are often guided primarily by a lower level of management.

Long-term goals and strategies must recognize the company's relative competitive strengths and determine how these can be used to create a sustainable advantage.[5] Therefore, prior to establishing the goals and strategies of an organization, a formal SWOT (**S**trengths, **W**eaknesses, **O**pportunities, and **T**hreats) analysis should be performed. An organization should be aware of its strengths, weaknesses, opportunities, and threats. This knowledge makes it more likely that organization members will understand the factors that are likely to impact future performance. This SWOT analysis is simply an organizationwide *current state* analysis.

Although it represents a complex undertaking, there is a simple reason a SWOT analysis is desirable. Charting a course of improvement requires change; it is the pursuit of an ideal state from the baseline current state. A SWOT analysis is similar to taking stock. It is a broad assessment of an organization's current state, which will offer credible arguments for the necessity for change. Before being able to address a future state, a gap analysis between the current and future states must be conducted. Knowledge of the current state allows it.

The "strengths" of a SWOT analysis refer to *internal* capabilities that are performed well. These should be identified because one wants to leverage these capabilities. Consider, for example, how one company's products compare with a competitor's products. "Weaknesses" refer to *internal* characteristics that deter a company from performing well. These too should be identified because they should be addressed. Consider, for example, the possibility that one company uses technology inferior to a competitor's technology. Either additional resources should be allocated to strengthen the weakness or the activity should be eliminated in some fashion if it is an unnecessary, non-value-adding activity. "Opportunities" refer to *external* trends, forces, events, ideas, or possibilities that a company may capitalize on. These should be identified so that an organization can prioritize how and when they will be addressed. As an example, consider the possible opportunity to offer services surrounding an existing product line. "Threats" refer to *external* potential events, trends, or forces typically beyond a firm's control. Threats should energize an organization into action in order to mitigate their influence. As an example, consider the prospects of rising costs such as health care or educational costs. There are approaches, which may be taken to mitigate these expenses such as group insurance programs or educational savings accounts.

Conducting a SWOT analysis is not an onetime event. An organization should continually keep abreast of its current state. Therefore, a SWOT analysis should be conducted as part of an ongoing activity. It should be performed in order to assist a gap analysis between the current and future states and prior to establishing objectives. It must also be objective, so internal and external organizational stakeholders should provide input.

Once the current state is well understood, transformation process goals should then be considered. There should be six goals for every transformation process: (a) lower cost, (b) higher quality, (c) greater speed, (d) improved employee safety, development, and morale, (e) improved flexibility, and (f) enhanced sustainability. In a world of global competition, consumers differentiate among competitors along these six goals of a transformation process.

The first three of these goals are easily agreed to and understood. All things being equal, achieving a lower cost of production, a higher level of system output quality, or a faster order response time each affords a competitive advantage. The fourth goal of improved employee safety, development, and morale represents a moral obligation of management to provide a safe working environment for all employees. Most agree the most important asset of any firm is its employees. Effective lean leaders should invest in this asset.

Less well understood and more recent is the fifth goal of flexibility. *Flexibility* refers to the quick adaptation to changing customer and market requirements. Flexibility has different dimensions, including volume, product, and process. *Volume flexibility* is the ability to operate profitably at varying output levels. Lean often seeks simple, inexpensive solutions. For example, manual operations are often preferred over automation because they often possess characteristics of being simpler, less expensive, and being more readily adapted. *Product flexibility* refers to the ability of a transformation process to introduce new products or services quickly. *Process flexibility* refers to an ability to produce a wide variety of existing products or services. Manual processes typically offer less adoption resistance as well as faster adaptation speed and therefore enhance both product and process flexibility.

The sixth and most recent goal is *sustainability*. It addresses how processes and operations can last longer and have less impact on ecological systems. It is the conservation of resources, natural or otherwise, through sustainable activities and processes across a value chain. Sustainability has economic, social, and environmental components. It is an emerging frontier of lean and extends lean principles externally across a value chain.

Although each of these objectives should be pursued, they are not necessarily equally important. For example, a consumer's budget may not allow him or her to consider quality to a greater extent than cost when purchasing a vehicle. It should be evident that these objectives are interdependent. Namely, lowering cost may impact quality through altered material specifications if allowed.

Achieving these goals will help to promote the long-term viability of the organization. Lean management pursues improvement in these goals endlessly. Before an organization embarks on its lean journey, everyone in the organization must understand why these objectives are essential. The saying, "You can lead a horse to water, but you can't make it drink" comes to mind. The message must convey the essential need for a voluntary pursuit of these six goals. In order for lean to be successful, the most important asset of an organization, its people, must agree with it. This is another fundamental reason why the leadership is so important. It is the leaders of the system who must convey the message and create the conditions so that it is understood, agreed to, and aligns the efforts of all.

Lean Management Components

Lean must be viewed as a comprehensive system consisting of leadership, culture, team, and practices and tools. These four key elements, shown in Figure 1.1, are similarly interdependent. Each of these elements impacts the others, but it must be clear, leadership is the keystone. A fundamental principle of any system comprising multiple elements is that if changes are made to only a few select elements at a time, even to their optimal values, system performance may not come close to achieving all the benefits that

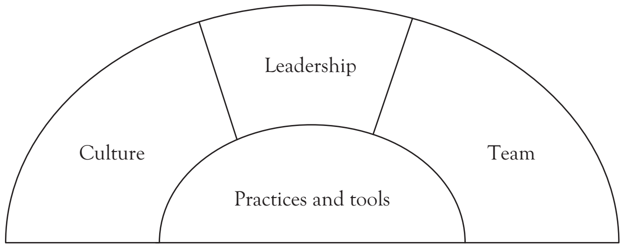


Figure 1.1 Lean management components

are available through a fully coordinated or centralized move.[6] In fact, it may even have a negative payoff, which underscores the argument of leadership's paramount importance.

Further evidence of the importance of leadership is offered by the observation that the failure of most lean initiatives can be attributed to a failure to change leadership practices.[7] Lean leadership establishes the culture or environment necessary to achieve the improvement and waste elimination. Lean leadership identifies, develops, and promotes the team required to achieve the multidisciplinary objectives of lean initiatives. It is lean leadership that is ultimately responsible for the practices and tools that are used in the discovery processes leading to improvement and waste elimination. Leadership is paramount for lean initiatives.

Leadership is commonly viewed as interpersonal influence, exercised in situations and directed through the communication process, toward the attainment of a specified goal or goals.[8] It is often regarded as the single most critical factor in the success or failure of institutions.[9] Leading entails aligning the efforts of resources to bring about improvement through change. Continuous improvement is typically achieved through small incremental change. Less often is improvement achieved through abrupt innovation. Lean leadership is explored in Chapter 2.

Leaders must create the environment that stimulates change. Organizational culture refers to workplace environment, which consists of values, beliefs, attitudes, practices, behaviors, norms, and habits. It is the principled atmosphere of the system. Culture develops from behaviors that leaders reinforce. Organizational culture can either promote or hinder change. Lean culture is explored in Chapter 3.

The third system component is lean team. This refers to a team-based approach, which promotes system goals. A team-based approach recognizes that group outcomes may be enhanced more so than any individuals could achieve acting independently. Lean team is explored in Chapter 4.

The final lean system element is various practices and tools. Lean practices and tools can help to reduce variation and eliminate waste as well as serve as a microscope for identifying improvement opportunities. Lean practices are planning approaches used throughout the transformation process. Lean tools are specific analytical methods and problem-solving approaches. Some of the more common practices and tools are examined in Chapter 5.

Lean Development

A driving force behind the historical development of lean has been globalized commerce. Globalization of commerce has reduced producers' control over prices. The intensification of competitive forces due in part to a larger, more global business environment has limited the ability of companies to mark up prices based on input cost increases. Information access has provided consumers knowledge, shifting leverage away from individual firms that no longer possess the pricing power they once enjoyed. Cost control, rather than pricing power, has become a significant driving force behind corporate profit margins and earnings growth.

Businesses must increasingly rely upon the simultaneous achievement of competitive advantages. Cost cutting alone no longer suffices. Rather, speed, waste elimination, productivity improvements, quality, and flexibility enhancements simultaneously serve as strategic means to achieve profit objectives. Lean management methods address these advantages and do work.[10]

It should be recognized that the lean body of knowledge has evolved considerably over the past several decades. It is not surprising how the challenging financial circumstances in the mid-1950s led Kiichiro Toyoda, Taiichi Ohno, Shigeo Shingo, and others at Toyota to pioneer the frequently cited seven lean principles shown in Table 1.1.[11] The term *lean* itself was originally suggested in 1988.[12] Since the 1980s, lean has

Table 1.1 The seven lean principles

1. Eliminate waste of overproduction
2. Eliminate waste of time on hand (waiting)
3. Eliminate waste in transportation
4. Eliminate waste of processing itself
5. Eliminate waste of stock on hand (inventory)
6. Eliminate waste of movement
7. Eliminate waste of making defective products

been a prominent business strategy gaining popularity with the comparative performance examination of global automotive plants.[13]

Although it may seem that lean is a relatively recent development, many ideas have simply been redeveloped throughout history. Most of the earliest contributions focused on lean practices and tools. One must actually go back to the origins of recorded history to identify the possible origin of the first practice that comprises today's lean body of knowledge. For example, the Egyptians used an assembly line (flow) practice and divided labor to enhance productivity and speed in the building of the pyramids.[14] It is estimated that as early as 1104, the Venetian Arsenal utilized a vertically integrated flow process consisting of dedicated workstations to assemble standardized parts into galley ships. The practice of a vertically integrated flow approach combined with standardized parts enhanced productivity in ship assembly.

The field of ergonomics contributes to important lean practices. The foundation of ergonomics appears to have emerged in ancient Greece. Evidence indicates that the Hellenic civilization in the fifth century BC used ergonomic principles in the design of their tools, jobs, and workplaces.[15]

In the late 1700s and throughout the 1800s there were a number of individuals who advanced lean practices with significant advancements in the management of processes. In 1776, Adam Smith published *The Wealth of Nations* in which he advocated that the division of labor provides managers with the greatest opportunity for increased productivity. In approximately 1778, Honoré Blanc is attributed with first introducing interchangeable parts for firearms.[16] In the United States, Eli Whitney introduced interchangeable parts in approximately 1798. Interchangeable parts must be seen as a major breakthrough as it is a precursor to the assembly line in the Industrial Revolution.

The existing railway infrastructure in the American Midwest during the 1870s has been attributed with influencing the industrial meatpacking to develop mass production disassembly technologies. This model was later followed encouraging industrialists in other industries to develop the moving assembly line, including Henry Ford.[17]

During the scientific management era of the late 1890s and early 1900s, several industrial engineers such as Frederick Taylor and Frank and Lillian Gilbreth contributed practices such as standardized work, time and motion studies, and process charting.[18] Starting in about 1910 through the 1920s, Henry Ford extended these practices by marrying interchangeable parts with standard work and moving conveyance as well as incorporating vertical integration and behavioral concepts such as worker motivation in order to design a more comprehensive lean system.[19]

Only during the middle and later 1900s came the contributions of some of the recognized founders of the Toyota Production System. Toyota expanded upon Henry Ford's ideas by including elements such as quality at the source, which encouraged workers to be more responsible for producing quality vehicles and teamwork.[20] It was not until the mid-1800s and later that the lean leadership and motivational contributions were first made. More recent contributions to the lean body of knowledge have focused on lean culture and lean team contributions.

Summary

This chapter has offered significant points to be remembered for the rest of the manuscript. The key points include the following:

1. The underlying concept of *lean management* is a customer-driven philosophy for organizationwide continuous or ongoing improvement and waste elimination.
2. Lean is applicable in all types of environments.

3. Regardless of the environment, lean management possesses a holistic systems perspective consisting of leadership, culture, team, and practices and tools.
4. The effectiveness of the four lean management components is interdependent.
5. Lean management consists of three, chronological planning phases: goals identification, strategy development, and tactical choices.
6. Contributions to the lean management body of knowledge date back many years, well beyond the contributions of Henry Ford and various individuals at Toyota.

The remainder of this book examines each of the four integral elements of lean management. Chapter 2 begins with the most important lean management component, lean leadership. Chapter 3 looks at lean culture. This is followed by a discussion of lean team in Chapter 4. Chapter 5 presents common lean practices and tools that are used to identify improvement opportunities and eliminate waste. Lean's inseparable companion, total quality management is examined in Chapter 6. Chapters 7 through 10 examine content that is particularly relevant to the entire body of lean knowledge. Chapter 7 explores how technology is being applied to further the objectives of lean efforts. This exploration considers a variety of industries with numerous example applications and supporting data that demonstrates the benefits of technology. Chapter 8 takes an in-depth look at the application of lean concepts and practices and how these are being extended across the entire supply or value chain. This includes the three common supply chain elements of procurement, transformation, and distribution or logistics. Chapter 9 examines the management philosophies, constructs, or paradigms of "flexibility," "agility," and "lean." Taken as a whole, the preponderance of the research for the three constructs suggests there are differences among them; yet there exists confusion and inconsistency associated with their use, which leads to difficulty differentiating among them. Finally, Chapter 10 introduces an emerging accounting concept, lean accounting. This chapter focuses on identifying various metrics lean practitioners use to assess firm performance and on the accounting practices that underlie the determination of some of these metrics. The content of this chapter is not to suggest a better means of accounting but rather to identify potential shortcomings of current accounting practices, which may lead to future improvement efforts.

It is the intent of this book to offer a fairly current and comprehensive examination of the current state of lean knowledge. A comprehensive lean model based on a sound framework is offered. A historical timeline of significant lean contributions is identified. The book ends with an extension of lean with a glimpse into its future. This book can serve as a core lean reference book if its intent is achieved.

CHAPTER 2

Lean Leadership

Leadership commonly brings to mind an image of a powerful person positioned at the top of a hierarchical structure directing and controlling the activities of subordinates toward the achievement of enterprise goals. However, this is a shortsighted view of the nature and significance of leadership. Today, the importance of leadership is derived in part due to environmental characteristics, which include global competition, technological advances, evolving governmental regulations, and changing worker attitudes, among many. For example, cultural differences found in today's global marketplace may act as a significant barrier to international commerce. These environmental characteristics place a greater premium on leadership than ever before.

Leadership has been defined in many ways. Today, more than 200 distinct definitions for it have been offered.[1] However it is defined, it is commonly viewed as interpersonal influence, exercised in situations and directed through the communication process, toward the attainment of a specified goal or goals.[2]

Leadership is often regarded as the single most critical factor in the success or failure of institutions.[3] This is true in part due to the transient nature of teams within organizations. Whenever there is a change in team composition, the developmental forming stage of the team development begins anew.[4] As noted earlier, lean management consists of four integral elements: leadership, culture, team, and practices and tools. Each of these elements is integral and necessary for any lean initiative. However, it must be clearly noted that leadership is the keystone. Leadership creates the culture. Leadership identifies and develops the team. Leadership also employs the practices and encourages the tools. As noted by Dennis Pawley, "Without leadership, lean will never get off the ground."[5]

This chapter explores the nature of leadership, examining key elements of exceptional leadership. The difference between leading and managing is explained. Historical leadership theories are briefly explored. These offer insights into how a leader can shape outcomes under various circumstances. By themselves, leadership theories are insufficient for explaining subordinate behaviors, so various seminal theories of motivation are explored for greater insight. This is followed by a brief exploration of conflict, as effective leaders must be able to defuse conflict often. A brief exploration of leader gender follows. This is included in the discussion for no other means than as an attempt to spark reflection about one's own leadership strengths and weaknesses. A list of critical leadership skills, traits, and behaviors essential for effective leaders is then suggested. Although this is not meant to be an exhaustive list, it may be used as a start. The chapter concludes by observing several poor leadership behaviors.

Regardless of the specific definition, key elements of leadership emerge from all the alternative definitions. Among these key elements are the following themes: (a) one's personality, (b) exercising influence over group processes, shaping and framing reality of others, or a willingness of subordinates to comply, (c) a form of persuasion, (d) a set of behaviors, (e) a dominant–submissive or power relationship, (f) the effect of interactions, (g) initiation of job structure, (h) consideration for subordinates, (i) a willingness to learn, and (j) most importantly, leadership is a means to achieve goals by *effecting change*, which leads to improvement.

Two points should be clear concerning leadership. First, leading entails aligning the efforts of resources. This may seem to be an insurmountable challenge in organizationally and politically complex environments. When a process crosses functional boundaries, utilizes shared functional resources, comingles functional budget items, or utilizes varying metrics between functions, attaining agreement is challenging. Aligning efforts amounts to creating the conditions so that all of the horses are willing to pull the cart in mostly the same direction. This necessitates communicating the vision by words and *actions* so subordinates understand and pursue *shared* goals. This means energizing people and inspiring them to overcome political, bureaucratic, resource, financial, performance metric, or other barriers and moving people toward the ideal state.[6] Leaders must be committed, engaged, and *involved*. All too often, strategic initiatives get assigned to one particular functional group and outcomes become its responsibility. For example, there is an engineering department responsible for design and development, there is a quality department to assure quality, and there is a human resources department for training. These should be *shared responsibilities* since everyone in the organization has a vested interest in achieving organizational outcomes.

Second, there is an important distinction between leading and managing. Managing is primarily concerned with consistently producing results stakeholders expect. This is sometimes referred to as *stability*.[7] Managing includes regular activities such as goal setting, strategic and operational planning, budgeting, organizing, staffing, directing, controlling, and problem solving. These regular activities are aimed at maintaining the current reality.

Conversely, leading also entails *improvement achieved through change*. The term *kaizen* is often referred to as improvement activities. Kaizen roughly translates as good (*zen*) change (*kai*). Leading involves establishing the direction of improvement, which requires developing the vision and choosing competing strategies for achieving the results or producing the changes needed. Leading refers to guiding improvement activities and establishing an organization's purpose, which changes over time. Leaders will find instilling change to be painful. Change necessitates learning and adaptation. Many people inherently resist change because it is disruptive, intrusive, and it upsets the balance of stability.[8] However difficult, centrally directed change may be important for altering and improving systems.

Change must be a fundamental, daily process requiring 100 percent participation all of the time, as organizations must be able to perform better tomorrow than they did today. Namely, improvement is everyone's responsibility and it begins with leadership. There is an old idiom that states, "You can't teach an old dog new tricks." If you believe this, then any initiative is likely to fail. Improvement itself necessitates doing things differently. Lean requires leaders create a learning organization capable of adaptation. The best way to achieve this is to recognize four important characteristics of change. First, everyone has the ability to learn. Learning simply means modifying behaviors. Leaders must accept the stewardship and responsibility for transformation and must personally demonstrate a desire to learn and improve. This requires they be deeply committed to change and that they participate in the improvement process. And, after learning a lesson, leaders must then become teachers and share the lesson with others. This fosters an environment for continuous improvement and quick adaptation. Leaders must create the environment that stimulates change by example.

Second, team members must see their workplace as a laboratory for experimentation and learning. Leaders must convey an understanding of the importance for making change. Given the right incentive, everyone has the ability to learn new tricks. Making change is critical to the long-term success of an organization.

Third, change is encouraged with a clear understanding of an organization's current state, its ideal state, and the disparity between them. However, achieving change based upon a perceived gap between the current and ideal states overly simplifies the likelihood of success. The social and organizational processes operating within an enterprise typically bring about slow, time-consuming change and make success difficult at best. Furthermore, change most commonly occurs through small, incremental alterations. Infrequently does change comes about through abrupt innovation. This makes it difficult to achieve sustainable momentum.

Fourth, the existing culture within an organization, interpersonal relationships, problem complexities, and metrics used to measure performance all have profound impacts on change and leadership choices. Nevertheless, lean leadership builds upon traditional leadership theories and includes additional skills of (a) teaching, (b) creating a source of energy that encourages employees to pursue stretch objectives, (c) eliminating fear that discourages the risk-taking associated with experimentation, action, and new thinking, (d) leading through participation, and (e) imbedding lean within one's own personal practices.[9]

As noted earlier, lean management consists of four integral elements: leadership, culture, team, and practices and tools. Although each is necessary, *the keystone is leadership.* A good starting point to better understand leadership is to examine some traditional leadership theories. Each of these theories offers salient ideas and valuable leadership lessons, both positive and negative.

Traditional Leadership Theories

Many leadership theories or models have been offered over the past century. These differ in the themes such as qualities that distinguish leaders from followers (subordinates), situational or environmental factors, skill levels, and other factors. The leadership theories that have emerged have been classified into one of eight broad types or groups. Roughly, in chronological order, these theories are (a) Great Man Theory, (b) Participative Theory, (c) Behavioral Theory, (d) Contingency Theory, (e) Trait Theory, (f) Situational Theory, (g) Transactional Theory, and (h) the most recent Transformational Theory. It is worthwhile to briefly examine each of these theory groups because each offers some valuable insight into the leadership function. Each of these is briefly described in the following text.

The *Great Man Theory* emerged in approximately the mid-1800s.[10] The theory group got its name because it is thought to be largely a male quality. This theory assumes that the capacity for leadership is *inherent*, that is, leaders are born with it. This theory portrays a preeminent person as heroic and mythic who uses his personal charisma, intelligence, wisdom, or cunning to command and enthuse followers to act toward achieving a goal. The examples of leaders cited are typically military leaders who rose when needed in a crisis situation such as a war. Subordinates often follow out of respect for the leader or out of fear of the consequences for not following directives. In these situations, followers tend to look for courage from others. Subordinates must be willing to surrender the power for another to shape and define their reality because of perceived need. However, this theory group does not account for the ability to learn to become an inspirational leader. Nor does it explain female leaders such as Joan of Arc, Indira Gandhi, Mother Teresa, Susan B. Anthony, Golda Meir, and many others. Nevertheless, there will be situations when followers tend to look for courage from others.

The second theory group, *Participative Theory* emerged in approximately 1939.[11] This theory group suggests that the ideal leadership style engages subordinates, but the decision to implement any of their suggestions lies with upper management. Namely, it rests on the concept of *participative management* and *delegation*. Allowing subordinates to participate in the managerial decision-making process has been credited with an ability to raise motivation, increase readiness to accept change, improve decision quality, develop teamwork, improve morale, and further individuals' managerial development. People have an inherent need to control, to some extent, processes in which they must be engaged. However, participative management can be time-consuming, and delegation is not a way of passing responsibility. Leaders should decide on their role prior to engaging the subordinate group. Additionally, leaders should articulate the extent of their involvement in any group decision-making process as well as indicating explicitly or implicitly the extent of the authority they are asking subordinates to assume in the decision-making process.

The third theory group, *Behavioral Theory* emerged in approximately 1957.[12] It is based upon the belief that great leaders are made, not born. Namely, this theory group suggests that people *learn*, or alter their behavior, to become leaders through teaching and observation. Therefore, this theory focuses on leader actions, not mental qualities or internal states. Specifically, this theory group suggests that leadership is not a natural or inherent quality. Most readers will probably agree that leadership may be attributable to both natural acumen and learning.

The fourth theory group, *Contingency Theory* emerged in approximately 1964.[13] This theory group focuses on particular variables related to the environment, which might dictate a particular leadership style at a moment. These environmental variables are often referred to as *contingent variables* or *situational factors*. This theory group recognizes that no one leadership style (e.g., authoritarian or participative) is always the best. Rather, it suggests that success depends upon contingent variables such as leadership style, qualities of subordinates, aspects of the situation such as time pressure, the strategic importance of the decision, group effectiveness, and others. Clearly, many variables impact leadership success, including internal and external organizational factors.

The fifth theory group, *Trait Theory* emerged in approximately 1968.[14] This theory group assumes people inherit personalities or behavioral characteristics that make them better suited to be leaders. This theory group suggests five generally agreed-upon personality traits inherent within leaders.[15] These five groups have been identified as (a) surgency or one's dominance or self-confidence, (b) openness to new experiences or one's imagination, intellectual curiosity, or willingness to experiment, (c) conscientiousness or one's commitment to details and discipline, (d) agreeableness or one's spirit of cooperation or need for social harmony, and (e) emotional stability or one's ability to remain even-tempered, calm, and less reactive to stress. These personalities or behavioral characteristics contribute by offering a more complete explanation of leadership success.

However, an issue with this theory group is explaining people who are not leaders who have these qualities.

The sixth theory group, *Situational Theory* emerged in approximately 1971.[16] The theory group proposes that different leadership styles may be more appropriate for certain types of decision-making circumstances, and leaders should choose the best course of action based upon situational variables. This group introduces situational variables such as a subordinate's competence. For example, low competence or low commitment suggests leaders pursue a directive style. Again, this theory group contributes by offering a more complete understanding of leadership success.

The seventh theory group, Management or *Transactional Theory* emerged in approximately 1975.[17] This theory group portrays leaders acting largely in a consultative style of decision making. It focuses on leaders and how they maintain their position through a series of tacit exchange agreements or *transactions* with subordinates. Namely, this group portrays leaders obtaining the efforts of subordinates in exchange for rewards. The role of supervision, organization, and group performance is often examined in this theory group. It frequently portrays an "in-favor group" (an inner circle of trusted colleagues who are given responsibility, decision influence, and access to resources) and "out-of-favor group" (an outer circle of colleagues who are given low levels of choice or influence). In exchange for membership in the "in-favor" group, subordinates are expected to be fully committed, loyal to the leader, and to work harder. In reality, "transactional" leaders may be perceived as selfish and sometimes unethical or immoral using "games" to establish bonds. This can be especially true in larger organizations where it would be more difficult to maintain valuable bonds with all employees through responsibility, decision influence, and access to resources.

The eighth and most recent theory group is *Relationship* or *Transformational Theory* (it has also been referred to as *Charismatic Leadership*). It emerged in approximately 1978.[18] This theory group focuses upon the connections formed between leaders and subordinates. Whereas "transactional" leaders are typically viewed as leading minor changes to existing organization goals, "transformational" leaders are perceived as instilling a fundamental and significant shift in goals, culture, or organizational structure. The idea proposed is that leaders motivate and inspire followers to pursue significant change by creating an awareness of the task importance, encouraging followers to focus on team or organization goals rather than self-interests, and assisting subordinates fulfill their potential. In contrast to transactional leaders, transformational leaders are often perceived as highly skilled, moral, ethical, and inspiring. This theory group contributes by offering a more complete understanding of leadership success, but by itself, it is not complete because it does not explain why companies led by transformational leaders have still failed.

With an abundance of theories attempting to explain leadership, which theory is right? There are salient points offered by each of these theory groups. Knowledge of each leadership style can prove beneficial for achieving organizational goals. What is missing from each leadership theory is the recognition of a holistic, systems perspective. There are many actors and numerous intervening variables both internal and external to an organization, which must be recognized by a leadership style choice. Knowing which leadership style is appropriate at any time is difficult at best because of the intervening variables or influencing factors. Although not an exhaustive list, some of the internal organizational factors, which influence a leader's success include (a) the leader's internal forces, (b) the culture of the organization itself, (c) position power of the leader, (d) group effectiveness, (e) time pressures, (f) the significance of the problem itself, and (g) subordinates' internal forces. Clearly, there are many external organizational factors beyond one's control such as economic considerations, political concerns, competitive factors, and so on. The internal organizational factors, which influence success, are discussed in the following text.

Examples of a leader's internal forces include the leader's personality; background, knowledge, and experiences; inclinations to issuing directives versus allowing participation; the leader's value system for allowing subordinates to participate in the decision-making process; confidence in subordinates; and the leader's feelings of security, knowing delegation leads to uncertain outcomes. Simply put, people are different. As a result, what works best for one person may not work well for another person.

The culture of the organization impacts a leader's success. Culture is a collection of behavioral norms, practices, beliefs, and so on, that represent the way a system functions. Culture impacts leadership style and success. Although this is discussed more fully in the subsequent chapter, examples of cultural elements include expectations regarding behavioral formalities; organizational bureaucracy and hierarchies; a desire to maintain discipline; a desire to foster entrepreneurship; a discipline to compare execution to objectives and plans; as well as a simple assessment of what was accomplished versus what was intended to be accomplished.

The influencing factor of position power refers to the degree of power and influence the leader has over subordinates. This degree of directive authority is typically issued by the leader's own supervisor. This influencing factor is clearly somewhat dependent upon the subordinates' respect for the leader, fear of the consequences for not following directives, the subordinates' willingness to surrender the power for another to shape and define their reality, or some other reason to submit to a leader's power and influence.

Most people would probably agree that a team-based approach promotes system goals more effectively than does individuals acting independently. Promoting and achieving effective working groups is challenging. It requires a high level of respect and trust, which promotes the potential for effective and efficient team performance to emerge. The consequences of functional teams include greater initiative and team member commitment, higher job satisfaction and morale through a sense of belonging, fewer conflicts, and more successful initiatives. The consequences of dysfunctional teams include lower motivation, frequent conflict and disagreement, greater lack of respect, poor communication, and an increased likelihood for initiative failure.

Pressure to achieve a solution or improvement clearly impacts a leader's success. Often, impending deadlines convey a crisis feeling, which frequently compels leaders to resort to a directive leadership style. The lack of time often does not allow for sharing of information, participation in the decision-making process, or even a simple explanation of decisions.

Sometimes the nature of the problem itself does not allow some leaders to engage subordinates in the decision-making process. Some leaders are uncomfortable surrendering some degree of decision-making authority that occurs in a more participative approach. This typically occurs more often for riskier, strategic decisions than for less risky operational decisions.

There are numerous internal forces acting upon subordinates, which influence a leader's success. These forces should be considered when choosing a leadership style. Examples of subordinates' internal forces include the extent of subordinates' need for independence; the subordinates' tolerance for ambiguity versus following directives; the subordinates' interest and investment in a decision-making problem; the subordinates' understanding and identification with an organization's goals; the subordinates' expectations concerning their decision-making role; the subordinates' degrees of confidence, trust, and respect in their leader; as well as the subordinates' motivation level. Knowledge of these internal factors is clearly ambiguous at best when choosing a style.

As a general observation, there are characteristics correlated with these internal subordinate forces that should reduce the ambiguity when choosing a leadership style. For example, white-collar workers, older and more mature workers, and workers in a higher managerial level typically prefer greater independence, have a greater ability to handle ambiguity or prefer less direction, possess a greater interest in decision-making participation, identify more with the organization's success, and are motivated by factors more varied than economic incentives.

It should be clear there are many factors that influence subordinate motivation. Some of these factors come from within subordinates. However, the leader plays an important role in enhancing the likelihood that subordinates contribute to organizational and team objectives. As there have been many theories offered to explain leadership styles, there are even more theories offered to explain subordinate motivation. It is worthwhile to briefly examine some of these theories as each offers some valuable insight into understanding subordinate behavior and how leaders can properly direct subordinate motivation.

Motivating Subordinates

The many motivation theories differ by the "currency" leaders may use to motivate subordinates. Some of these currencies are characteristically positive ("carrots"), while others are negative ("sticks"). Since positive methods of reinforcement are more favorably received, carrots typically are more effective. Unfortunately, the use of sticks is sometimes chosen such as when time is critical.

In addition to these currencies, motivation theories often differ on whether the motivation is intrinsic or extrinsic in nature. Intrinsic motivation refers to initiating an activity for its own sake because it is interesting and satisfying in itself. Intrinsic motivators refer to attributes of the work itself that drive people to engage and perform, provide energy, as well as create enthusiasm. Examples of intrinsic motivators are the leader's capability or expertise, the respect the work will afford, the challenge and interest of the work goal(s) or the ownership of the work, opportunities the work offers for learning and expanding one's skills, an opportunity to provide value, or the opportunity to work with friends or respected colleagues. It has been observed that challenging work goals that are clear and specific are the single best intrinsic motivators.[19] It is important to understand that intrinsic rewards can have significant monetary value for subordinates. Many of these intrinsic rewards are low cost to firms but can offer high value to employees.

In contrast, extrinsic motivators refer to attributes or motivation sources outside of the work. Examples of extrinsic motivators are promotion possibilities, economic incentives, and the possibility of penalties. Less mature, younger workers often have greater or more immediate financial needs and consequently relate better to economic incentives. Many of these extrinsic rewards can represent significant cost to firms and can be easily misunderstood by employees as something owed rather than an earned reward.

Motivation Theories

Of the earliest motivation frameworks is Maslow's *Hierarchy of Needs*. It suggests that subordinates possess a set of intrinsic needs including physiological needs, safety needs, love and belonging, and self-esteem, which must be met hierarchically prior to one's higher-level self-actualization needs. It is this highest level of self-actualization where a subordinate's full potential may be reached. It is suggested that self-actualization people focus not on themselves, but on the problem at hand. Criticisms of this theory have focused both on the ordered nature of the hierarchy as well as its individualist perspective. Some suggest the order of needs in the hierarchy with a focus on the self at the top may not represent the needs of a group culture. A group culture may promote the benefit of the group prior to the benefit of the self.

Two-Factor Theory proposes both satisfying, motivating job factors as well as dissatisfying, demotivating job factors.[20] This theory suggests these factors operate independently of each other and do not represent a single satisfaction continuum. Examples of satisfying motivators include achievement, recognition, the work challenge, responsibility, promotion, and growth. These act to satisfy higher-level psychological needs. Dissatisfaction results from unfavorable assessments of environmental (hygiene) factors such as pay and benefits, company policy and administration, relationships with co-workers, supervision, status, job security, working conditions, and personal life.

Theories X and Y represent negative and positive views of personnel respectively.[21] Theory X represents a negative view of employees under which management assumes employees are inherently lazy and therefore workers need close supervision, a comprehensive control system, and managerial hierarchies to narrow the span of control. This theory relies heavily upon threat and coercion. Alternatively, Theory Y represents a positive view of employees; management assumes employees may be ambitious, self-motivated, and enjoy their mental and physical work. This theory relies heavily upon open communication, minimizing superior–subordinate status differences, and creating a supportive culture.

Expectancy Theory suggests subordinates follow a voluntary decision-making process in order to maximize the motivational force of the perceived, alternative behavioral consequences.[22] This theory recognizes that metrics or rewards drive behavior. The theory suggests that one's choice is based upon an estimation of the likelihood the outcome will be achieved (expectancy probability), the likelihood the reward will be awarded (instrumentality probability), and the value of the reward to the subordinate (valence). Expectancy probability is based upon one's assessment for successfully completing the task based upon past experiences, self-confidence, and the perceived task difficulty. Instrumentality probability reflects one's perception for receiving the expected reward if performance expectations are achieved. Valence refers to the value one places on the reward. The motivational force is the product of these probabilities.

Control Theory proposes that behavior is never caused by a response to an outside stimulus.[23] Instead, the theory states that behavior is determined by a person's desire to maximize basic needs. Directive leaders use rewards and punishment to coerce subordinates to comply with rules and complete assignments. Alternatively, participative leaders avoid coercion and suggest that the intrinsic rewards of doing the work will satisfy one's needs.

Goal-Setting Theory suggests subordinates have a strong need for success and achievement and therefore are best motivated by challenging but realistic goals.[24] These are sometimes referred to as *stretch* goals. The theory suggests that working toward an achievable goal provides a major source of motivation, which, in turn, improves performance. A clearly articulated and difficult but achievable goal provides greater motivation and better task performance than a vague or easy goal because it represents more of a challenge and accomplishment. In addition, setting impossible goals is possibly more demotivating than setting a goal that is too easy.

Acquired Needs Theory suggests that individuals acquire needs over their life experiences.[25] These needs are classified as achievement, affiliation, and power needs. A person's achievement needs reflect a desire to excel, typically leading to the avoidance of both low- and high-risk opportunities. This theory suggests that a person feeling a great need to achieve should be given challenging tasks. Affiliation needs reflect a desire for environmental harmony and therefore one tends to conform to group norms. People with high-affiliation needs typically perform better in cooperative environments. Power needs are divided between personal and institutional types. Personal power reflects the need for a person to direct others and is therefore often perceived negatively. Institutional power reflects the desire to direct group efforts toward organizational goals and is therefore often perceived positively. In general, power seekers desire the opportunity to direct group efforts.

Positive psychology is seemingly a relatively recent development of the field of psychology, which attempts to offer an optimistic view for people, getting away from the predominant negative bias of traditional psychology. The idea is that positive emotions (e.g., happiness, interest, anticipation) broaden one's awareness and encourage novel, varied, and exploratory thoughts and actions. Over time, this broadened behavioral repertoire builds skills and resources. This is in contrast to negative emotions, which prompt narrow survival-oriented behaviors. In an environment that encourages improvement, experimentation (novel, varied, and exploratory thoughts and actions) should be encouraged. It is easy assume this development has spurred the Transformational Theory of leadership to an extent.

Conflict

In any group setting, conflict is almost always inevitable. Because of this, it is worthwhile to briefly examine the concept of conflict. Conflict may be defined as the behavior of an individual or a group, which impedes or restricts, possibly only temporarily, another party from attaining its desired goals.[26]

Interestingly, to the extent it is beneficial, conflict may be encouraged, even pursued. Conflict may provide positive results. It can lead to creativity and innovation. It can lead to the discovery of better solutions or a better understanding of another person. It may assist professionals with the development of interpersonal problem-solving skills to handle conflict. In turn, these interpersonal problem-solving skills may lead to the ability to develop mutual trust and respect, candid communication, and awareness of the needs of others in relationships. Despite its benefits, conflict must be addressed as it can reduce or eliminate the possibility of achieving project goals.

Conflict becomes dysfunctional if it results in poor decision making, lengthy delays over issues that do not importantly affect the project outcome, or a disintegration of a team's efforts. The key to resolving conflict rests on the leader's ability to transform a "win–lose" situation into a "win–win" situation. To start, it is important for the participants involved in the conflict to understand that conflicts occur between allies, not opponents. Conflict resolution requires collaboration in which the involved parties must rely upon one another; otherwise, mistrust will prevail.

There are various strategies and skills that assist in resolving or even preventing conflicts from occurring. The managerial style itself, such as the choice to allow subordinate participation may reduce the potential of conflict. A leader's ability to listen, demonstrate compassion, generate greater participation, as well as recognizing the value of and rewarding contributions can reduce conflict potential. It is important to understand that professionals have a need to be heard, to demonstrate that their ideas have merit, to be involved, and subsequently to be recognized and rewarded for their efforts.

A leader's honesty and willingness to reveal feelings establishes and promotes credibility. A leader's ability and willingness to admit mistakes or concessions can help to establish credibility. Admissions coming from one's self are not nearly as harmful as when they are exposed by others. Additionally, a leader's prejudices can destroy credibility.

Similarly, a leader should enhance his ability to interpret body language. Bodies can reflect fear, boredom, interest, repulsion, openness, attraction, caring, hatred, and other emotions. The ability to interpret these allows leaders to better understand subordinates needs.

Additional methods useful to possibly prevent conflict include known methods for resolving disagreements, clearly defined ground rules, should disagreements arise, clearly identified expectations regarding acceptable team member behaviors, as well as efforts to build team *esprit de corps* before conflict occurs. However, in the event a conflict arises, there is a useful path for resolving conflicts.

Conflict Resolution

Since both parties have a vested interest in the outcome, the conflict must be defined by those involved and solutions must be generated by those who share the responsibility for assuring that the solution will work satisfactorily. Before a solution can be reached, both parties must realize that collaboration has the potential to resolve the matter in an equitable fashion. The goal must be to solve the problem, not to accommodate different points of view. In order to achieve a solution, the parties involved must be flexible. There should be recognition that both sides of the controversy have potential strengths and weaknesses. This suggests that there must be an effort to understand and accept the other party's viewpoint. Each party must look at conflict from an objective point of view and examine one's own attitudes (hostilities) before interpersonal contact can become effective. Face-saving solutions are important as these allow people to give in so that a change in one's viewpoint is not perceived as being weak or as capitulation. The leader may need to minimize the effects of status differences, defensiveness, prejudices, and other barriers, which may prevent people from working together effectively. Similarly, all parties must be aware of the limitations of arguing and downgrading the other party's position.

Leaders possess various methods of influence or "currencies" as a means of reducing potential conflicts. These are the same intrinsic and extrinsic motivators and include one's expertise, authority, the work challenge, friendship, promotion, salary, as well as various penalties. As noted earlier, these currencies vary in effectiveness.

Prior to any attempt to resolve a conflict, it is important to remember the four points of *principled negotiation*.[27] First, separate the people from the problem. Namely, the leader must have the involved parties define the substantive problem, as emotions and fact get confused. Second, there must be a focus on interests, not positions. Positions tend to exhibit demands, while interests allow for movement in the search for an equitable settlement. Third, the involved parties need to seek solution options for mutual gain. The leader should want to advance the mutual interests of the conflicting parties. Finally, it is important to use objective criteria or standards to determine the quality of an outcome. Use expert opinion, company policy, market value, competitive benchmarks, or some other neutral and objective criterion for decision outcomes.

When conflict does occur, there are five commonly accepted negotiation methods for conflict resolution.[28] The first method is *withdrawal*. This refers to avoiding a disagreement by refraining and retreating from an argument. Withdrawal does not resolve the matter. It only postpones resolution to a later date, so it is more commonly used when the concern of disagreement is minor or when a cooling-off period may offer the possibility to achieve movement at a later time, given high tempers.

A second method is known as *smoothing*, which refers to deemphasizing or playing down differences while emphasizing common interests and subsequently avoiding issues that may cause divisions and hurt feelings. It too does not resolve the matter. Rather, it is often used as a tactic to initiate a solution process and it is sometimes beneficial when conflict members are behaving irrationally due to high tempers.

A third method for resolution is *compromise*. This refers to splitting the difference, bargaining, or searching for an intermediate position. As a result, it is sometimes viewed as though no one loses, but no one wins. It is useful if a win–win solution can be found through compromise, for instance, if both of the conflicting parties can agree to a solution neither had been demanding.

A fourth method, known as *forcing*, refers to a command-and-control approach by the decision maker. It represents a win–lose situation. Using this approach, participants are antagonists. It creates a victor and a vanquished. Although it resolves the issue, it is the most ineffective resolution method. It is difficult to achieve success using this approach, as subordinates may not follow after a solution is imposed.

The fifth method, and preferred resolution method, is *confrontation*. This represents a problem-solving approach through an open and direct exchange of information about a problem or conflict as each participant sees it and working through differences to reach a solution that is equitable to both. An objective approach is sought through a focus on issues, not positions or demands. A win–win solution is sought by keeping the goal foremost in mind.

It is important the leader keep in mind the following 10 solution characteristics, which are necessary for negotiation.

1. All individuals must remember that they have vested interest in the outcome and that collaboration has the potential to resolve the matter in an equitable fashion.
2. There must be recognition that conflict occurs; it must be defined by those in the relationship and solutions must be generated by those who share the responsibility for assuring the solution will work satisfactorily.
3. The goal must be to solve the problem, not to accommodate different points of view.
4. There must be a realization that both sides of the controversy have potential strengths and weaknesses, so all individuals involved must be flexible. Namely, there must be an effort to understand and accept the other individual's argument(s).

5. All individuals must look at conflict from an objective viewpoint, as emotions, attitudes, and hostilities cloud judgment.
6. It is beneficial to understand the effectiveness of the five negotiation methods for conflict resolution.
7. "Face-saving" solutions are important as they allow people to give in so that a change in one's viewpoint is not perceived as being weak or as capitulation.
8. Leaders may need to minimize effects of status differences, defensiveness, prejudices, and other barriers, which prevent people from working together effectively.
9. All individuals must be aware of limitations of arguing.
10. All individuals must be aware of limitations of downgrading the other person's position.

These 10 solution characteristics are essential for achieving settlements that will be perceived to possess a positive outcome to the conflict.

Leader Gender

Emerging research is showing that women executives score higher on a wide variety of leadership measures, from producing high-quality work to goal setting to mentoring employees and others. One survey evaluating 425 high-level executives showed women executives scored higher ratings on 42 of the 52 leadership skills measured.[29] Specific examples of these skills women achieved significantly higher scores on include skills such as motivating others, fostering communication, listening to others, teamwork, and partnering.

Some suggest that women think decisions through better than men, are more collaborative, and seek less glory. It is interesting to note that most people, especially women, immediately suggest that the specific examples of skills noted in the preceding text that women achieved significantly higher scores on are maternalistic in nature.

Historically, one common managerial pipeline problem women face is that many get stuck in jobs that involve human resources or public relations. These jobs rarely translate into upper management leadership opportunities. However, this research is worth noting because it may provide leaders the prompting for greater self-reflection.

Critical Leadership Skills, Traits, and Behaviors

In the following text is a list of critical leadership skills, traits, and behaviors essential for effective leaders. This is not meant to be an exhaustive list. Your preferences and experiences enable you to modify or add to it. These are not presented in order of importance. Your preferences and experiences will suggest some being more important than others to you. Finally, there is interdependence or overlap among these.

Effective leaders must lead by example. There have been various phrases that exemplify this concept, including "Practice what you preach"; "Put your money where your mouth is"; "Walk the walk and talk the talk"; and "Do as I say, not as I do." When leaders do not "practice what they preach," followers will soon follow.

Effective leaders must be personable, accessible, and highly visible. Historically, this has been referred to as *management by wandering around*. Although some people regard this as interference and possibly micromanaging, a leader should be personable, accessible, and visible. Leaders should go to the *gemba*, a Japanese term that refers to the place where value is created, namely, the factory floor. Leaders should not always rely upon written reports and verbal characterizations by others. Rather, leaders see how the system is operating with their own eyes and ask many questions in the process.

Effective leaders should possess a systems perspective. It is imperative to understand that each function of an organization, each process, even just a portion of a process makes a contribution to the system's output. Leaders must possess a general management outlook seeing the larger picture, not just the immediate surroundings. Problem-solving skills or domain expertise lend credibility, but a systems view is more important than technical expertise. It takes contributions by engineers, accountants, human resources personnel, plant floor personnel, and many others to offer a product or a service. Optimization of a subsystem does not necessarily promote system optimization. Tweaking any portion of a transformation process causes downstream consequences.

In this day and age, it seems that not a day goes by without another world, regional, or local leader being exposed for a lack of honesty, integrity, and ethics. Needless to say, these are the foundations of leadership. Leaders are in the position of evaluating and promoting subordinates.

Honesty, integrity, and ethics are vital if leaders want subordinates to follow. Honesty, integrity, and ethics subsequently allow leaders to build character. Character allows leaders to build trust. All of these are essential for a successful leader–subordinate relationship and are critical leadership traits.

Leaders must create the environment or culture that is conducive to achieving lean objectives. This necessitates eliminating bureaucracy and hierarchies as well as fostering entrepreneurship within a disciplined framework. Improvement requires change; bureaucracy and hierarchies stifle change. However, one must also maintain discipline for performing daily activities such as data collection and reflection of results. Lean requires comparing execution to objectives and well-developed plans and understanding successes as well as failures. Consequently, lean leaders take time and encourage the use of the *Shewhart Cycle* or *Deming Wheel* (Plan, Do, Check, Act).

A successful lean culture is led by leaders who have created a learning organization where they were first learners and then teachers. While creating the culture, leaders must individually accept the stewardship and responsibility for the transformation. These leaders must be personally committed to change and participate in the pursuit of excellence. This will facilitate the creation of a continuous improvement environment.

Lean leaders should be risk-takers, not risk avoiders. Leaders should seek out learning opportunities and problems as well as adapt to new challenges. A lean philosophy promotes improvement. In order to improve, one must first encounter opportunities to seize upon or flaws to correct. This suggests a desire to experiment in order to discover improvement. Lean leaders need courage, as sometimes chances need to be taken. Courage will enable one to consider testing the limits of a process in order to expose its weakness so it can be addressed. The culture must overcome resistance and not yield to resistance, skepticism, or reluctance, which are common in complacent organizations.

Naturally when experiments are conducted, mistakes occur. The appropriate lean culture recognizes that problems and mistakes occur. Lean leaders realize that people are not typically the problem, but rather they are the problem solvers. A prerequisite for the appropriate culture is the establishment of an atmosphere that allows problems to be brought to light sooner rather than later. An environment of trust ensues when leaders demonstrate that it is okay to make legitimate mistakes. This encourages the sharing of all problems and mistakes, which is a critical lesson: Problems and mistakes represent learning opportunities that can be shared across the organization. This serves as a significant prevention cost. The emphasis should be placed on finding and sharing solutions, instead of pointing fingers. Lean leaders should constantly encourage the "5 Whys" or the 5W2H (**w**ho, **w**hat, **w**hen, **w**here, **w**hy, **h**ow, and **h**ow much) questions to be asked to promote a richer understanding of outcomes.

Lean leaders will understand the value of developing one's team. Included in this process is assessing and understanding team member capabilities, providing training and mentoring when needed, as well as aligning people with their capabilities. Lean leaders may develop and position subordinates for future success by delegating and sharing decision-making authority. Lean leaders will actively share information as well as solicit and listen to subordinate opinions. Demonstrating sensitivity and empathy and acting selflessly rather than selfishly engenders support as well as an ability to motivate, engage, and inspire. Sharing information fosters communication and teamwork. As noted earlier, a participative management style raises motivation, increases readiness to accept change, improves decision quality, develops teamwork, improves morale, and further promotes individuals' development. Praising individual and team efforts as well as supporting and rewarding efforts and success also raises motivation, increases readiness to accept change, develops teamwork, and improves morale. Leaders who are effective for long-term horizons typically do not crave the limelight. Rather, they channel their ego and ambitions into the success of their subordinates and organization. This approach pays long-term dividends.

Lean leaders must possess a process orientation. If a proper process has been designed, good results will typically follow. It is imperative to focus on variance reduction. Variability will preclude achieving the desired objectives regardless of the process effectiveness. Keep in mind, within any system, discipline and maintenance are required as these promote variance reduction. Discipline represents the adherence to a schedule; while maintenance for machines is the performance of routine preventive maintenance, for people, it is a corresponding wellness program.

Although it is important for lean leaders to possess a disciplined, process orientation, it is also important for leaders to have imaginative versatility and flexibility. A lean culture values flexibility or quick adaptation to changing needs. Unexpected outcomes occur in an environment that embraces continuous improvement. In a global environment, internal and external events are happening with an ever-faster pace. Unexpected outcomes and unforeseen events require adaption. Lean leaders must recognize it is necessary to depart from plans and respond to these unexpected outcomes and events quickly.

Similarly, lean leaders must possess a results orientation. At times, the scope of improvement projects may be too large to allow a leader to attend to many details. Projects of large scope will require leaders to allow the team to determine how to perform work. The point is to focus on results, not on how particular assignments are conducted as long as subordinates take ethical actions and follow standardized procedures. Once completed, results should be measured against planned outcomes or expectations. Prompt feedback must be provided as this allows for adjustments to be made quickly. Until consistent, verifiable results are achieved, one should measure more often in order to reduce variation. Performance metrics should allow for proactive measures, not reactive measures, to reduce variability.

Leaders must be organizationally savvy and politically connected. Strategic initiatives typically require an initial increase in resources until successful results begin. This requires leaders to be organizationally savvy and politically connected, which increases the likelihood that needed resources can be obtained.

Leaders will require negotiation and persuasion skills. Strategic initiatives are filled with diverse stakeholders and consequently diverse opinions. It is imperative leaders possess the ability to defuse conflicts.

Effective leaders must possess humility. Leaders should recognize that everyone has the capacity for learning and improvement. Leadership must allow and encourage people to ask challenging questions, even of themselves. All too often, people accept what they read and hear. We frequently do not challenge and ask questions. Those who do ask questions are sometimes seen as disruptive. Leaders who are effective for long-term horizons typically do not crave the limelight. Rather, these leaders commonly solicit constructive comments and criticisms of their own actions as this demonstrates a willingness to improve. They channel their ego and ambitions into the success of their subordinates and organization. This approach pays long-term dividends. Leaders who keep learning may be the ultimate source of sustainable competitive advantage.[30]

Effective leaders must also possess the ability to maintain their passion. Improvement initiatives are commonly long-term propositions. Good results typically occur slowly and in small increments. Lean leaders will need stamina because sometimes failures result.

It is interesting to realize that the skills, traits, and behaviors noted in this section require leaders to utilize both left- and right-brain orientations. A right-brain orientation is generally associated with creativity, imagery, and vision. A left-brain orientation is generally associated with linearity and analysis. Leaders need both and need to know when to apply each.[31]

Poor Leadership Behaviors

Just as there are effective leadership behaviors, there are poor leadership behaviors. Although not an exhaustive list, some of the more common ineffective behaviors are noted in the text that follows.

All too often, we avoid change and prefer to cling to the past. There are various expressions, which reflect this pattern of behavior including, "That's the way things are done around here." Creating change is one of the most important value-added activities leaders offer.

Everyone makes mistakes. Mistakes are further compounded when people refuse to express regret or apologize. The simple reason is that those that are hurt or damaged by the mistake can more easily put it behind them once an apology is offered. It is important to look toward the future and manage what will happen rather than what has happened.

Sometime leaders have a need to win too much or to add too much value. Individuals must put team or organizational objectives before personal objectives. What is important is for the team to win, not necessarily the person. Oftentimes, adding one's two cents simply reiterates what has already been said. There comes a time when one must simply get on with the work.

Another poor leadership behavior centers on negativity. Examples of this behavior include making destructive comments, starting with "no," "but," or "however" rather than saying, "You're right." Negativity simply puts up roadblocks or obstacles. Lean is about overcoming obstacles and breaking down barriers. Taiichi Ohno once noted that lean initiatives should begin from need. Whatever stops you from starting or progressing tells you what to fix first.

Another poor leadership behavior is passing judgment or telling the world just how smart we are. It is really not for us to judge as we should never be satisfied with the current reality. There is room for improvement in everyone.

Emotions cloud good judgment. A poor leadership behavior is speaking when angry. Although it is not an effective negotiation technique, withdrawal has its use when emotions run high. It is always better to allow for a cooling period when emotions can cloud perspectives.

Withholding information is another poor behavior. Eventually information is revealed and when it is, one of the first questions asked is "When did you know about this?" Surprises are typically not good. It is best to share information upon its receipt.

Finally, failing to give proper recognition or an inability to praise and reward often creates enmity. As noted earlier, effective leaders channel their ego and ambitions into the success of their subordinates and organization. This approach pays long-term dividends.

Summary

Leadership is the single most critical factor in the success or failure of lean initiatives. Lean initiatives require the contributions of a team of people pursuing common goals. These people must act in unison. It is the leadership of the organization that creates the environment, establishes the team, and conveys the message that promotes change in pursuit of these goals.

Many key elements of leadership exist. When making leadership choices, leaders must be cognizant of the following key points:

1. Understand one's personality and how choices will work for you personally. At different times, different style choices are appropriate. It is imperative that the leader is able to adapt to differing styles and abide with these choices.
2. Leadership is exercising influence over group processes, shaping and framing the reality of others, and achieving a willingness of subordinates to comply. Leadership does require consideration for subordinates, and leaders will need to address differences among all subordinates, as each possesses varying wants, needs, and preferences.
3. At times, leadership will be a form of persuasion. It does require marketing efforts.
4. Leadership is the collection of many behaviors. It will be difficult to effectively practice all of these all the time.
5. By its nature, leadership implies a dominant–submissive or power relationship, which should not be abused. Leaders should remember the *golden rule* of reciprocity and treat subordinates as they would like to be treated.
6. The effectiveness of leadership style choices is dependent upon numerous intervening variables, which will make understanding outcomes confounding.
7. Leadership does require the initiation of job structure. It requires discipline, which must be coupled with subordinates possessing authority, responsibility, and accountability.
8. Leaders must possess a willingness to learn and, in turn, share the knowledge.
9. Most importantly, leadership means more than simply managing day-to-day activities. Leadership is a means to achieve goals by *effecting change*, which leads to improvement.

It is often thought that all leaders are the same and that any leader can implement strategic goals and choices. Leadership must reflect a fit with goals and strategic choices. There is no single leader for all initiatives. However, people do have the ability to learn, adapt, and to improve.

CHAPTER 3

Lean Culture

Its Meaning and Creation

Anyone who has never made a mistake has never tried anything new.
—Albert Einstein

Imagination is more important than knowledge.
—Albert Einstein

Any intelligent fool can make things bigger and more complex. . . . It takes a touch of genius—and a lot of courage to move in the opposite direction.
—Albert Einstein

Some of the best lessons we ever learn are learned from our past mistakes. The error of the past is the wisdom and success of the future.
—Dale E. Turner

The underlying principle of lean is a customer-driven philosophy for organizationwide continuous or ongoing improvement and waste elimination. Improvement, or *kaizen*, which roughly translates as good (*zen*) change (*kai*), necessitates doing things differently. Kaizen is a learning approach based largely on evaluating past experiences through observation, questioning, experimentation, and making changes based upon data-driven results. The quotes noted in the preceding text convey a significant concept for the creation of a lean culture. Continuous improvement requires intellectual curiosity to innovate as well as courage because mistakes will occur. An important prerequisite for achieving change is a supportive organizational culture because the culture of an organization can act either as a facilitator or as an obstacle to change. Kaizen requires a supportive organizational culture.

I often ask the proverbial question, “Can you teach an old dog new tricks?” Typically, half the audience answers “no” and the other half “yes.” In the previous chapter, it was noted that leading entails guiding improvement activities and establishing an organization’s purpose, which changes over time. Instilling change is difficult at best as change necessitates learning and adaptation, and many people inherently resist change because it is disruptive, intrusive, and upsets the balance of stability.[1] The culture of an organization, which is created by organizational founders and leaders and is a product of its workforce, has a significant inertia that resists change. Bringing about cultural change is a time-consuming, often wrenching process. However, you can teach people new tricks as long as there is sufficient incentive. Simply put, people and organizational culture typically resist change. A clear understanding of the importance for change is paramount to achieving and sustaining it.

Organizational culture is a critical element when attempting to achieve continuous improvement. In an online survey of practitioners, respondents ranked lean culture as a critical element of lean organizations.[2] Only a “systems perspective,” lean leadership, and lean knowledge and experience ranked higher. Lean implementations often change companies, threatening (or appearing to threaten) both corporate culture and customary ways of conducting work.

A simple but effective test to better understand if there is a sound foundation upon which to improve the organizational culture is to ask and truly understand if employees look forward to going to work each day. Results of two surveys conducted in 2012 and 2014 found the company Clockwork Active Media as one of the best places for employees to work, in large part due to the organizational culture.[3] The morale of the workforce, or its *esprit de corps*, is a simple yardstick leadership may use to assess the level of longer-term improvement commitment. The answer to this question must be a resounding “yes.” But remember, the four elements of lean systems, leadership, teams, practices and tools, and culture, are interdependent. Namely, the ability to answer “yes” to this question is why leadership is the keystone to lean management as founders and leaders create the culture.

This chapter begins with an examination of culture. It follows by exploring a stepwise process for implementing change. The chapter concludes with a discussion of nine system elements that can promote a more entrepreneurial culture.

Organizational Culture Defined

Culture itself refers to a set of assumptions that are learned over a long-term time horizon. The assumptions serve to guide overt attitudes and practices of a group such as a team.[4] Culture manifests itself in the form of shared elements including company documents, norms of behavior, beliefs, values, metrics, and rewards. These shared elements are causal determinants of attitudes and practices. Organizational culture refers to these shared elements in a workplace environment. It is the principled atmosphere of the system. Simply put, it is the way things are done in an organization.[5]

The culture of an organization is created by founders and current leaders. However, it is developed from reinforced behaviors.[6] The most important source of reinforcement is leadership. This is one reason why lean leadership is critical to lean implementation success. The failure of most lean initiatives can be pinned on the failure to change leadership practices.[7]

Organizational culture is composed of day-to-day practices and behaviors.[8] In a lean system, these day-to-day practices and behaviors need to include standardization of methods, a clear understanding of current system performance, a team-based approach to work, workplace health and safety, and the recognition that lean is a lifelong path of continuous improvement, which if pursued honestly and diligently promotes a culture with energy, focus, and longevity.

The creation of a lean culture is an inherently iterative, ongoing process. It is not a onetime event. It is infused with both an entrepreneurial spirit and discipline. The long-term maintenance of continuous improvement activities requires that an organizational culture be produced by individuals who embrace change.[9] Namely, an important aspect of continuous improvement avoids bureaucracy and hierarchy, yet expects discipline. It does not focus on what you accomplished: only what you have accomplished relative to exactly what you said you were going to accomplish.

Anyone who has worked in a highly bureaucratic system with too many rules and regulations to follow has probably witnessed that bureaucracy and layers of management eventually stifle peoples' willingness to participate and to take the initiative for change. Systems attempt to reduce dissonance and maintain the status quo.[10] Cultures also provide stability and comfort, which may make change more difficult.[11] Furthermore, as organizations grow over time, depending upon leader choices, they will at times become more bureaucratic with vertical functional structures and horizontal management layers, which serve to impede change. A lean culture must promote creativity, involvement, experimentation, and new thinking. An entrepreneurial spirit can promote improved productivity, quality, lowered cost, shortened delivery time, enhanced safety and environment, and improved morale.

Lean culture is disciplined thought complete with the brutal facts of reality so that a simple, yet deeply insightful, frame of reference for all decisions and the path for improvement may be more easily discernable. Lean culture must be hostile to complacency, confronting brutal performance facts without demoralizing people and creating an environment that leads to improvement. Leaders can facilitate achieving this environment by adopting the following four suggestions.[12]

1. Possess the humility to acknowledge that one often does not yet understand enough to have the solutions to problems.
2. Investigate with questions (e.g., asking the "5 Whys") that will lead to the best possible insights.
3. Engage in dialogue and debate, not coercion, as a means to search for the best answers.
4. Conduct investigations without blame, which encourages openness and participation.

Lean culture will grow from the consistent effort of a constant, disciplined approach.[13] Disciplined actions lead to an opportunity for an enhanced focus on a process. This includes a daily routine, which is easily audited for understanding process performance. Discipline begins with floor personnel. It must be made clear that these individuals have been given the *responsibility* or the obligation to effectively perform assignments. This means following standardized work instructions. If followed correctly, expected outcomes should be achieved with little variation. Discipline must go further than this. Personnel must also be given the *authority* or the power to make final decisions to complete their assignments correctly. This is important as it will be these individuals who have the responsibility for making recommended improvements and maintaining them in the future. Without authority, there cannot be *accountability*, which is the state of being totally answerable for the satisfactory completion of a specific assignment. Namely, accountability is responsibility coupled with authority. This has sometimes been referred to as *quality at the source*. It should be emphasized that the person who knows best whether or not a job has been done right and doing it correctly should be the person doing the job.

There must be checks at various managerial levels creating a "network of support."[14] This network consists of levels: worker, shift supervisor, plant manager, and so on. Each level must support its immediate lower level with standardized job responsibilities and authority to take corrective action. Standardized work enables an ability to focus on process. This leads to not only expected output being achieved but also an ability to subsequently strive for improving expected outcomes. Standardization is an important precursor to kaizen. However, it must be remembered that hierarchies or layers of management can stifle participation, so care must be taken to emphasize responsibility of decisions and corrective actions.

The Process of Change

As noted earlier, leading involves establishing direction, which requires developing the vision and choosing competing strategies for achieving the results or producing the changes needed. Change itself necessitates adaptation, and many people inherently resist change because it is disruptive and intrusive, which upsets the balance of stability.[15] Company culture often acts as a barrier to change as some people get comfortable with day-to-day routines. This is one significant reason why leadership is critical to the success of managing lean.

Change itself is not easy. Machiavelli is acknowledged for noting that there is nothing more difficult to plan, more doubtful of success, and more dangerous to manage than the creation of a new system. The innovator has the enmity of all who profit by the preservation of the old system and only lukewarm defense by those who would gain by the new system.[16]

The process of implementing change typically proceeds in a stepwise manner.[17] First, process-based change in capabilities is instilled internally in a localized, single set of related (typically sequential) transformation activities. For example, this can be as simple as the outcome of experimentation or Plan-Do-Check-Act (PDCA; see section on PDCA and Hansei in this chapter). Or, this can be the outcome of a kaizen event. This typically involves a small group of 1 to 10 individuals. It is important that individuals working in the area of local change understand and largely agree with the importance and the need for change, which is easier for a small group.

Resistance to change diminishes when subordinates identify the need for change in response to problems or opportunities, see investigations and associated responses, or experience improvements that change brings. Success allows further improvement. Success can serve as a platform that enables greater buy-in and participation. Once mastered, the firm will seek to integrate and coordinate these improved capabilities across a broader set of several activities or systems within the firm. This is the second phase of change, which involves a greater number of individuals.

The third phase of change broadens improvement further, allowing even greater participation. Embedding these improvement capabilities within the routines and knowledge of the entire firm, making them multifunctional, organizational-based capabilities follow as the third phase. Specific practices or tools such as *hoshin* planning or value stream mapping may be quite useful in these later change phases.

Finally, in the fourth phase, world-class firms will seek to enlarge these improvements into network-based capabilities that reach outside the limits of the transformation process in order to encompass the value chain network. In this phase, downstream customers and upstream suppliers are typically engaged in the improvement process.

Creating and Maintaining a Lean Culture

The process of improvement for most is slow but is typically contagious. It is important to manage expectations because change can be slow. It is usually better to reduce the possibility of discouragement, which encourages withdrawal from improvement efforts. Expectations can be managed with a posted timetable that identifies when one can expect results. Eventually improvement must engage everyone, both internally and externally.

Successful organizational adaption and the creation of a lean culture is increasingly reliant on generating employee support and enthusiasm for change.[18] A lean culture must be hostile to complacency, continuously seeking improvement by learning through evaluating past experiences with observation, questioning, experimentation, and making changes based upon data-driven results, all without demoralizing people. The inherent nature of a lean culture is depicted in Figure 3.1.

It is the organization's leadership that must reduce ambivalence to change and create the environment that possesses the enthusiasm and support, which encourages change from subordinates through participation and agreement. In order for change to be permanent, it must be agreed upon and supported by those who will enact it.

Organizational founders and key leaders play a central role in establishing organizational culture through a variety of mechanisms that establish and promote the assumptions that guide team member attitudes and

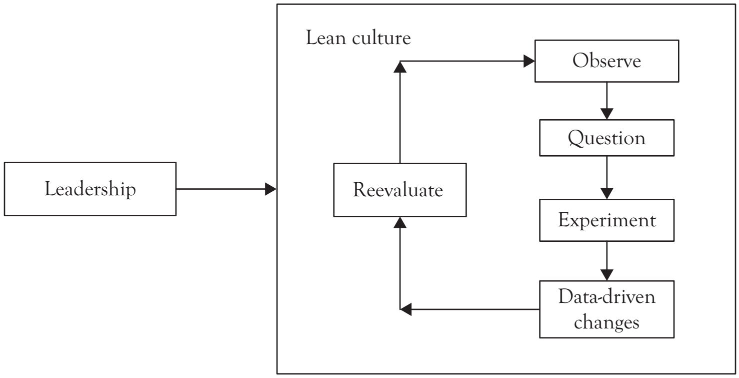


Figure 3.1 The inherent nature of a lean culture

Table 3.1 Nine mechanisms for creating a lean culture

1. Agreement of a shared long-term vision, goals, and strategies
2. Standardization of methods for variance reduction
3. Plan-Do-Check-Act and *hansei*
4. *Hoshin kanri* and *nemawashi*: Group planning and ladder ball
5. Creation of a learning organization
6. Recognizing one's team as an asset
7. Wellness programs
8. Ergonomics
9. Metrics and rewards

practical choices.[19] A lean culture is created and maintained by engaging, encouraging, empowering, investing in, and rewarding one's team. Nine mechanisms that play a vital role in today's organizations for the creation of a kaizen culture are shown in Table 3.1. These mechanisms are intended to promote subordinate understanding of the assumptions, which eventually shape attitudes and practices. It should be noted that these mechanisms are not independent but rather interdependent. There are common means for establishing several of these mechanisms in a simultaneous fashion. Each of these lean culture creation mechanisms is explored in the text that follows.

Agreement of a Shared Long-Term Vision, Goals, and Strategies

Leadership is best defined as effecting change.[20] In order to effect change, leaders must align the efforts of resources toward a shared vision and goals, which may be challenging in organizationally and politically complex cultures, as processes often cross functional boundaries, utilize shared functional resources, rely upon comingled functional budgets, and utilize varying metrics. However, improvement necessitates change, which implies there is a perceived or observed gap between the current system state and the desired future system state. Attaining agreement among various stakeholders in order to address performance gaps is essential for establishing a lean culture. Ambivalence to change makes attaining agreement and resultant improvement initiatives difficult as those who perceive benefits by maintaining the status quo may resist change.

Achieving agreement of a shared long-term vision, goals, and strategies places a premium upon the leader's ability to communicate the need and attain the shared vision that is necessary for a commitment to change. Example mechanisms that play a vital role in attaining this agreement are one's leadership style, communication skills, as well as various company documents.

Standardization of Methods for Variance Reduction

There is an important saying that is useful to keep in mind during lean implementations, namely, "There is more than one way to do it." Although this suggests there usually exist many ways to perform a task, there should be only one standardized company way to perform it. Standardization, or one outcome regardless of who performs the task, reduces variability. Take the case where a company operates a 10-stage, sequential process. If the operator for each successive process stage performs his task in any one of three ways, then there are 59,049 possible outcomes. Furthermore, as a product moves along a process, variation tends to compound.

A lean culture depends upon continuous improvement. A lean culture must encourage experimentation and innovation in order to achieve improvement. It must be observed that lean culture comprises day-to-day practices and behaviors.[21] However, the desire to experiment and innovate sometimes contradicts a lean culture's stated rules and practices, which can be detrimental to lean initiatives.[22] This can occur because the day-to-day practices and behaviors of a lean culture need to include standardization of methods. Namely, on any given day there needs to be recognition of the value for doing work following prescribed company policies and procedures in order to achieve consistent results. This statement may be best explained by a second example. Assume a company produces a single product possessing multiple specifications. A three-step process is utilized to produce it. Further, assume three shifts are utilized, given the volume of demand. This example may be explained pictorially using Figure 3.2.

For any single product, it is desirable to have an identical outcome for each copy. The company has identified a prescribed method for

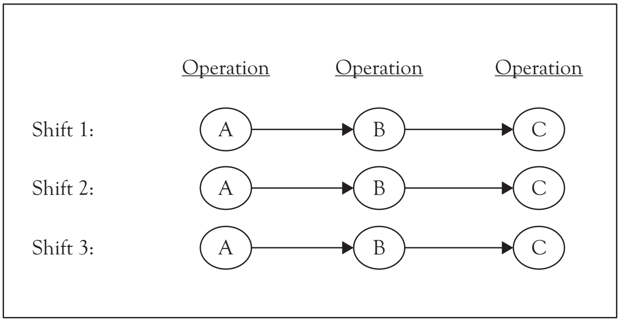


Figure 3.2 Variation example

performing each operation, A, B, and C, in order to achieve this single outcome. However, assume each of the three workers on each of the three shifts is convinced that an alternative method will yield a better outcome. Should one perform this task using the prescribed company method or one's own method? Using the prescribed company procedure at each operation for each shift should yield a single outcome. Using three alternative procedures (one for each worker on each shift) at each of the three successive workstations will yield 27 different outcomes (3 procedures × 3 workers × 3 workstations) or variations.

The example above points out the importance of recognizing the value of performing work according to company standards. However, it also recognizes the importance of employees requesting permission to conduct an experiment following a scientific management approach. This approach begins with the development of a hypothesized improvement process as the first step. The second step develops an experiment, complete with decision variables and performance metrics, that is to be carried out to assess the hypothesis. The third step represents conducting the experiment, during which one decision variable is manipulated at a time so that performance differences may be attributed back to this decision variable. The fourth step follows with the results evaluation. Once the hypothesized method demonstrates an ability to enhance process results, it becomes the standardized company procedure. Achieving standardization in processes is vital for achieving process outcome stability. Process outcome stability promotes the ability to understand both the current state and potential benefits of improvement efforts. Namely, it must be recognized that standardization does allow for change. Change, either small, incremental improvements or significant (radical) breakthrough improvements, comes about through experimentation. In order to correctly assess experimental outcomes, process stability must have been achieved.

A culture that promotes experimentation ultimately leads to greater improvement discovery. However, it must be recognized that experimentation leads to failures and mistakes. It is important for the culture of an organization to understand that failures and mistakes do offer benefits in the form of valuable learning opportunities. Failures and mistakes, although potentially costly, promote organizational learning as everyone can share in the knowledge. Repeating failures and mistakes can then be avoided by everyone else if the learning is shared. The appropriate organizational culture has not been established if failures or mistakes are hidden because of threats. Hidden failures and mistakes suggest a fearful environment. Furthermore, even when not visible, leaders should seek out problems and subsequently strive to eliminate causes. This will drive even further improvement.

PDCA and Hansei

A valuable approach for discovering continuous improvement is PDCA. When embedded in one's daily practices, PDCA can provide a clearer understanding of current system performance. It is also known as the Deming circle (cycle or wheel), Shewhart cycle, Plan–Do–Study–Act (PDSA), Six Sigma's acronym of DMAIC (Design, Measure, Analyze, Improve, Control), as well as other acronyms.

PDCA represents an iterative, four-step problem-solving process. The four steps proceed as follows.

1. **P**lan: Establish the objectives and processes necessary to deliver results in accordance with output specifications. By making the expected output the focus, it differs from other techniques in that the completeness and accuracy of specifications is also part of the improvement.
2. **D**o: Execute or implement the new processes.
3. **C**heck: Measure or assess the new processes and compare execution versus the plan in order to ascertain any variances.

4. **A**ct: Analyze the differences to determine their cause. Determine how or where to make changes that will lead to improvement. When a pass through these four steps does not result in the need to improve, alter the hypothesis to which PDCA is applied until there is an outcome that provides improvement.

The concept of PDCA is based on the scientific management approach noted in the preceding text. PDCA goes one step further, however. It looks for improvement, which suggests iteration(s). The fundamental principle of PDCA is iteration. Once a hypothesis is confirmed or refuted, executing the cycle again will extend the knowledge or improvement even further, bringing the organization closer to its goal(s). PDCA should be repeatedly executed in spirals of increasing knowledge or continuous improvement as shown in Figure 3.1.

Similar to PDCA is the Japanese practice of *hansei*, an important practice of lean cultures. The term means self-reflection. It acknowledges there is often an opportunity for improvement when team members can reflect honestly upon outcomes with modesty and humility. Similar to PDCA, hansei emphasizes identifying how the results of activity differed from expectations, acknowledging one's mistake, and pledging future improvement. The desired outcome of the practice is identifying plans for ensuring the mistake will not occur again.

Hoshin Kanri and Nemawashi: Group Planning and Ladder Ball

As noted in an earlier chapter, participative management is a leadership style that engages subordinates. It is a strategic, group planning approach of engaging stakeholders. Allowing stakeholders to participate in the managerial decision-making process has been credited with an ability to raise motivation, increase readiness to accept change, improve decision quality, develop teamwork, improve morale, and further individuals' managerial development. People have an inherent need to control, to some extent, processes in which they will be engaged.

Hoshin kanri is an example of a participative group planning process. It is a Japanese term where *hoshin* means compass or pointing the direction and *kanri* means management or control. The participative group planning process is a systematic planning methodology for defining key long-range objectives. Because it is a group process, it is designed to use the collective thinking power of all employees. It is intended to ensure that everyone in the organization is working toward the same goal(s).

The process utilizes a *catch ball* or *ladder ball* approach because it is hierarchical. It cascades down through the organization, engaging and negotiating with process owners for ideas and feedback, while giving every stakeholder a voice. Hoshin kanri represents a team-based approach for conducting work, which has the potential for greatly enhancing the *esprit de corps* as people have an inherent need to control processes in which they must be engaged. This practice encourages greater stakeholder involvement, which in turn can promote an environment more readily accepting of change.

The group planning process is a purposeful attempt to lay the strategic foundation by talking to the people concerned, gathering support and feedback, until a final consensus is reached. The Japanese term *nemawashi* is sometimes used to refer to this purposeful process as it means digging around the roots of a tree in order to prepare it for a transplant (change). Engaging others is an important step in any major change. Before any formal steps are taken, successful group planning enhances the possibility of change with the consent of all stakeholders. Although it is time-consuming, the hoshin kanri process can turn skepticism and resistance into support, create cross functional cooperation, fully engage the workforce in developing executable strategies, link improvement and corrective actions with financial results, and better enable the team to respond to changes and setbacks.

Participative management approaches can be time-consuming, and delegation is not a way of passing responsibility. Leaders should decide on their role prior to engaging the subordinate group. Additionally, leaders should articulate the extent of their involvement in any group decision-making process as well as indicating explicitly or implicitly the extent of the authority they are asking subordinates to assume in the decision-making process.

Experience and research indicates that high-performance teams are more likely to develop using participative approaches. Although there are exceptions, team performance also tends to improve when members volunteer, work full-time (vs. part-time), and in small teams (e.g., 10 or fewer members) for projects that have compelling objectives. Furthermore, effective use of teams tends to offer a self-regulating feature. Teams commonly promote norms of productivity and behavior. Individual team members are expected to adhere to these norms through informal peer pressure or formal assessment mechanisms. The concept of a team-based approach is explored more fully in the next chapter.

Creation of a Learning Organization

Kaizen requires leaders to create a learning organization capable of quick adaptation. As noted earlier, kaizen is a learning approach based largely on evaluating past experiences through observation, questioning, and making subsequent changes. The best way to achieve this is to recognize four important characteristics of change. First, everyone has the ability to learn. Learning simply means modifying behaviors. Learning is often best accomplished by conducting performance investigations with open dialogue and debate, even confrontation, but not coercion, as a means to search for solutions. Investigating with questions often promotes a shared and more complete current state understanding, leading to better insight. Altering future behavior without assigning blame for first-time subpar performance will promote openness and participation and may ultimately lead to greater agreement. And, sharing accolades for superior past performance will promote a receptive culture.

Second, leaders must accept the stewardship and responsibility for transformation and must personally demonstrate a desire to learn through their own participation. All team members must possess the humility to acknowledge that a single person does not often understand enough to have all the solutions. And, after learning a lesson, students must become teachers and share the lesson with others. Leaders must create the environment that stimulates change by example.

Third, team members must see their workplace as a laboratory for experimentation, reflection, learning, and change. Leaders must demonstrate their support for experimentation, which entails the risk of failures and mistakes, as it enables discoveries. Although potentially costly, failures and mistakes promote valuable organizational learning where everyone can share in the knowledge. A lean culture has not been established if failures or mistakes are hidden because of perceived threats.

Fourth, change should be encouraged with a clear understanding of an organization's current state, its ideal state, and the disparity between them. The importance of making change is critical to the long-term success of an organization. However, achieving change based upon a perceived gap between the current and ideal states overly simplifies the likelihood of success. Social and organizational processes operating within an enterprise typically bring about slow, time-consuming change and challenge success. Infrequently does change come about through abrupt innovation; rather, it most commonly occurs through small, incremental alterations, making long-term sustainable momentum challenging.

Promoting collaboration and information exchange facilitate innovation. Collaboration, information sharing, and resultant organization adaption is reliant upon choices such as decentralized decision making, flatter organizational structures, reduced bureaucracy, and lessened status differences among colleagues.[23] These choices should enhance the organizational knowledge base as well as promote a kaizen culture possessing an entrepreneurial spirit with greater creativity, involvement, and a willingness to experiment.

Recognizing One's Team as an Asset

For decades, Toyota's Production System (TPS) has referred to its team-based approach as respect for people. Championship teams combine good teamwork with individual skills.[24] A team-based approach promotes system goals more effectively than any group of individuals acting independently can. The logic for utilizing teams can be summed up by Aristotle's idea that the whole is greater than the sum of the parts.[25]

Kaizen activities, which typically require contributions from many individuals and functional disciplines, may be disruptive, often changing processes and threatening (or appearing to threaten) both corporate culture and customary ways of conducting work. Therefore, the creation, composition, and development of one's team is critical to maintain momentum. Leaders should invest in individuals and teams, just like any other asset. When leaders recognize the team as an asset, it facilitates creating a learning organization. Investing in one's team is another means for promoting a kaizen culture.

Effective working groups require a high level of respect and trust, which enhances the potential for superior team performance. The benefits of effective teams include greater initiative and team member commitment, higher job satisfaction and morale through a sense of belonging, fewer conflicts, and more successful initiatives. The consequences of dysfunctional teams include lower motivation, frequent conflict and disagreement, greater lack of respect, poor communication, and an increased likelihood of initiative failure.

Leaders must assess and understand team member capabilities before investing in one's team. This enables leaders to better align people with their current capabilities as well as affording a more directed investment in team members' training, education, and skills, including cross-training. Cross-training promotes benefits to the organization including enhanced flexibility and greater idea generation.

Lean leaders may develop and position subordinates for future success by delegating and sharing decision-making authority. Lean leaders will actively share information as well as solicit and listen to subordinate opinions. Demonstrating sensitivity and empathy and acting selflessly rather than selfishly engenders support as well as an ability to motivate, engage, and inspire. Sharing information fosters communication and teamwork. As noted earlier, a participative management style raises motivation, increases readiness to accept change, improves decision quality, develops teamwork, improves morale, and further promotes an individual's development. Praising individual and team efforts as well as supporting and rewarding efforts and success also raises motivation, increases readiness to accept change, develops teamwork, and improves morale. Leaders who are effective for long-term horizons typically do not crave the limelight. Rather, they channel their ego and ambitions into the success of their subordinates and the organization. This approach pays long-term dividends.

Three salient points for the establishment of a team follow.[26] First, leaders should examine a potential team member's inherent traits and characteristics, which are difficult to change or to learn, in addition to educational background, practical skills, specialized knowledge, and work experience. Although important, these latter items can be learned. Second, people with desirable inherent traits and characteristics may require less managerial and motivational effort, may more easily and more quickly adapt to a changing world, may more likely support needed changes in direction, and may unify behind decisions, regardless of parochial interests. Desirable personal traits and characteristics are especially valuable as firms alter course from the current state to pursue objectives associated with an ideal state. Third, establishing an agenda with the team creates team building, motivation, more solution options, develops leaders for the future, and increases the likelihood for agreement.

Beyond training, education, and skill enhancement, investing in one's team can be done in additional ways. Once an appropriate team is formed, leaders must subsequently demonstrate respect by trusting workers. Problem solving requires team-based solutions, which should be provided by the personnel closest to the problem, those who implement the solution, and by those who provide needed resources and understand the larger competitive picture. Once employees understand their participation is essential, greater team member involvement in team-based methods such as cross-training programs, hoshin kanri, quality circles, kaizen and *kaikaku* events, and suggestion programs may be possible.

Wellness Programs

The maintenance of a kaizen culture can be enhanced with various employee-focused investments. Employee wellness programs have recently recognized that machines are not the only valuable resource that needs regular maintenance. The most valuable resource of any enterprise is its people. Human resources must be available when needed and therefore this resource requires regular maintenance as well. *Wellness programs* are employee-centered programs featuring proactive personal fitness programs, including physical examinations, substance abuse and group counseling, and individualized diet and exercise programs.

Wellness programs have been effective in improving employee productivity while reducing absenteeism and health care costs. However, cost–benefit evidence demonstration of wellness program value is limited because of their more recent development. One example of a wellness program, occurring in Oakland County, Michigan, began in 2007. After four years, the program is providing measureable results. The year 2009 saw a 12 percent decline relative to 2008 in health insurance costs for the county.[27]

The Oakland County wellness program consists of health surveys, risk assessments, blood pressure screening, glucose tests, nutrition and exercise classes, and smoking cessation classes. During 2009, 56 percent of the employees were enrolled in the voluntary program. So, like many lean initiatives, success has encouraged greater participation. As more evidence of cost-effectiveness emerges, more wellness programs will similarly emerge.

Ergonomics

Ergonomics, another employee-focused investment, is concerned with safety and the "fit" between people and their work. It takes account of the worker's capabilities and limitations in seeking to ensure that tasks, equipment, information, and the environment suit each worker. Ergonomic injuries comprise more than 50 percent of all workplace injuries in North America, with the most important ergonomic risk factors being posture, force, and repetition, all of which depend on workplace design.[28]

The International Ergonomics Association divides ergonomics broadly into three domains: (a) physical ergonomics, which is concerned with human anatomy and delves into relevant topics such as working postures, materials handling, repetitive movements, lifting, workplace layout, as well as safety and health; (b) cognitive ergonomics, which is concerned with mental processes and mental workload among other relevant topics; and (c) organizational ergonomics, which is concerned with relevant topics that include work design, design of working times, teamwork, and quality management among other relevant topics.

The foundation of ergonomics appears to have emerged in ancient Greece. Evidence indicates that the Hellenic civilization in the fifth century BC used ergonomic principles in the design of their tools, jobs, and workplaces.[29] Similarly, TPS uses ergonomic principles measuring success in four areas: safety and ergonomics, quality, delivery, and cost. The TPS philosophy suggests ergonomics is a precursor to delivering on objectives of quality, delivery, and low cost. Since ergonomics focuses on employee safety and comfort, it is clearly central to promoting a lean organizational culture.

Metrics and Rewards

Metrics and rewards are an integral element of a firm's culture. Metrics are used in a variety of ways. They are used to assess performance. They are also used to allocate assets and to assist in the selection of strategic alternatives. Metrics effect decisions and actions as well as influence behavior. Interestingly, we have all witnessed the case where metrics can have subtle, counterproductive consequences. For example, if one evaluates assembly-line workers simply based upon a piece rate, disastrous quality is likely to result. Therefore, choosing the correct set of metrics to achieve system goals is critical to success.

Similarly, rewards are used to encourage improvement and to reinforce good behavior. There are some useful practices to both avoid and follow when designing a metric system for assessing performance and rewarding superior behavior or performance. In the following text are some useful guidelines for establishing metrics and reward systems.

People do possess the ability to learn. Learning simply means altering behavior. Metrics and rewards can alter behavior, so both are important. In order to effectively alter behavior, it must be understood that most people have an inherent need to immediately see their ideas have merit and their actions add value. Metrics and rewards used to assess performance and to reinforce appropriate behavior in moving a firm toward its objectives must be timely. Metrics must measure today's outcomes, and rewards must follow soon after. People will tend to perform activities, which have a more immediate impact if metrics are used to assess long-term performance (e.g., several years). Similarly, if rewards occur late, they will not offer good value.

In order to design an effective metric and rewards system, a thorough understanding of customers, employees, work processes, suppliers, and the underlying nature of each metric is essential.[30] Since metrics and rewards alter behavior, understanding the wants, needs, and desires of customers is an essential input for designing a behavior altering system. Direct interviews enable customers to articulate this understanding and better enable a firm to prioritize system outcomes. It is imperative to promote this *voice of the customer*.

In a similar manner, employees are internal customers and have an important voice that should be heard. People have different motivating forces. Therefore, when designing a metrics and rewards system, one should consider the different types of rewards. There are positive and negative methods of reinforcement. Similarly, there are both intrinsic and extrinsic rewards. As noted earlier, intrinsic motivators refer to attributes of the work itself that drive people to engage and perform, provide energy, as well as create enthusiasm. Examples of intrinsic motivators are the leader's capability or expertise, the respect the work will afford, the challenge and interest of the work goal(s) or the ownership of the work, opportunities the work offers for learning and expanding one's skills, an opportunity to provide value, or the opportunity to work with friends or respected colleagues. Again, it has been observed that challenging work goals that are clear and specific are the single best intrinsic motivators.[31] It is important to understand that intrinsic rewards can have significant monetary value for subordinates. Many of these intrinsic rewards are low cost to firms but can offer high value to employees.

In contrast, extrinsic motivators refer to attributes or motivation sources outside of the work. Examples of extrinsic motivators are promotion possibilities, economic incentives, and the possibility of penalties. Less mature, younger workers often have greater or more immediate financial needs and consequently relate better to economic incentives. Many of these extrinsic rewards can represent significant cost to firms and can be easily misunderstood by employees as an owed rather than an earned reward.

Metrics and subsequent rewards should be under the control of the individual. Metrics and outcome rewards that are dependent upon the behavior of another individual(s) may not effectively drive the desired behavior. People will gravitate toward activities they have full control over. However, it must be recognized that a mixture of both individual and group rewards is important. Individual rewards are important because group rewards offer reinforcement to all team members, some of whom may not have contributed. Group rewards are important because people tend to withdraw if they are not recognized for long-term efforts and individual rewards do not recognize all contributors. Group rewards also recognize and emphasize *team* performance. In order to afford control, individuals should be allowed to participate in metric and reward system design.

Metrics and rewards can have subtle, counterproductive consequences. For example, it may be possible to achieve target quality levels, but in doing so, a firm can lose sight of a competing objective of low cost per unit. For instance, products can be overly engineered in order to achieve quality targets. Metrics and rewards that alter behavior must recognize all of a firm's intended objectives.

Prior to designing metric and rewards systems, an understanding of work processes should exist. A thorough understanding of the *current state* of a process or system, an example of which can include current cycle times, downtimes, inventory levels, material flow paths, and information flow paths, is intended to serve as a baseline to guide implementation efforts toward achieving a desired *future state* and to evaluate those efforts.

It is also important to have a systems perspective. It must be recognized that system elements, including customers, employees, work processes, suppliers, and even each metric exert interdependent influences on system metrics and resultant rewards. For example, customers may desire superior quality, but the chosen supplier may be experiencing pressures to reduce costs leading to reduced quality of incoming materials.

It is also important for metrics to be parsimonious. If the effort of a metric exceeds its usefulness, it is clearly not worth the collection effort. Data collection efforts can lead employees away from value-added activities. The process location, frequency of collection, and the extent of information collected must be predetermined. Data may be defects due to unmet specifications regarding characteristics such as length, width, height, weight, or volume. Data may be flow interruptions due to late materials, poor machine reliability, missing tools, or unavailable operators. Data may also reflect simple abnormalities. Regardless of the nature of the data, the information captured must be honest. It is easy for data to be distorted, biased, or skewed. We all know averages can be misleading. The metrics captured must be reliable for adjusting output for continuous improvement. Smaller time increments between data capture may bring issues to light sooner. It is difficult at best to determine an appropriate time interval, but as a rule of thumb, established and stable operations should use a smaller or more frequent increment. Similarly, if performance results are taken at more locations, it may be easier to pinpoint the source of variation.

Summary

Organizational culture refers to a set of workplace assumptions that are learned over a long-term time horizon, which serve to guide overt attitudes and practices of a group. The culture of an organization consists of values, beliefs, attitudes, practices, behaviors, norms, and habits. Culture is simply the way things are done in an organization. Leadership has the responsibility for establishing a lean culture by reinforcing appropriate behaviors, which promote improvement and waste elimination change efforts. The process of change often proceeds in a stepwise manner. Small, localized efforts typically occur first and if successful, may eventually lead to larger-scale, multifunctional, or even value chain network initiatives.

There are many contributing elements to organizational culture. Important elements impacting organizational culture examined in this chapter include

1. Agreement of a shared long-term vision, goals, and strategies. Attaining agreement among various stakeholders in order to address performance gaps is essential for establishing a lean culture. Ambivalence to change makes attaining agreement and resultant improvement initiatives difficult as those who perceive benefits by maintaining the status quo may resist change.
2. Standardization of methods for reducing variability. Standardization does not refer to eliminating differences of opinion. Rather, a lean environment should encourage the generation of different ideas. Standardization is aimed at eliminating variability that is encountered in the performance of a single activity.
3. The PDCA cycle. This concept recognizes the important benefits to be derived from planning and checking (verifying) activities. Planning facilitates later accomplishment, significantly shortening effective execution durations. Checking entails comparing actual

execution versus planned execution so that learning and corrective action may be taken in the future.

4. Hoshin kanri and nemawashi. All levels of planning, strategic, tactical, and operational, should be done following a group process. Although more time-consuming, it promotes numerous benefits, including increased idea generation, greater plan support, subordinate development, enhanced morale, and the promotion of team-based norms of productivity.
5. Creation of a learning organization. Kaizen is a learning approach based largely on evaluating past experiences through observation, questioning, and making subsequent changes.
6. Recognizing one's team as an asset. Recognizing one's team as an asset and investing in one's team facilitates creating a learning organization.
7. Wellness programs. These programs recognize the value of people, the single most important asset of an organization.
8. Ergonomics. This promotes the safety, comfort, and productivity of employees.
9. Metrics and rewards. The measures and rewards used to assess and recognize the efforts of people eventually lead to directing employee behaviors. It is imperative to align these with initiative goals. Useful guidelines for establishing metric and reward programs have been noted.

Although the theme throughout this chapter has focused on the creation of a lean organizational culture, it must also reflect the fact that business is increasingly conducted on a global scale today. This is true even for services, as technology is increasingly making it easier to export a variety services. Therefore, when discussing culture, one must be cognizant not only of organizational culture but also of geographic cultures.

Although the concept of varying global cultures goes beyond the scope of this book, multinational organizations must be cognizant of widely divergent local cultures and business practices to survive and thrive. Varying cultural differences represent change. Improvement practices, regardless of their origin, should always be encouraged and sought.

CHAPTER 4

Lean Team

The third element of lean management is the use of a team-based approach. The logic for utilizing teams can be summed up by Aristotle's idea that "the whole is greater than the sum of the parts."[1] Namely, a team possessing the correct camaraderie and *esprit de corps* will facilitate objective attainment. As noted by Taiichi Ohno, "A championship team combines good teamwork with individual skill."[2] A team-based approach promotes system goals further than any group of individuals acting independently can. Baines and Langfield-Smith observe in their study of 151 organizations that a shift toward a strategy to differentiate the organization from competition typically results in an organization design that relies upon greater use of team-based structures.[3]

Lean is primarily about management, workers, and the trust that binds the two. These are the critical elements of a lean system.[4] The Italian philosopher Machiavelli (1469–1527) has been attributed with the following observation:

> There is nothing more difficult to plan, more doubtful of success, nor more dangerous to manage than the creation of a new system. For the initiator has the enmity of all who profit by the preservation of the old system and merely lukewarm defenders in those who would gain by the new one.[5]

The point to be understood from this observation is that lean implementations often change companies, threatening (or appearing to threaten) both corporate culture and customary ways of conducting work. This observation underscores the importance of a team-based approach and gaining 100 percent agreement and participation for achieving improvement objectives.

This chapter examines four key concepts regarding the use of teams. First, the identification of team members and team composition is discussed. Second, the leader's role in approaching and developing a team is discussed. Third, a seminal team development process and maturation model is reviewed. Finally, effective teams require team member participation. Five approaches for gaining team member involvement are discussed to conclude the chapter.

Team Member Identification and Team Composition

There exists some thought-provoking and debatable insight into the development of a team.[6] In an earlier chapter, it was noted that people have the capacity to learn or to alter their behavior and to add to their skills and capabilities. An interesting guideline for team construction is based upon this notion. Namely, one should first consider examining a person's inherent traits and characteristics rather than the person's specific educational background, practical skills, specialized knowledge, or work experience. Although these latter items can assist people to "hit the ground running," they can also be learned. A person's inherent traits and characteristics are difficult to change or to learn.

It has been suggested that people with desirable inherent traits and characteristics will require less managerial and motivational effort, will more easily and more quickly adapt to a changing world, will more likely support needed changes in direction, and will unify behind decisions, regardless of parochial interests.[7] These qualities are clearly desirable as firms alter course from the current state to pursue objectives associated with an ideal state. Team member traits and characteristics are positively correlated with the ability to achieve improvement objectives.

It is important to establish your team prior to establishing the objectives and strategies for your team for five reasons.[8] First, establishing your team and then setting the agenda with them creates team building, a "buy-in" consensus, motivation, and a longer list of options to consider, and it develops leaders for the future.

Second, if you begin with your team prior to establishing the plan and strategies, you can identify those team members who can more easily adapt to a subsequent changing team composition. There is a well-defined team development and maturation process (discussed in "Team Development Process and Maturation Model"). Changes in team member composition, especially in the form of the team leader, have significant consequences on team performance. Teams comprising people who easily adapt will find changes in team composition less disruptive.

Third, it is desirable for team leaders to spend less time motivating team members and more time pursuing improvement objectives. Inherent traits and characteristics will determine in part how much time is spent motivating team members. Some people are self-motivating. Furthermore, the savings of reduced absenteeism when workers look forward to going to work can be significant.

Fourth, even if an outstanding vision, plan, and strategies are outlined for a team, if the team is composed of the wrong members, the likelihood of success is greatly diminished. Great vision without an effective team is largely irrelevant. This is true for the duration of an improvement project as well. Namely, if you believe you need to make a personnel change, act and make a change. Otherwise, you will expend a lot of energy on and off the job dealing with the wrong person(s), and the right people will question your leadership abilities.

Finally, it may be prudent for a leader to put the "best" person(s) on the firm's biggest opportunities, not the biggest problems. The reason for this suggestion is that if you put him on problems, you limit his abilities. The best that can happen is that the problem is solved and goes away. The limits of an opportunity, by its nature, are often unknown. By placing this person on the biggest opportunity, you can leverage his capabilities to the fullest extent and take advantage of the most the opportunity has to offer.

It is important for leaders to realize that a team possessing the correct camaraderie and *espirit de corps* will facilitate objective attainment. Leaders who instill successful change often do not first develop a plan and then identify the team. Rather, these leaders typically identify the team and then jointly develop the plan.

Leader's Role in Developing Teams

Leaders do play an important role in developing a team. Many of the following suggestions were noted in the chapter devoted to lean leadership.

First, the style of leadership is critical for promoting objective attainment. Good practices such as relying upon a participative approach, communicating an awareness of the task importance, encouraging members to focus on the team or organization goals rather than self-interests, and assisting subordinates to fulfill their potential should be utilized. Most people respond more favorably to positive methods of reinforcement. Highlighting the challenge and interest of the work goal(s), delegating and granting greater authority or the ownership of the work to team members, providing opportunities to learn and expand one's skills, as well as an opportunity to demonstrate one's value to the team are highly effective motivators for leaders to remember.

Team leaders must be cognizant of individual team member's needs. People have differing needs regarding the extent of job structure, attention and contact, sharing ideas, as well as receiving praise and rewards. Initial team member identification is not sufficient. It is imperative that team leaders develop the team during initiatives as well.

Team leader attributes are important too. Leader attributes such as honesty, integrity, and character are vital for achieving an effective culture, team unity, an ability to resolve conflict, and leadership support. Team leaders play an integral role in evaluating, compensating, and promoting team members. These attributes will help to create a fear-free environment where nothing is sacred, questions can be asked often, and problems can be revealed. These attributes are critical for success.

Since lean is based upon improvement through change, it is imperative that leaders invest in team members' training, education, and skills. This includes cross-training team members, which promotes flexibility and greater idea generation. These are prerequisites to facilitating tomorrow's change, as tomorrow's work needs to be performed better than it has been today. Recognition that the most important asset of any firm is its employees necessitates investing in the capabilities of this asset. Leadership must promote, encourage, and actually involve itself in the process for improving education and skills through continuing teaching, learning, and training. An organization that can effectively build quality into its people is more likely going to be able to produce quality in its products and services. Simply put, leaders must devise an effective system. This is not the vision of a single person but of the many who participate in it.

Knowledge management (KM) is an emerging area of commercial and academic research. Presently, it comprises a range of strategies and practices used in an organization to identify, create, represent, share, and preserve information. The information comprising the knowledge base of KM systems resides in the lessons learned by individuals. KM is employee capabilities. KM is embedded in organizational processes or practices. This knowledge base should be considered a valuable organizational asset. Similar to other organizational assets, leaders must recognize the importance of investing in employee capabilities as well as preserving and sharing this asset within value chain networks.

Similar to the process of implementing change referred to in earlier chapters, knowledge base develops in a phased manner. Initially, the information, insights, and experiences of an internal, localized transformation activity are created. The firm then typically seeks to integrate and coordinate this knowledge across a broader set of activities or systems within the firm. Subsequently, these capabilities are embedded within the processes and practices of the entire firm, making them multifunctional and organization based. Eventually, firms that have successfully deployed the knowledge base on a multifunctional scale will seek to have this knowledge base serve as a network-based asset reaching outside the limits of their transformation processes in order to encompass the value chain network.

The knowledge base of one's team is critical to the attainment of lean objectives. Effective lean leaders understand its value for sustaining the organization. As it accrues, the sustainability of an organization should improve as long as the entrepreneurial spirit remains.

Team Development Process and Maturation Model

As noted in the section "Team Member Identification and Team Composition," the development of a team should consider peoples' inherent traits and characteristics, not simply their capabilities. People with superior or more desirable inherent traits and characteristics may require less managerial and motivational effort and may more easily and quickly adapt to a changing world. These people often unify behind decisions, regardless of their own self interests.

Once a team has been formed, there is a well-defined team development and maturation process.[9] We have all experienced it. This process model merits discussion as we can benefit from a clear understanding of it. The process is best described by the following four stages.

The first stage of the team development and maturation process model has been referred to as *forming*. In this initial stage, team member introductions occur and initiative objectives are shared. This stage represents a discovery process. Therefore, during this stage, team member behavior is typically cordial, reserved, and formal.

The second stage of the process is not typically characterized by such cordial and formal behavior. Rather, it is during this stage that confrontational behavior often begins. This stage is commonly referred to as the *storming* stage. Here, members begin trying to establish a "pecking order." Members often attempt to establish a dominance hierarchy, which is believed to reduce the incidence of conflicts. Civil people subconsciously understand that conflicts represent the potential for a greater expenditure of energy.

The third stage of the process is referred to as the *norming* stage. Effective work patterns begin to emerge during this stage because team members have developed a familiarity with one another. It is during this stage that team members begin to tackle improvement efforts and problems rather than personal issues. During this stage, mutual respect develops; so joint decision making may begin to emerge.

The fourth stage of the process represents mature group development. This stage is often referred to as *performing*. In it, a high level of respect and trust has been achieved, and consequently there is the potential for effective and efficient team performance to emerge.

An understanding of this process model suggests that lean leaders adapt their leadership styles to account for team member behaviors and development along this model's path. Earlier development stages suggest that a directive style may be more appropriate. Later development stages suggest that a delegating style may be more appropriate.

The consequences of functional teams include greater initiative and team member commitment, higher job satisfaction and morale through a sense of belonging, fewer conflicts, and more successful initiatives. The consequences of dysfunctional teams include lower motivation, frequent conflict and disagreement, greater lack of respect, poor communication, and an increased likelihood for initiative failure.

Furthermore, whenever there is a change in team composition, the development stages typically start over again. This is one reason why it is so critical to have the right team and why leadership is the most important lean element.

Team Member Involvement: *Hoshin Kanri*, Quality Circles, *Kaizen* Events, and Suggestion Programs

Team member involvement is the heart of lean production. The most important asset of any firm is its human resources. Using teams represents an understanding by leaders that people are the firm's most important asset. Team member involvement is aimed at nurturing a company's human resources.

For decades, Toyota's Production System has referred to its team-based approach as *respect for people*. In order to gain employee involvement, leadership must demonstrate respect for the worker by sharing the vision and communicating the need for employee involvement. Leadership must instill confidence in workers that continuous improvement efforts are necessary and will not result in job losses but rather deployment. Otherwise, mistrust will prevail and employees will withdraw and possibly even sabotage improvement efforts. The leadership skills and motivation concepts previously addressed are absolutely critical for achieving employee involvement.

Not only must leaders share the vision and communicate the need for employee involvement but there must also be an understanding by team members of the necessity for improvement changes. One of the best sources for improvement ideas is the factory floor. Various tools are used to achieve greater involvement, including group planning (hoshin kanri), quality circles (QCs), kaizen events, and employee suggestion programs.

Although it is time-consuming, the *hoshin kanri* process (discussed in Chapter 3) can turn skepticism and resistance into support, create cross functional cooperation, fully engage the workforce in developing executable strategies, link improvement and corrective actions with financial results, and better enable the team to respond to changes and setbacks.

Furthermore, effective use of teams tends to offer a self-regulating feature. Teams commonly promote norms of productivity and behavior in a horizontal manner. Individual team members are expected to adhere to these norms through informal peer pressure or formal assessment mechanisms. Teams possessing strong identities can serve as powerful horizontal incentive mechanisms, with the possibility of rendering sanctions, enforceable side contracting, as well as peer pressure resulting in enhanced performance.[10]

A QC is tool used to generate direct employee involvement in the improvement process. It is typically a small group of 3 to 10 employees doing related work that meets at regular intervals. QCs represent a decentralization of leadership's responsibility for continuous improvement. QCs offer numerous benefits, including the opportunity to provide substantial individual motivation and confidence, improve managerial decision making as two heads are usually better than one, provide an opportunity to promote a sense of teamwork, a tendency to enforce group norms or expectations, as well as an opportunity to improve morale and meet social needs.

There are several caveats regarding the use of QCs. First, although one objective for the tool is to encourage greater involvement, QCs should operate on a voluntary basis. This is the reason why it is important to communicate the need for employee involvement. It is also important for leadership to convey expectations for this involvement tool. Its regular agenda should be confined to improvement objectives. Similarly, it is important to manage members' expectations. Most improvement comes in small incremental steps. Rarely are significant improvement leaps encountered. Managing expectations attempts to keep motivation higher as leadership and team members alike may become frustrated with small and infrequent improvement achievements.

Similar to QCs are the use of kaizen events or kaizen circle activities. Although kaizen itself recognizes never-ending, continuous improvement, a *kaizen event* is typically a short-term activity aimed at achieving small, incremental improvement commonly in a localized aspect of a process.

Suggestion programs should be an integral element of any kaizen program. A *suggestion program* is a tool that solicits ideas for improvement directly from employees. It recognizes that many improvement ideas are generated by employees themselves. Suggestion programs focus on continually engaging employees.

Suggestion programs that have been the most successful over the long term possess the following characteristics. First, management response time to suggestions must be standardized. For example, a response must be forthcoming within a week of the suggestion. It can be demoralizing if effort is put forth, with no response being offered.

Second, the response offered must provide constructive feedback. It must acknowledge the value of the suggestion, provide an explanation of what will be done with the suggestion, explain why the chosen course of action is being taken, and note when the action is to be taken.

Third, any changes implemented as a result of improvement initiatives should become standardized practice. Standardization of practices (discussed in Chapter 5) reduces variation.

Fourth, suggestion programs must provide a mix of rewards, both individual and group rewards as well as rewards that go beyond financial incentives. If an individual receives an award that ignores the contribution by several others, those not recognized will find the process demoralizing. If a group receives an award when a member(s) did not make a contribution, as a minimum, frustration by deserving recipients will ensue. Suggestion programs should also be aimed at intrinsic and extrinsic motivators. Remember, the single best motivator for most people is challenging work goals. Suggestion program rewards ought to have a process focus in addition to a results focus.[11] For example, it is important to emphasize the extent of involvement such as the number of participants and the number of suggestions, not simply the value of the suggestions.

Fifth, suggestion programs must not overlook the contributions made by the evaluators themselves. A prompt and thorough assessment program of the hopefully numerous suggestions can represent a valuable but significant workload. Rewards for evaluators should not be overlooked.

Metrics and Rewards

The design of metrics and reward systems are also important for encouraging involvement. As noted earlier, metrics affect decisions and actions as well as influence behavior. Rewards are used to encourage improvement

Table 4.1 Guidelines for metric and reward systems design

1. Metrics and rewards must be timely.
2. A thorough understanding of customers, employees, work processes, suppliers, and the underlying nature of each metric is essential.
3. Consider a mixture of reward types: positive and negative, intrinsic and extrinsic, individual and group.
4. Metrics and subsequent rewards should be under the control (design) of the individual.
5. Metrics and rewards that alter behavior must recognize all of a firm's intended objectives.
6. Metrics and rewards should have a systems (holistic) perspective.
7. Metrics should be to be parsimonious (simple, yet effective for the intended purpose).

and to reinforce good behavior. Aligning rewards with desired behaviors is important for integrated team-based systems.[12] Guidelines for establishing metrics and reward systems were identified in the previous chapter. In order to reduce repetition, these guidelines are simply reiterated in Table 4.1.

Summary

Individuals often perceive the change resulting from lean implementations as threatening. It may be as benign as a change in the standard methods for performing a task, possibly changing the organizational culture itself, or more dramatically, threatening one's employment.

This chapter examines four key concepts regarding the use of teams. The concepts addressed are

1. The identification of team members and team composition. Five observations are offered for identifying team members.

2. The leader's role in approaching and developing a team. Suggestions are offered for the role leaders can play in developing effective teams over time.
3. A seminal team development process and maturation model is reviewed.
4. Effective teams require team member participation. Five approaches for gaining team member involvement are discussed.

It is imperative that the leader align team member efforts. The leader must create the conditions so that all of the team members are working toward organizational goals. This necessitates communicating the vision by words and *actions* so subordinates understand and pursue *shared* goals. It is important to remember that a team possessing the correct camaraderie and *espirit de corps* will facilitate objective attainment.

CHAPTER 5

Lean Practices and Tools

Reducing variation in any system or process is a fundamental principle, which precludes waste elimination. When followed and used, lean practices and tools can help to reduce variation and waste as well as serve as a microscope for identifying improvement opportunities. Lean practices are planning approaches used throughout the transformation process. Lean tools are specific analytical methods and problem-solving approaches. It is not the intention to differentiate between practices and tools here because it is often only a subtle difference between the two. Rather, the focus for both is helping to identify causes of variation and waste, which can eventually lead to variance reductions and improvement.

Typically, a keen understanding of the process is required in order to understand the source of variation prior to its reduction. Namely, you want to put the process under a microscopic focus in order to address process improvement. It must be understood that all processes have random variability. It is inherent. It is imperative that processes are stable in order to differentiate between random variability and actual waste (assignable variation). Lean tools help promote a common understanding of the current system state as well as direct improvement efforts of stable processes. If a process is unstable, any improvement pursuit may simply be chasing phantoms.

Often the application point for the lean microscope differs, depending upon the environment. For example, in lower-volume, batch environments, the examination of connections and flows between resources is critical for waste reductions. This is true due to downstream arrival delays, given longer upstream process times of batches. Therefore, it is important for system drumbeat or *takt time* (defined in "Takt Time") to be consistent between connecting process resources. Alternatively, in higher-volume, repetitive processes, it is assumed that processes are initially designed with a common takt time across system resources. Therefore, a greater focus on the productivity of the resources themselves should be pursued. In particular, a measure such as *overall equipment effectiveness* (OEE) and the six big losses of equipment utilization, which focus on equipment availability (equipment failure, setup, and adjustment), equipment speed loss (idling, minor stoppages, and reduced speeds), and output loss due to lower quality (defects and reduced yields) are useful.[1]

In addition to a sharp focus on process for identifying and reducing sources of waste, not all lean practices and tools are equally applicable in all types of environments. For example, consider the use of *heijunka* or production leveling for service environments. Although production leveling may be accomplished to a degree, it is difficult at best for services to level production because of an inability to inventory a finished product and because of an expectation for offering a relatively short order response time. Although it may be possible to level or influence demand to some extent using incentives or other devices, transformation processes of services must be flexible in order to be responsive to varying demands.

There are numerous lean practices and tools. Although it may not be an exhaustive list, many of these are examined in the following sections. Is should be noted that one's imagination and creativity in solving problems is useful for identifying and designing lean practices and tools.

Standardization

A *standard* is a rule or an example that provides clear explanation for an outcome. A standard is the current, best method. It serves as a benchmark to assess or judge alternatives, and, as such, standards should always be changing to reflect achieved improvements. Standards also serve to make out-of-control conditions obvious.

Characteristics of effective standards include the following. First, they should be simple and specific so that they are readily understood. Second, it is desirable for them to be visual to further reduce the possibility of misunderstanding. And, third, it must be recognized by all that they are to be followed. If five employees, each doing the same task, ignored the standard and did it their own way, there would likely be five different outcomes or variations.

Masaaki Imai noted that standards should have the following six points.

1. Individual authorization and responsibility
2. Transmission of individual experience to the next generation of workers
3. Transmission of individual experience and know-how to the organization
4. Accumulation of experience (particularly with failures) within the organization
5. Deployment of know-how from one workshop to another
6. Discipline[2]

The first point reflects that individuals have the obligation in their formal roles in the organization to follow standards. It further suggests that individuals must have the authority, or the power, to implement the standard to complete their assignment. This point should also include that when one possesses the responsibility and authority, one should be accountable for applying the standard as well. Namely, *accountability* is the state of being totally answerable for the satisfactory completion of a specific assignment. Points 2 through 5 suggest that workers must be involved in sharing their knowledge. It should be shared with others in addition to making it part of the organizational history. This includes mistakes, as they are learning opportunities for all. Mistakes are costly. The impact of the mistake can be lessened if it can prevent others from repeating it. The last point of discipline refers to the fact that standards must be requirements that are to be adhered to religiously in order to reduce variation.

Whereas standards refer to a current best method, standardization means achieving the expected outcome using planned routines. The act of standardization refers to developing, communicating (orally, written, and visually), utilizing, improving, and sharing standards throughout the organization. The development of standards (and improvements) is based upon a scientific method. This is a process of inquiry based on formulating a hypothesis (an expectation), capturing observable and measureable evidence to test the hypothesis, assessing the validity of the evidence, and drawing conclusions to accept, reject, or modify the hypothesis to guide future standards.

An integral element of standardization is the use of *standard work instructions* (SWIs). An SWI is simply a set of specific instructions that allow tasks to be completed in a consistent, timely, and repeatable manner. It is desirable for SWIs to be written and accompanied by a visual portrayal depicting the sequential nature of the work to be completed. SWIs should be posted at or near the location of the task to be performed.

SMED or Quick Changeover

The concept of single-minute exchange of dies (SMED) refers to quick tool changeover times between production orders. The phrase "single minute" does not mean that all changeovers and startups should take only 1 minute, but that they should take less than 10 minutes or be a single digit. This rapid changeover is key to reducing production lot sizes and improving flow, and it is an absolute prerequisite to achieving an objective of system flexibility.

The SMED concept was conceived in the mid-1950s.[3] In an environment producing a diversified group of commonly ordered items, it was observed that bottlenecks were caused by long tool changeover times, which drove up production lot sizes resulting in large inventories. Traditionally, if setup times were long, lot sizes for these commonly ordered items were large in order to achieve economies of scale. This preference spread setup costs over a greater number of units, thereby driving unit costs down.

If setup times could be reduced, the consequential lot size and inventory would also be reduced. Three common implementation techniques promote SMED.[4] These three steps include the following.

1. Separate internal setup activities from external setup activities. This is the most important step. One should perform external setup activities for the next production order while the current production order is being processed. *Internal* setup activities are those that can be performed only when the machine is stopped. *External* setup

activities (e.g., prestaging the required tools for the next order) for the subsequent order can be done while the current order is being processed.

2. When possible, convert internal setup activities to external setup activities. Examples include preheating parts and using self-aligning jigs.
3. Streamline all aspects of the setup task, both internal and external activities. Several practices can be followed to achieve streamlining, including

    a. Standardize function, not shape: For example, standardized or common parts, standardized assembly tools and steps, and utilization of common tooling can all reduce setup times or the number of setups. For example, use multipurpose die sets.
    b. Use functional clamps or one-turn attachment devices, which are faster than threaded rods for hold-downs (or eliminate fasteners altogether if possible).
    c. Use standardized jig plates.
    d. Adopt parallel operators to avoid non-value-added (NVA) activities such as walking while performing setups.
    e. Eliminate adjustments. This reduces variation and results in first pieces being good pieces.
    f. Finally, mechanization of die movements, tightening, loosening, and adjustments may permit further setup time reductions.

After SMED improvements have been achieved, the next challenge, which is closely associated, yet more difficult is one-touch exchange of dies (OTED), which refers to performing setup changes in less than one minute. The concept suggests that as long as a changeover is necessary, it should be performed with a single motion. The ultimate objective for SMED and OTED is *one piece flow*, or single-unit production lot sizes.

Value Stream Mapping

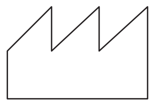
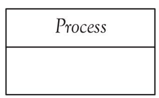
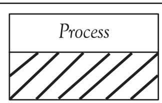
Value stream mapping (VSM) is best understood as a visual technique for depicting the sequence of activities required to design, produce, and offer a product or a service as well as the necessary information and support flows. The tool entails creating a visual portrayal of the *current state* of a process or system, which includes current cycle times, downtimes, inventory levels (raw materials, work in process, and finished goods), material flow paths, and information flow paths. The depiction of the current state is intended to guide the user's efforts toward determining a desired or ideal *future state* and possible implementation plan. Although the scope of a VSM can be small, it was originally intended to be a broader tool than process mapping, as it is often used to portray an entire supply chain's value stream.

Although most certainly derived from Gilbreth's process mapping approach, the development of VSM in its most popular form is credited to the Toyota Production System (TPS) and was first popularized in 1988.[5] Various VSM symbols are used to portray the placement of an order by a customer, activities within a supplier order processing system, relaying of information to a vendor, and subsequent value-added (VA) order process activities (e.g., fabrication, assembly, distribution), as well as any and all NVA delays (e.g., setups, queues, material movements, and storage).

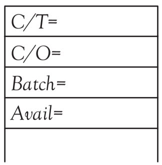
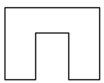
There are many VSM symbols, which are used to portray the material and information flows. These symbols are often divided into four groups: (a) process, (b) material, (c) information, and (d) general symbols. Some of the more common symbols along with a symbol interpretation are shown in the following text in Table 5.1.

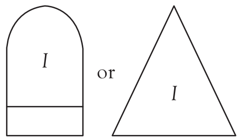
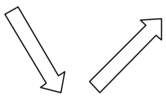
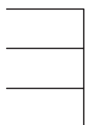
One of the more important symbols is the *timeline* symbol depicting VA times and NVA times. It often reveals common wastes due to queue times, material movements, long setup times, storage times, and inspection times, all of which are NVA activities as viewed by the customer. Two additional important VSM points need to be observed. First, although timeline values may be attributed to NVA activities, that does not necessarily mean NVA times are *avoidable*. Some NVA activities are simply *unavoidable*. An example of this is material movements or transports. Although it may be possible to reduce the extent of NVA activities, goods must be moved from one location to another during any transformation process. While being an NVA activity, movements, as well as many other activities, are simply unavoidable waste. Second, it should also be noted that the user is encouraged to create new VSM symbols for specialized applications.

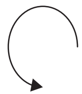
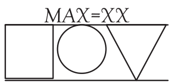
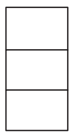
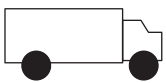
*Table 5.1 Common value stream mapping symbols**

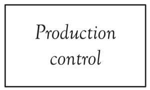
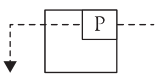
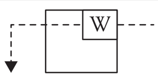
VSM process symbols	Symbol interpretation
 Customer/supplier	This icon represents the supplier when in the upper left, the usual starting point for material flow. The customer is represented when placed in the upper right, the usual end point for material flow.
 Dedicated process	This icon is a process, operation, machine, or department, through which material flows. Typically, to avoid unwieldy mapping of every single processing step, it represents one department with a continuous, internal fixed flow path. In the case of assembly with several connected workstations, even if some work in process (WIP) inventory accumulates between machines (or stations), the entire line would show as a single box. If there are separate operations, where one is disconnected from the next, inventory between, and batch transfers, multiple boxes would be used.
 Shared process	This is a process, operation, department, or work center that other value stream families share. Estimate the number of operators required for the value stream being mapped, not the number of operators required for processing all products.

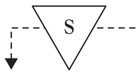
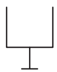
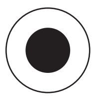
* Adapted from http://www.strategosinc.com/value-stream-mapping-3.htm

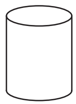
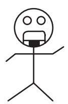
VSM process symbols	Symbol interpretation
 Data box	This icon goes under other icons that have significant information or data required for analyzing and observing the system. Typical information placed in a data box underneath “Factory” icons includes the frequency of shipping during any shift; material handling information; transfer batch size; demand quantity per period; etc. Typical information in a data box underneath “Manufacturing Process” icons includes:—C/T (cycle time) = the time (in seconds) that elapses between one part coming off the process to the next part coming off; C/O (changeover time) = the time to switch from producing one product on the process to another; uptime = the percentage time that the machine is available for processing; EPE (a measure of production rate/s; the acronym refers to “Every Part Every___.”); Number of operators (use OPERATOR icon inside process boxes); Number of product variations; Available Capacity; Scrap rate; Transfer batch size (based on process batch size and material transfer rate).
 Work cell	This symbol indicates that multiple processes are integrated in a manufacturing work cell. Such cells usually process a part family or a single product. Product moves from process step to process step in small batches or single pieces.

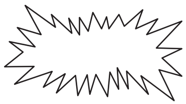
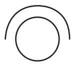
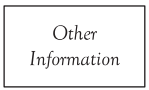
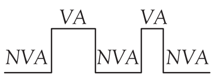
VSM material symbols	Symbol interpretation
 **Inventory**	These icons show inventory between two processes. While mapping the current state, the amount of inventory can be approximated by a quick count, and that amount is noted beneath the triangle. If there is more than one inventory accumulation, use an icon for each. This icon also represents storage for raw materials and finished goods.
 **Shipments**	This icon represents movement of raw materials from suppliers to the receiving dock/s of the factory or the movement of finished goods from the shipping dock/s of the factory to the customers.
 **Push arrow**	This icon represents the "pushing" of material from one process to the next process. Push means that a process produces something regardless of the immediate needs of the downstream process.
 **Supermarket**	This is an inventory store or "supermarket" where a small inventory is available, and one or more downstream customers come to the supermarket to pick out what they need. The upstream work center then replenishes stocks as required. When continuous flow is impractical, and the upstream process must operate in batch mode, a supermarket reduces overproduction and limits total inventory.

VSM material symbols	Symbol interpretation
 Material Pull	Supermarkets connect to downstream processes with this "pull" icon that indicates physical removal.
 FIFO lane	First in, first out (FIFO) inventory. Use this icon when processes are connected with a FIFO system that limits input. An accumulating roller conveyor is an example. Record the maximum possible inventory.
 Safety stock	This icon represents an inventory buffer (or safety stock) against problems such as downtime, to protect the system against sudden fluctuations in customer orders or system failures. Notice that the icon is closed on all sides. It is intended as a temporary, not a permanent storage of stock.
 External shipment	Shipments from suppliers or to customers using external transport.

VSM information symbols	Symbol interpretation
 **Production control**	This box represents a central production scheduling or control department, person, or operation.
 **Manual info**	A straight, thin arrow shows general flow of information from memos, reports, or conversation. Frequency and other notes may be relevant.
 **Electronic info**	This wiggle arrow represents electronic flow of information or data. It can indicate the frequency of information or data interchange, the type of media used, (e.g., fax or phone), and the type of data exchanged.
 **Production kanban**	This icon triggers or pulls production of a predefined number of parts. It signals a supplying process to provide parts to a downstream process.
 **Withdrawal kanban**	This icon represents a card or device that instructs a material handler to transfer parts from an inventory store (e.g., a supermarket) to the receiving process. The material handler (or operator) goes to the supermarket and withdraws the necessary items.

VSM information symbols	Symbol interpretation
 Signal kanban	This icon is used whenever the on-hand inventory levels in the inventory store (e.g., a supermarket) between two processes drops to a trigger or minimum point. When a triangle kanban arrives at a supplying process, it signals a changeover and production of a predetermined batch size of the part noted on the kanban. It is also referred to as "one-per-batch" kanban.
 Kanban post	A location where kanban signals reside for pickup, for example, a simple sign board.
 Sequenced pull	This icon represents a pull system that gives instruction to subassembly processes to produce a predetermined type and quantity of product, typically one unit, without using a supermarket.
 Load leveling	This icon is used to represent production leveling over a period of time.

 MRP/ERP	Scheduling using material requirements planning (MRP), enterprise resource planning (ERP), or other centralized system information planning system.
 Go see	Gathering of information through visual means, for example, gemba walk.
 Verbal information	This icon represents verbal or personal information flow.

VSM general symbols	Symbol interpretation
 **Kaizen burst**	This icon is used to highlight improvement needs and plan kaizen workshops at specific processes that are critical to achieving the future state map of the value stream.
 **Operator**	This icon represents an operator. It shows the number of operators required to process the VSM family at a particular workstation.
 **Other**	Other useful or potentially useful information.
 **Timeline**	The timeline shows value-added (VA) times (cycle times) and non-value-added (NVA) times. Use this to calculate lead time or throughput time.

While creating the current state map, it is best to involve a diverse team representing the affected area. Involve affected customers or suppliers or both to get a complete picture if the VSM extends outside the transformation process. Use averages for process times. The essential question to ask when assessing the current state is whether an activity adds value from the customer viewpoint. Remember a few simple rules: Constraints are good places to examine closely; simple solutions are often better; identify and exploit bottlenecks; and maximize the use of human resource capacity.

Kaizen and *Kaikaku* Events

VSMs are useful for conducting kaizen and kaikaku events. Remember, kaizen roughly translates as good (*zen*) change (*kai*). A *kaizen event* is typically a short-term project targeted to find localized process improvement over a period of about three to five days. The common objective of a kaizen event is incremental minor change(s).

Kaikaku events possess a larger scope. This is typically true for the duration as well as the extent of process involvement. *Kaikaku events* have a process focus, but they are typically aimed at finding radical change. Kaikaku events may entail introducing new knowledge, new strategies, new approaches, new production techniques, or simply new equipment.

Takt Time

Although attributed to German aircraft engineers in the early 1930s with Mitsubishi bringing the concept back to Japan, the TPS embraced takt (tact) time as a tool to improve assembly-line efficiency. Takt time refers to the drumbeat of the system, the beat, which should set the pace or speed for operations. It is derived from the German word *taktzeit*, which translates as cycle time. Simply put, it is the maximum time allowed per unit to produce a product in order to meet demand.

The goal behind establishing a takt time is to match output speed (total cycle time) with customer demand. Ideally, system output should correspond with demand. In its simplest form, takt time (T) per unit would be determined as

T = Work time available per day/units of demand per day.

T is subsequently used to establish the speed or pace and to balance workloads of transformation processes.

It should be evident that an important issue to address while establishing takt time is the performance of NVA activities. Using a microscope provided by various investigative lean tools better enables the examination of connections and flows between resources. This is critical for achieving waste reductions. In low-volume, batch transformation processes, it is not uncommon for NVA activities such as material movement times, queue (wait) times, storage times, setup times, and inspection times to exceed 70 percent of the total throughput time. Any activity performed that is not valued by the customer takes work time away from performing VA transformation activities. This actually increases the minimum possible value of T and therefore lengthens the possible response time for meeting demand.

Similar to takt time is pitch. *Pitch* indirectly refers to takt time, but it makes an adjustment for container size. For example, if takt time is 1 minute per unit and a container holds 10 units, then pitch is 10 minutes, the time required for a container to be produced and sent downstream. Both takt time and pitch time should correspond with demand.

Production Leveling and Balancing

This practice refers to producing at a constant rate over time as well as maintaining a constant ratio or *balance* among items being produced. It is also known as uniform plant loading, production smoothing, or by its Japanese counterpart *heijunka.* In any process, fluctuations in performance typically increase waste. This is because it becomes increasing difficult to effectively utilize capacity provided by resources (equipment, workers, and inventory), which must be ready to meet demand as demand occurs.

A simple numerical example can be used to explain the production leveling and balancing concept. Assume a company produces six items, products A to F, using a single process. Let us say over the course of a five-day workweek, the expected demands for the six items are 40, 80, 20, 30, 15, and 0 units, respectively. For a single eight-hour shift, production leveling suggests using a ratio that reflects the relative demand values over the time interval, and these values would remain the same each day of the workweek. The rate of production for each item that would maintain this constant ratio over the entire eight-hour interval would be 8, 16, 4, 6, 3, and 0 units, respectively.

Following production leveling and balancing, batches are made as small as possible in contrast to traditional mass production, where bigger is considered better. A more traditional mass production approach would produce 40, 80, 20, 30, 15, and 0 units in single batches once a week or 8, 16, 4, 6, 3, and 0 units, respectively, in batches once per day, five times a week. The ability to justify small-batch production rests on a firm's ability to achieve SMED, as changeover or setup time indirectly controls batch size. The argument has always been based upon the notion of economies of scale. Namely, if it takes longer to perform a changeover, subsequent batch size must be greater in order to achieve a lower per-unit cost. If a firm can achieve a lower changeover time and cost, then it should be more willing to pursue changeovers, as the objective should be to minimize total system cost, which, for the workstation, is a combination of changeover costs and inventory costs. While more changeovers promotes higher changeover costs, if the time is lowered, the increased number of changeovers may not greatly impact changeover costs. Meanwhile, lower batch size clearly reduces inventory costs. This can result in lower total system costs.

A *heijunka box,* a scheduling tool used to visually depict what to produce, when to produce it, and how many to produce, may further explain the concept. This tool is commonly divided into a grid of rows and columns creating a set of pigeonhole receptacles. Each row of the box represents a particular product, while each column of the box represents a specific time period such as an hour of the day or day of the week. Colored cards (*kanbans*) representing individual jobs are placed in the heijunka box to provide a visual representation of the upcoming production runs. Please refer to Figure 5.1 in the following text, which depicts a production plan for the six items (A–F) over an eight-hour shift.

In Figure 5.1, the heijunka box is divided into eight columns of equal length representing the hours in an eight-hour shift. The plan shown

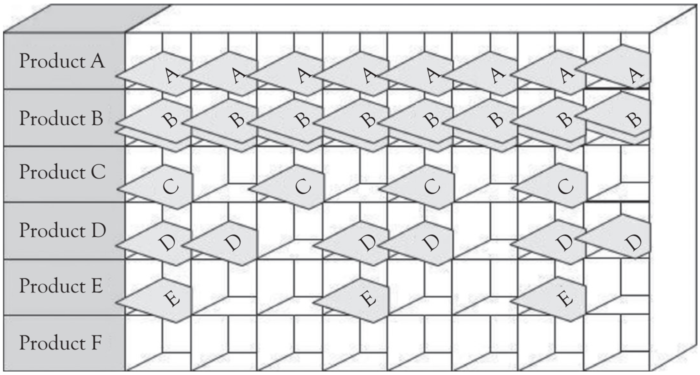


Figure 5.1 Heijunka box with kanbans

depicts building an A and then two Bs along with a mix of Cs, Ds, and Es in each of the one-hour intervals. The simple repeating pattern of kanbans in each row and multiple columns smoothes planned production for each of these products. The heijunka box allows visual control of a smoothed production schedule. This helps to ensure that planned production capacity is kept constant, thereby eliminating many issues associated with variable demand. Furthermore, the kanbans reflect downstream demands. So, the kanbans act to *pull* production out of the upstream workstations by authorizing upstream production.

It should be noted, however, that there is a significant difference between planning and executing. Ideally, production can easily be leveled when demand is constant over time. One would simply match capacity, or the planned rate of output, with the demand rate. In reality, demand varies and it is costly to vary capacity (people, machines, or inventory). Capacity is typically added or subtracted in chunks. Furthermore, it is difficult, if not impossible, to know demand in advance, and adding capacity may take significant time. As a result, there is often a mismatch between demand and capacity as shown in Figure 5.2. Because demand varies, it becomes necessary to either maintain underutilized capacity at times to meet demand, allow some demand to go unmet, or to absorb variations in demand with flexible capacity if possible.

The ability of a company to level production is governed by the flexibility of capacity. This refers to the ability of the workforce and equipment to shift production as required or to the use of inventory to absorb

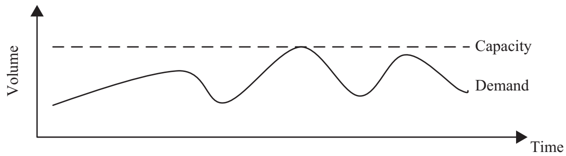


Figure 5.2 Mismatch between variable demand and level capacity

demand variations. It is desirable for upstream processes to be flexible in order to offer the necessary response if downstream consumption varies its withdrawal rate in terms of timing, quantity, or both. Furthermore, the variance or amplification of demand will typically increase as demand passes further upstream. This variance in the demand amplification has often been referred to as the *bullwhip effect*. This effect is greatly exacerbated as demand is extended further upstream in the supply chain.

In response to demand fluctuations, the process must possess the flexibility to quickly expand or contract capacity as needed. Greater flexibility can be achieved through various means, including redeploying idle cross-trained workers, working overtime for short periods, maintaining minimal inventories, changing the cycle time pace of the process, or some other inventive means.

To prevent fluctuations in production, even in outside affiliates, it is important to try to keep fluctuation in the final assembly line to zero. One noteworthy alternative to production leveling aimed at achieving a lower variance in production is demand leveling. It is sometimes practiced to smooth out demand variations. *Demand leveling* is the deliberate influencing of demand itself to achieve a more predictable pattern of customer demand. Influencing demand may be achieved by manipulating the product offering, offering price incentives, advertising, or some other means. However it is accomplished, the idea is to shift demand to off-peak periods, thereby enabling a firm to reduce demand variance and the overall level of capacity needed to meet demand as demand occurs.

Visual Management Techniques

There is an old adage that “a picture is worth a thousand words.” Visual management techniques employed within a lean management system have the ability to convey a lot of information quickly. Furthermore, people remember information better when it is represented and learned verbally and visually.

The principal purpose of visual management techniques is to readily depict the current status or performance of the system in comparison with its expected performance and to signal the need for action. Deviations depicted suggest assigning the responsibility for conducting an investigation to find the cause, which allows for corrective action to be taken and the permanent elimination of the cause.

The number of visual management techniques is only limited by one's imagination. Practice suggests several guidelines that should be adhered to while using visual management techniques. First, the tool should clearly depict the current state of the process. Further, the current state should be depicted relative to the expected state. Various colors can be used to depict multiple-state conditions. Visual boards or charts can assist the ability of shop floor workers to detect and identify process problems and needs as well as enhance their ability to communicate with technicians. Anecdotal evidence suggests visual boards, charts, and tool boards play an integral role in facilitating lean practices.[6]

Second, simpler is typically better. Visual management techniques do not require the use of sophisticated technology, as technology is not a prerequisite. Rather, visual tools should be easily and quickly updated. These tools should engage the individual(s) close to the process and the individuals who are responsible for maintaining the tool and correcting the process.

Third, these tools require discipline. The information must be captured on a regular basis over time. Information collected following a defined plan is more likely to depict patterns, which reveal assignable causes of variation over time. This information must serve as the basis for taking corrective action. Namely, leadership must be committed to using the tool, it must be used as the basis to assign responsibility for undertaking an investigation, and it should be used for accountability regarding investigative results.

Fourth, smaller time increments between data capture may bring issues to light sooner. It is difficult at best to determine an appropriate time interval, but as a rule of thumb, established and stable operations should use a smaller or more frequent increment, as variability is more likely due to assignable causes and less likely due to random causes. Similarly, if performance results are taken at more locations, it may be easier to pinpoint the source of variation.

Fifth, it is imperative that the data captured be useful. The process location, frequency of collection, and the extent of information collected must be determined. Data may be defects due to unmet specifications regarding characteristics such as length, width, height, weight, or volume. Data may be flow interruptions due to late materials, poor machine reliability, missing tools, unavailable operators, and so on. Data may also reflect simple abnormalities. Regardless of the nature of the data, the information captured must be honest. It is easy for data to be distorted, biased, or skewed. We all know averages can be misleading. The metrics captured must be reliable for adjusting output for continuous improvement. Two visual examples can portray these concepts. The data portrayed in Table 5.2 depicts a jumbled set of process output data values. The same data, depicted as an ordered array in Table 5.3, conveys a richer understanding of the process output. Combining the ordered array with the distribution plot in Figure 5.3 is even more powerful.

Table 5.2 Jumbled data

6	5	6	6	7
8	11	4	10	9
5	2	4	5	5
6	6	4	7	9
7	9	11	2	5
4	5	7	5	6

Table 5.3 Ordered array

2	2	4	4	4
4	5	5	5	5
5	5	5	6	6
6	6	6	6	7
7	7	7	8	9
9	9	10	11	11

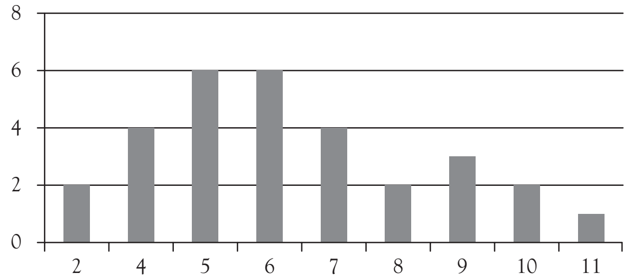


Figure 5.3 Ordered array data distribution

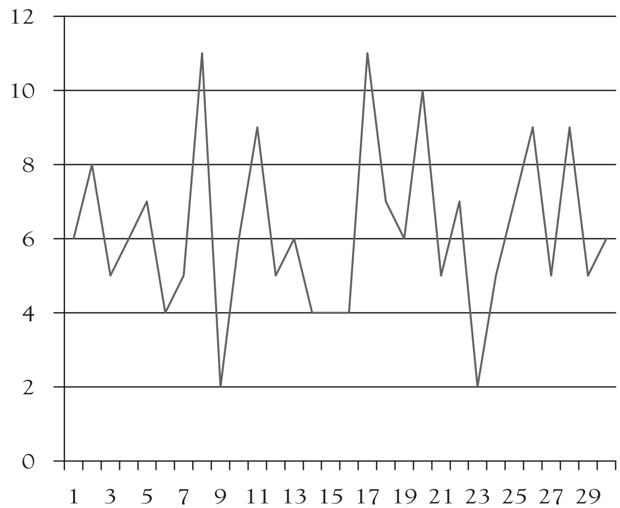


Figure 5.4a Ordered time series values

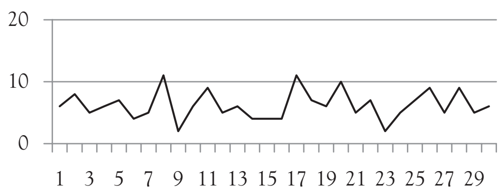


Figure 5.4b Ordered time series values

The second visual example conveys possible data bias due to scaling effects. Figure 5.4a depicts a set of time series values of a process. The same set of values is shown in Figure 5.4b, but with a compressed scale. The data in Figure 5.4a appear highly variable when compared with the data of Figure 5.4b. Yet, it is the same data set.

Finally, it is often useful to couple audio signals with visual signals. This will reduce the likelihood that a single signal will be overlooked.

Investigations conducted as a result of an abnormality depicted by visual management techniques commonly ask the "*5W2H*" questions (who, what, when, where, why, how, and how much) or "*5 Whys*" to get to the root cause of the problem or variation. Numerous investigative tools are useful, including, but not limited to, benchmarking, brainstorming, value stream or process maps, Pareto analyses, cause and effect or 6M (man, machine, methods, materials, metrics, Mother Nature) diagrams, check sheets, scatter diagrams, run diagrams, and others. Many of these are discussed in Chapter 6.

There is an old idiom that "seeing is believing." A powerful tool that offers this capability is a *gemba walk*. It refers to visiting the factory floor in order to see firsthand what is going on. A problem with seeing firsthand is that interpretation of what is seen may be difficult. There are various reasons for this, including that the work may be unfamiliar to the viewer, problems are not typically uncovered until after they have occurred, the work may be complex making problem diagnosis or definition difficult, problems may be hidden as teams may be composed of friends and colleagues, distinguishing between human error and random chance may be difficult, and leaders may see control as an ad hoc responsibility versus a continuous requirement. Nevertheless, gemba walks allow leaders to observe, provide team members access to leaders, and demonstrate leader involvement in improvement.

A3 Problem-Solving Report

The term A3 is derived from the paper size used for the report, which is the metric equivalent to 11" × 17" paper. Similar to VSM, the development of the A3 as a tool has been attributed to the TPS. The A3 is commonly used in conjunction with VSM. Whereas the VSM's view is aimed at a higher-level value stream, the A3 offers a structure that always begins by defining the issue from the detailed customer's perspective. The A3 problem-solving process represents a structured approach to help people engage in collaborative, in-depth problem solving. It drives problem solvers to address the root causes of problems, which surface in day-to-day work routines.

The A3 problem-solving approach suggests a stepwise orientation. A sample A3 template is shown in Figure 5.5 and a common six-step A3 problem-solving procedure is outlined in the following list:

1. Identify the problem or need.
2. Observe the process firsthand, involve local workers to explain and document the current state preferably with a visual depiction, quantify the magnitude of the problem, and identify ideal state to be targeted.
3. Conduct root cause analysis to identify problem source.
4. Devise detailed plan consisting of alternative solutions to address root cause(s) and identify preferred solution alternative. Planning facilitates accomplishment, so it should address the 5W2H (who,

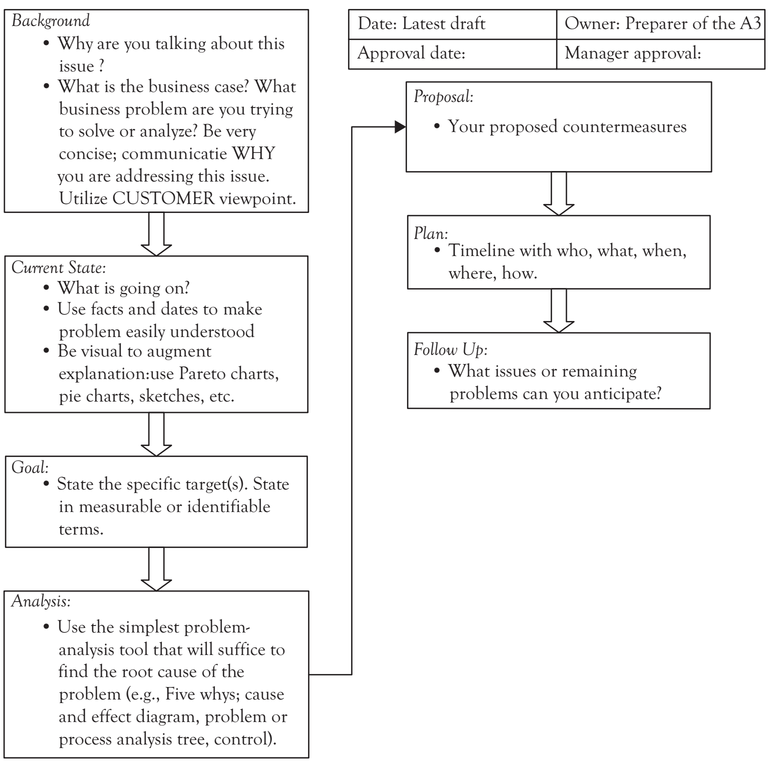


Figure 5.5 Sample A3 template*

* Borrowed from lean.org

what, when, where, why, how, and how much) questions. The template should address the individual(s) responsible for each task, the tasks that need to be done to get the solution(s) in place, due date(s), affected location(s), an expected target condition to be realized, which addresses benefits to be achieved, standardizes the new tasks in written and preferably visual fashion, expected costs to be incurred, and it should attempt to anticipate remaining issues or future problems. It has been suggested that the plan specify work outcomes, content, sequence, and tasks; create a clear, binomial connection between source and destination of workflows; and eliminate possible cycles or loops, "workarounds," or delays for inferior outcomes.

5. Implement and test plan.
6. Monitor, collect performance data, and iterate back to step 1 if necessary.

Workplace Organization: 5 Ss

Workplace organization, or the 5 Ss, refers to a set of sequential steps designed to improve efficiency, strengthen maintenance, spotlight the emergence of issues, and promote continuous improvement.[7] The sequential 5S steps are often identified (with their Japanese counterparts) as sorting (*seiri*), straightening (*seiton*), sweeping (*seiso*), standardizing (*seiketsu*), and sustaining (*shitsuke*). These five sequential steps are explained in the following text.

Sorting (seiri) refers to eliminating anything unnecessary in the workspace. This includes tools, parts, and instructions. Only essential items are kept in easily accessible and typically designated workspace places. Everything else is stored in remote locations or discarded.

Straightening or setting in order (seiton) suggests there should be a place for everything, and everything should be kept in its place when not in use. The place for each item should be clearly identified or labeled. For example, tool cribs often accomplish this with shadow boards. Items should be arranged in a manner that promotes efficient workflow, with equipment used most often being the most easily accessible, and each part, tool, and piece of equipment or supply source should be kept close to where it will be used. Knowing where items are kept reduces searches while promoting traceability and productivity.

Sweeping, shining, or cleanliness (seiso) refers to keeping the workplace neat and organized. At the end of each shift, clean the work area and be sure everything is restored to its place. This makes it easy to know what goes where and ensures that everything is where it belongs. A key point is that maintaining cleanliness should be part of the daily work, not an ad hoc activity undertaken only when things get too messy. Keeping the workplace clean will spotlight problem identification earlier, as a mess typically suggests problems such as a machine fluid leak.

Standardizing (seiketsu) refers to consistent and standardized work practices. All workstations for the same job should largely be identical. All employees doing the same job should be able to work in any station with the same tools that are in the same location in every station. The benefit for this is variance reduction. Team members must understand and value the benefit for doing work following company standards rather than their own way.

Sustaining the discipline (shitsuke) suggests the previous four steps must become habitual. It is often noted by practitioners that this is the most difficult step as it does require discipline to maintain. People seemingly find it easy to slide back into old habits.

Spaghetti Diagrams

A *spaghetti diagram* is a visual flow-charting tool that uses a continuous line tracing depicting the flow of work. It is used to depict both VA and NVA flows. There are a couple of simple rules for its use. First, it is typically hand drawn, taken from observations over a period of time. Second, it is not necessarily drawn to scale. It is intended to simply represent material or worker flow paths to promote the elimination of NVA movements. It is often used in conjunction with 5S projects.

Cellular Manufacturing

Cellular Manufacturing is based upon the concept of group technology, which seeks to take full advantage of economies of scale offered by part similarity. The goal of cellular manufacturing is achieving greater flexibility to produce a wide variety of lower-demand parts or products, while still maintaining the high productivity and lower unit costs of large-scale production.

Group technology commonly examines parts for similar shape characteristics. Similar shapes may imply similar processing requirements. Similar processing requirements may translate into reduced or minimal setup changes when switching from one part to another in the family. This presents the economies of scale and provides greater demand volume through a family, which justifies moving the equipment into the cells.

More commonly found in low-to-moderate volume, batch-manufacturing environments, cellular manufacturing groups the machines necessary to produce an entire family of parts in close proximity. Cells are typically U-shaped or C-shaped. An example is shown in Figure 5.6. You will note the VSM symbol for an operator is used while lighter-colored arrows depict material flows and darker arrows depict operator movements.

This U-shaped cell configuration allows an operator to start and finish work in virtually the same location, thereby eliminating movement. This design offers major advantages in greatly reduced material flow distance and time, reduced setup time, reduced inventory levels, and cumulative lead times. The U or C shape also fosters greater communication as workers are near one another.

It is common to design the flow to occur in a counterclockwise manner. This direction keeps employees' dominant hand in the direction of arriving material, as most people are right-handed. It is also possible to vary cell output in the form of increasing or decreasing the number of cell operators as demand warrants.

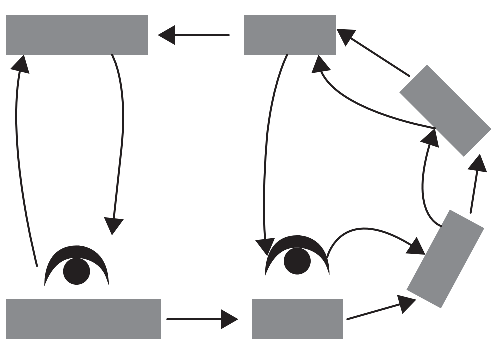


Figure 5.6 U-shaped or C-shaped manufacturing cell

Total Preventive Maintenance

Total preventive maintenance (TPM) is a process developed for improving productivity by enhancing the likelihood that equipment resources will be available when needed. TPM has basically three goals: zero defects, zero equipment failures, and zero accidents. If maintenance is done properly, uptime will improve, as will OEE (how well equipment performs relative to design capacity during the periods of scheduled production).

Although TPM has been practiced for many years, it got firmly established in Japan during the 1950s. At that time, Deming and others demonstrated the application of statistical methods for monitoring and controlling processes to ensure that they operate at full potential to produce conforming products.[8]

An important objective for a TPM program is to provide the machine operator with the training for performing much of the routine, ongoing maintenance, and problem detection capability. Activities such as routine adjustments, cleaning, and lubricating are simple examples. TPM goes further by training workers to use senses including feeling, seeing, hearing, and smelling for anomalies such as vibrations, heat, breaks or cracks, bangs, smoke, and so on. The intimate knowledge acquired during operations along with the training affords the machine operator a keen ability to detect impending issues or decreasing quality. Coupling the maintenance capabilities of a machine operator with a preventive maintenance team responsible for activities such as predictive maintenance and extensive overhauls turns TPM into more of a proactive approach that aims to identify potential downtime issues as soon as possible and prevent them even occurring.

Wellness Programs

More recently, wellness programs have recognized that machines are not the only valuable resource that needs regular maintenance. The most valuable resource of any enterprise is its people. This resource requires regular maintenance as well, because human resources must be available when needed. *Wellness programs* are employee-centered programs featuring proactive personal fitness programs, including physical examinations, substance abuse and group counseling, and individualized diet and exercise programs. Wellness programs have been very effective in improving employee productivity while reducing absenteeism and health care costs.

Because wellness programs are a more recent development than TPM programs, cost–benefit evidence demonstration of their value is limited. One example of a wellness program demonstrating benefits has been in use in Oakland County, Michigan, since 2007. Its program consists of health surveys, risk assessments, blood pressure screening, glucose tests, nutrition and exercise classes, as well as smoking cessation classes. After four years, the program is providing measureable results. The year 2009 saw a 12 percent decline relative to 2008 in health insurance costs for the county.[9] Also during 2009, the voluntary program accounted for 56 percent of the employees. Like many lean initiatives, success has encouraged greater participation.

Employee Cross-Training

Since lean is based upon improvement through change, it is imperative that leaders invest in team members' training, education, and skills. This includes *cross-training*, or capability of a team member to perform a variety of tasks. Cross-training promotes benefits to the organization including enhanced flexibility and greater idea generation.

Recognition that the most important asset of any firm is its employees necessitates investing in the capabilities of this asset. Leadership must promote, encourage, and actually involve itself in the process for improving education and skills through continuing teaching, learning, and training. An organization that can effectively build greater capabilities into its people is more likely going to be able to produce quality in its products and services.

Cross-training offers employee benefits as well. *Job enrichment* (vertical job expansion, which includes offering additional tasks, resulting in more control and responsibility) and *job enlargement* (horizontal expansion of the job, which includes additional tasks on the same level of skill and responsibility) offer employees the opportunity to learn new skills, enhance motivation through greater employee value, and combat boredom.

Training is critically important in companies utilizing new technologies, as these technologies typically require more advanced skills.[10] Flexible work practices are positively correlated with off-the-job training and cross-training.[11]

Ergonomics

The field of ergonomics contributes to important lean practices. It is concerned with safety and the "fit" between people and their work. It takes account of the worker's capabilities and limitations in seeking to ensure that tasks, equipment, information, and the environment suit each worker. The most important ergonomic risk factors are posture, force, and repetition, all of which depend on workplace design. Ergonomic injuries comprise more than 50 percent of all workplace injuries in North America.[12]

The International Ergonomics Association divides ergonomics broadly into three domains: (a) physical ergonomics, which is concerned with human anatomy and delves into relevant topics such as working postures, materials handling, repetitive movements, lifting, workplace layout, as well as safety and health; (b) cognitive ergonomics, which is concerned with mental processes and mental workload among other relevant topics; and (c) organizational ergonomics, which is concerned with relevant topics that include work design, design of working times, teamwork, and quality management among other relevant topics.

The foundation of ergonomics appears to have emerged in ancient Greece. Evidence indicates that the Hellenic civilization in the fifth century BC used ergonomic principles in the design of their tools, jobs, and workplaces.[13] TPS also uses ergonomic principles. The TPS philosophy suggests ergonomics is a precursor to delivering on objectives of quality, delivery, and low cost. Since ergonomics focuses on employee safety and eliminating waste in tasks such as repetitive movements, work design, and improving quality, it is clearly central to lean practices.

Error Proofing: *Jidoka, Poka-Yoke,* and *Andon*

The principle of *jidoka* essentially refers to a machine stopping itself when a problem occurs. It has been described as the combined effort of automation and workers to quickly identify errors and taking corrective action or automation with a human touch. The concept has been attributed to Sakichi Toyoda, the founder of Toyota Industries Co. Ltd. and its incorporation into an automatic loom-weaving process.

Jidoka, or autonomous automation, relieves the need for the worker to continuously assess whether the operation of the machine is normal. Rather, his effort is required only when there is a problem alerted by the machine. This degree of automation implements some supervisory function by a worker, which has also been referred to as self-checking or *quality at the source*. It engages both worker and machine capabilities in the assessment process. This typically means that if an abnormal situation is detected, the machine stops and the worker will stop the production line so that attention is focused on understanding the problem and eliminating the source of variation.

Defect production may be attributed to either random or assignable causes of variation. Random causes of variation cannot be eliminated. On the other hand, assignable variation such as human errors can be eliminated. *Poka-yoke* is a Japanese term that means to render fail-safe or error proofing. The concept has been attributed to Shigeo Shingo. He observed that the human element of complex systems is a significant contributing factor to the production of mistakes or errors. In response, he developed the poka-yoke, which is any mechanism that helps to avoid (*yokeru*) mistakes (*poka*). Its purpose is to eliminate product defects by preventing, correcting, or drawing attention to human errors as they occur. It has also been described as *baka-yoke* or fool proofing.[14]

More broadly, poka-yoke refers to any device or constraint purposefully designed to prevent a failure or incorrect outcome. It prevents a mistake from occurring or progressing downstream. It could be a device that allows only one possible outcome for an action, the single outcome being good, which prevents mistakes from occurring.

There are two broad types of poka-yokes. The first is a *warning* poka-yoke, which alerts an operator to an impending mistake. This does not prevent the error, but immediately stops the process when an error is detected. Many types of sensory measuring or detection devices can perform this function. The second type is a *control* poka-yoke, which actually prevents the mistake from being made. The control poka-yoke does not allow a process to begin or continue after an error has occurred. It removes the response to a specific type of error from the hands of the operator. Examples of a control poka-yoke include jigs that hold successive products in an identical orientation or fixed position for processing or fixture pins that keep incorrectly placed parts from fitting properly. Good poka-yokes are simple, reliable, assure 100 percent compliance with specifications, provide immediate feedback, and are low cost.

An *andon* refers to a status display indicator used to notify management, maintenance, or workers of a quality or process problem. It is commonly either an audible signal such as a warning horn or a visual signal such as a light. The signal is typically activated manually by a worker using a pull cord or button or automatically by the production equipment itself. The intent is to stop production immediately so the issue can be corrected. Common reasons for manual activation of the andon are part shortage, defects, tool malfunction, or the existence of a safety problem.

5 Whys

The 5 Whys is a questions-asking practice used to explore the cause–effect relationships underlying a particular problem. Ultimately, the goal for asking these questions is to determine a root cause of a defect or problem.

The development of the 5 Whys approach has been attributed to Sakichi Toyoda, the founder of Toyota Industries Co. Ltd. As noted in the previous section, he is also known for inventing the automatic weaving loom, which employed jidoka, or autonomous automation.

Total Quality Management

Like lean management, total quality management (TQM) possesses a customer-driven philosophy for organizationwide continuous or ongoing improvement. It possesses a methodical foundation of numerous principles and tools, experimentation, scientific analysis, and problem solving. Although TQM often conjures up images of statistics and tools such as Pareto charts and control charts, it goes well beyond statistics and tools to incorporate components of leadership, culture, and teamwork as well.

Similar to lean management, TQM should be viewed in a systematic manner with activities that eventually lead to enhancing customer value.

An examination of lean management practices and tools cannot be devoid of a discussion of TQM; the two are inseparable. In the subsequent chapter, effective management of quality is discussed. It too follows a systems approach. The discussion involves the execution of three interdependent planning stages (strategic quality planning, tactical quality assurance, and operational quality control and improvement), each comprising various activities.

An examination of various TQM process improvement tools is included. Specific TQM tools examined in the chapter are benchmarking, brainstorming, process mapping, histograms and Pareto charts, cause-and-effect diagrams, check sheets, scatter diagrams, control charts, and acceptance plans.

Summary

Reducing or eliminating variation in any system or process is a fundamental lean principle. Lean practices and tools can help to reduce variation and waste in addition to serving as a microscope for identifying improvement opportunities. In this chapter, numerous lean practices and tools are identified and explained. It is noted that lean practices are planning approaches used throughout the transformation process. Lean tools are specific analytical methods and problem-solving approaches. The focus of both is helping to identify causes of variation and waste, which can eventually lead to variance reductions and improvement.

In addition to identifying and explaining lean practices and tools, this chapter also identified several key points for the use of lean tools. These points are summarized in the following text.

1. Typically, a keen understanding of the process's current state is required in order to understand the source of variation prior to its reduction. Lean tools help promote a common understanding of the current system state as well as to help direct improvement efforts of stable processes.

2. Often the application point for lean tools differs depending upon the environment. In lower-volume, batch environments, the examination often focuses on connections and flows between resources. In higher-volume, repetitive processes, the focus is typically on the productivity of the resources, given a common takt time across system resources.
3. Not all lean practices and tools are equally applicable in all types of environments. Differences between manufacturing and service environments limit the applicability of some lean practices and tools. Consequently, flexibility is key for services in order to be responsive to varying demands.
4. Lean practices and tools are limited only by one's imagination and creativity in solving problems. The variety of practices and tools is unlimited.

CHAPTER 6

Total Quality Management

Any exploration of lean management would be incomplete without examining its vital companion, total quality management (TQM). Philip Crosby gained fame with his belief that organizations that establish a quality program will see savings returns more than offset the cost of the quality program.[1] He referred to this as "quality is free." Although there are increased prevention costs, well-executed TQM programs pay for themselves in the form of decreased internal and external failure costs. Numerous research reports have shown that quality can enhance return on sales and investment and can lower total system costs.[2]

Like lean management, TQM possesses a customer-driven philosophy for organizationwide continuous or ongoing improvement and waste elimination. It possesses a methodical foundation of numerous principles and tools, experimentation, scientific analysis, and problem solving. Although TQM often conjures up images of statistics and tools such as Pareto charts and control charts, it goes well beyond statistics and tools to incorporate components of leadership, culture, and teamwork as well. Similar to lean management, TQM should be viewed in a systematic manner with activities eventually leading to enhancing customer value.

Many definitions of quality have been offered. One definition suggests the term fitness for use to assess quality. However, variations of fitness exist in grades or levels of quality. Terms such as basic and premium are example descriptors used to portray various quality grades. Distilled from all the definitions is the single important dimension for all outcomes of TQM programs. Quality must be viewed from the standpoint of the downstream customer.

From the ultimate consumer standpoint, the concept of conformance to specifications conveys the idea that consumers have an expectation to be met. This expectation is best viewed in terms of a specific outcome for a transaction. Because all processes possess inherent variability (random

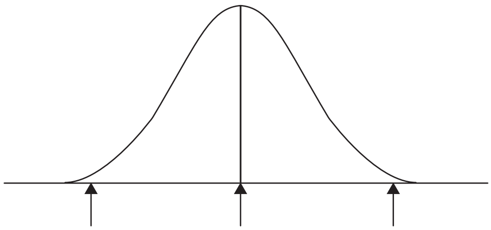


Figure 6.1 Distribution of process outcomes

variation), consumers recognize three components to measure outcomes: an expected value and a reasonable output range made up of upper and lower specifications within which satisfactory outputs lie. This concept is shown in Figure 6.1. As long as process outcomes lie within upper and lower specification limits, an honest consumer will be satisfied.

Consumers should establish their expectations (the three components) prior to a transaction. Variability that leads to unexpected outcomes exceeding specification limits leads to dissatisfied consumers. The best approach to measure quality assesses whether consumer expectations are being met. Therefore, quality should be defined as the elimination of variability because if variability is eliminated, consumer's expectations will be met.

As with lean management, a firm should understand its strengths and capabilities, its weaknesses, potential opportunities, and any threats assessed with a SWOT (discussed in Chapter 1) analysis prior to establishing a TQM program. After its completion, quality planning and management may proceed.

Effective planning and management of quality follows with a systems approach. TQM involves the execution of three interdependent planning stages, each comprising various activities. These three planning stages are strategic quality planning, tactical quality assurance, and operational quality management, control, and improvement.[3] These three stages begin with quality planning, a strategic approach to identifying and understanding consumers' wants, needs, and preferences and assessing an organization's ability to meet them. Tactical quality assurance is a proactive set of activities having a goal of adherence and maintenance of

Table 6.1 Six TQM principles

1. It must have a customer focus: externally and internally
2. It must have top management's utmost commitment
3. Quality can be built into product design
4. Quality can be built into process design
5. After-the-sale service quality is essential
6. Use of a variety of quality tools is necessary

product and service quality levels. Operational quality management, control, and improvement assess operational process outputs in an ongoing manner to ensure conformance to specifications, all the while attempting to improve future process outputs as well.

Furthermore, in order to truly design an effective TQM program throughout these three planning stages, organizations must adhere to six specific TQM principles. These six principles are shown in Table 6.1. Each of the three planning stages as well as the six principles is addressed in the following sections.

Strategic Quality Planning

At the onset of any strategic planning, it is imperative to clearly understand program goal(s). Quality planning is a strategic approach to (a) identify and understand consumers wants, needs, and preferences, (b) establish TQM program goals, (c) assess an organization's ability to meet these goals, and (d) quantify the costs for achieving the goals.

First, quality planning must engage customers to solicit market requirements. Consumers' quality expectations must be understood. Second, specific and measureable goals that allow for subsequent assessment must be established. These goals must recognize market requirements as well as the various costs of quality (internal, external, appraisal and prevention costs). Third, products and services must be designed, developed, and produced, which meet consumers' wants, needs, and preferences. Fourth, the costs for achieving these goals must be estimated. The costs include internal and external failure costs, prevention costs, as well as the cost of inspection and the cost of passing defects downstream.

During this stage, there must be a clear understanding of the importance upper management attaches to quality. A critical link exists between leadership, its commitment, and the ultimate success of the quality program. Leadership is often regarded as the single most critical factor in the success or failure of institutions.[4] This is true for organizations as a whole or simply for programs such as TQM.

A good starting point to assess the management's understanding of this importance is to examine an organization's mission statement. A mission statement is typically viewed as a formal, short statement of the purpose of an organization. It is intended to guide the actions of the organization or to provide it with a sense of direction. It guides subsequent strategic choices such as strategic quality planning, tactical quality assurance, and quality management, control and improvement. If quality is important, reference to its importance should appear in the mission statement.

Remember, leadership should be viewed as interpersonal influence, exercised in situations and directed through the communication process, toward the attainment of a specified goal or goals. It includes setting the direction of the organization through a thorough, long-term vision of the organization's value-producing processes. TQM and lean management should represent lifelong commitments to continuous improvement. In order to promote quality, there must be a concerted effort by all to better understand the customer's wants, needs, and preferences. The practice of asking many questions to promote a better understanding is essential. People often assume they know what customers want, based upon their own preferences. Well, odd as it may seem, people actually do have wants, needs, and preferences that differ from our own.

It is during this stage of developing a quality plan that the strategic, group *hoshin kanri* and *nemawashi* process discussed in Chapter 3 is again utilized. What is sought is a long-term systematic plan agreed to by all that will be used year after year to assess performance and alter future activities.

As noted earlier, engaging others is an important step in any major change. Before any formal steps are taken, successful group planning enhances the possibility of change with the consent of all stakeholders. Although it is time-consuming, the hoshin kanri process can turn skepticism and resistance into support, create cross functional cooperation, fully engage the workforce in developing executable strategies, link improvement and corrective actions with financial results, as well as enhance the ability for the team to respond to changes and setbacks.

Tactical Quality Assurance

The second stage in the development of a TQM program is tactical quality assurance. This stage represents a proactive set of activities having a goal of adherence and maintenance of product and service quality levels. This includes providing inputs for establishing policies and standardized specifications, documenting outcomes for assessment and verification, and specific procedures to remedy deficiencies.

Tactical quality assurance entails multifunctional processes. As a result, numerous stakeholders should participate to provide process inputs. An example of this extols the third principle noted in Table 6.1, which argues that quality can be built into the product or service design. This has sometimes been referred to as the product's *manufacturability* or its ease of production and the ability to conform to specifications. The essential idea is to design and build in quality rather than inspect it, as nonconformance is costly. Product designs ought to start with obtaining market information such as customer needs. The needs must be reflected in procurement decisions, engineering design requirements, production processes, as well as distribution choices.

An invaluable tool used to reflect *external* customers' specifications for various functional units is *quality function deployment* (QFD). QFD is designed to help planners focus on characteristics of a new or existing product or service from the consumer viewpoint. The QFD process begins with assessing consumers' requirements (sometimes referred to as listening to the *voice of the customer*), sorting and prioritizing the requirements, and then translating these requirements into specific product or service characteristics. One tool that has proven useful in the QFD process is known as the *House of Quality*. This tool attempts to map customer requirements with product or service characteristics. This tool has also proven to facilitate communications among functional units of an organization.

Product or service design quality may be enhanced with several additional practices. Product simplicity utilizing fewer parts (e.g., fewer mechanical fasteners), reliance upon robotic technology, vertical orientation for assembly, product redundancies, improved supplier relations, and preventative maintenance are all practices aimed at ensuring adherence and maintenance of product and service quality levels.

The fourth principle noted in Table 6.1 suggests that quality can also be built into process design. Elements of process design, including standardizing operating practices with approaches such as International Organization for Standardization (ISO) 9000 or TS 16949, reduced bureaucracy through fewer management levels, as well as the involvement of employees, support adherence and maintenance of product and service quality levels.

The expression, "The next process is the customer," attributed to Kaoru Ishikawa, acknowledges that downstream workers are essentially *internal* process customers.[5] It is important to understand that the quality of downstream process work is limited to the best quality of upstream sources. Namely, upstream work limits the quality found downstream. Process design can lead to enhanced quality with an internal customer focus. To do so, it is first essential for everyone in the organization to understand the shared vision of a quality objective. Organizational leadership must convey this message and it must create the conditions so that it is understood, agreed to, and voluntarily pursued by all. Leadership is more likely to engage employees with an understanding of their importance with a demonstration of various practices such as participative management and teamwork, and through an emphasis on *quality at the source*.

Once the quality culture is established, quality at the source, which is as much of a principle as it is practice, can be utilized. It acknowledges that quality is the responsibility of every upstream source: employee, work group, department, or vendor. It represents a decentralization of the responsibility for quality outcomes through a culture that appreciates the importance of adhering to standards and through the use of practices such as visual management and mistake proofing. However, it is incumbent on leadership to understand that *accountability* (being answerable for the satisfactory completion of a specific assignment) only occurs if employees possess both *responsibility* (the obligation incurred by individuals in their roles in the formal organization in order to effectively perform assignments) as well as *authority* (the power granted to individuals so that they can make final decisions to complete their assignments). Accountability is responsibility coupled with authority. Employees must be given the opportunity to take corrective actions, which may entail various responses ranging from simple reporting measures to root cause investigations to more extensive preventive measures.

An internal customer focus can be emphasized with further recognition of the vital contributions of employees. The skillset of employees should be regularly improved with an emphasis on education and training. Employees must be provided the necessary knowledge to use investigative tools and apply the technology to achieve quality objectives.

Further direct employee involvement can be achieved with a tool such as quality circles. These too represent a decentralization of management's responsibility for achieving quality objectives. It is commonly a small group of employees doing related work, which meets at regular intervals to pursue objectives of increased productivity and quality. It can provide for substantial individual motivation and improve managerial decision making. Involving employees with education and training programs, utilization of participative management programs including quality circles, or team-based matrix organizational structure simply recognizes the value of employees.

Product or service quality can also be enhanced with both upstream (vendor) and downstream (customer) supply chain support. For example, consider process design elements that warrant potential examination including distribution choices, possible product installation, as well as continued after-the-sale support. Each of these can significantly impact product or service quality.

Operational Quality Management, Control, and Improvement

Nonconformities do occur despite an organization's best efforts to proactively eliminate them. Quality management, control, and improvement refers to efforts to detect nonconformities and to ensure that operational process outputs meet consumer expectations today and exceed expectations tomorrow. The essential goal of this stage is to identify the source of variation so it may be reduced, or to possibly eliminate its source.

The sixth principle noted in Table 6.1 recognizes the numerous quality control and improvement tools that exist, which can enhance quality management, control, and improvement efforts. There are two broad categories of quality tools. These two categories are often referred to as process improvement and statistical process control tools. Some of these tools are discussed in the following sections.

Process Improvement Tools

Benchmarking is a process of comparing one's business processes and performance to industry bests. It may imply a comparison within a peer group. It need not be in the same industry. Namely, it may be a comparison with best practices from other industries. Quality is a common dimension for benchmark comparisons.

The simple intent is to achieve improvements through learning from other organizations. The process begins with an organization attempting to better understand an existing performance gap, to devise strategies for narrowing the gap, implementing the plan, and monitoring and controlling subsequent performance.

Brainstorming is a popular group creativity technique designed to generate a large number of ideas for improving quality. Although evidence suggests that its benefits for improving quality may be limited, it clearly offers the potential to boost morale, enhance work enjoyment, and to improve teamwork.

There are four basic rules in brainstorming, which are intended to reduce group member social inhibitions, stimulate idea generation, and to increase group creativity. The first rule supports the generation of many ideas. It suggests that the greater the number of ideas generated, the greater the chance of producing a radical and effective innovative solution. The second rule is to withhold criticism. In a group environment, criticism of another's ideas often defeats the brainstorming process. Criticism frequently leads to either sharp disagreements, withdrawals, or both among participants. Instead, participants should focus on extending or adding to ideas. By suspending judgment, participants will feel free to generate unusual ideas. Participants should be advised to reserve criticism for a later stage of the process. The third rule is to welcome unusual ideas.

Unusual ideas and new ways of thinking typically provide a greater range of options to be considered. The fourth rule suggests that ideas be combined to form better solutions.

Process mapping or flowcharting is a tool that utilizes different shapes to represent different types of process flow tasks. An example is portrayed in Figure 6.2. This is an example of an "engineering" process map where the rectangular shape represents a task, while the triangular shape represents assessment. Similarly, there is also an "operational" process map that uses five different symbols that depict items in one of five process flow states: (a) the performance of a process task (operation), (b) transportation (movement), (c) being stored in inventory, (d) a delay (e.g., waiting to be moved), or (e) being inspected. It commonly uses a circular shape to portray a task, an arrow to portray a movement, a triangular shape to portray an inventory, a D shape to portray a delay, and a square to portray inspection. In either process map type, the user should depict the process in sufficient detail so that value-added activities may be distinguished from non-value-added activities.

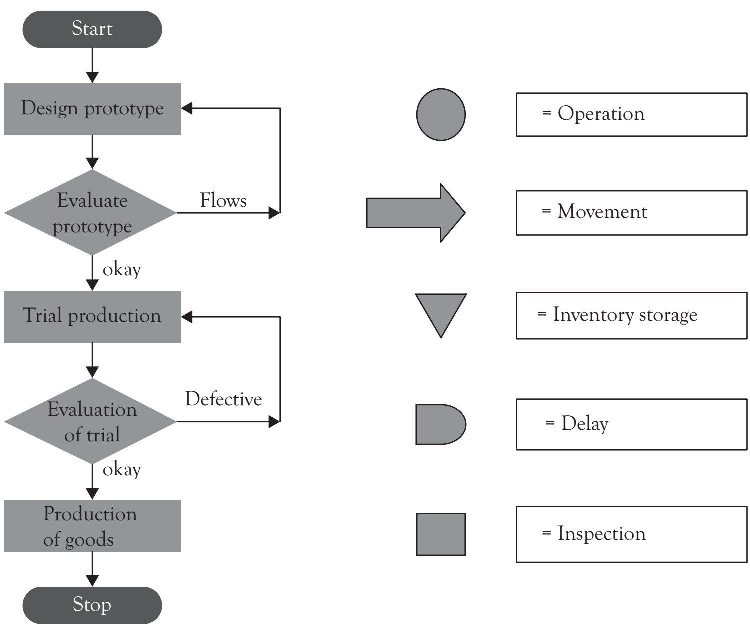


Figure 6.2 Engineering process map and operation process map symbols

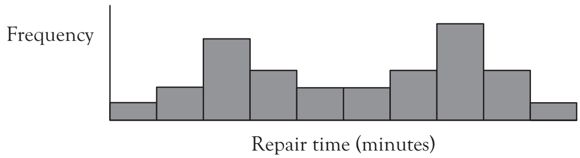


Figure 6.3 Example histogram

Another tool, a *histogram*, is a graphical representation of a data distribution. It typically consists of tabular frequencies, shown as adjacent rectangles, drawn over discrete intervals with an area equal to the frequency of the observations in the interval. An example is shown in the following text as Figure 6.3. The x-axis represents the categories of concern, for example, repair times for various failures. Reading over to the y-axis from the height of the x-axis concern category is the frequency (or the probability) of the category occurring. This tool can help direct improvement efforts by identifying those concerns that happen with the greatest frequency.

A *Pareto chart* is a visual tool that represents a frequency distribution by classes or categories of concern. It is often thought of as an ordered histogram whereby categories of concern are arranged from most frequently occurring to least frequently occurring. The chart suggests the most frequently occurring issue be addressed first, but it is important to note that it may not be the most important. An example of a Pareto chart appears in the following text as Figure 6.4.

You will note that the horizontal x-axis of the chart identifies the categories of concern while the vertical y-axis of the chart depicts the relative frequency of each category. In all cases, the sum of the relative frequencies of the respective categories of concern will be 1.00. The dashed line in the figure corresponds with the cumulative frequency of the various categories. There are also several variations of Pareto charts.

Cause-and-effect diagrams are often referred to by several alternative names. These names include *Ishikawa diagram* after its developer Kaoru Ishikawa. It is also called a *fishbone diagram* as it resembles the skeleton of a fish. And it is called a *6M diagram* as the six primary "casual" branches emanating from the central "effect" trunk begin with the letter M (**m**an,

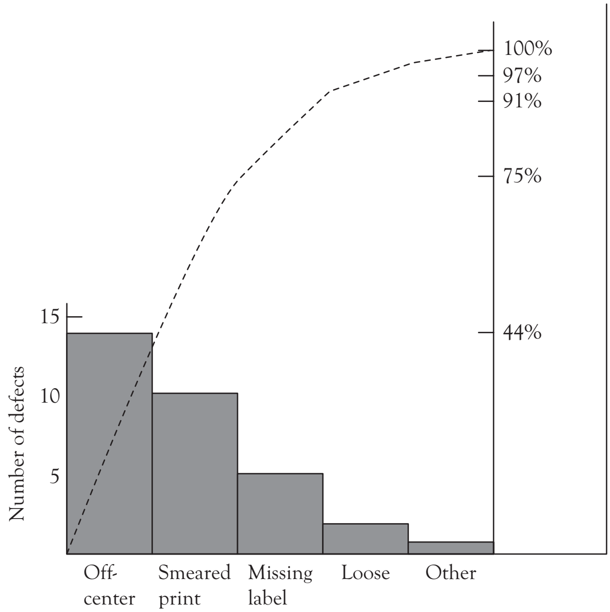


Figure 6.4 Example Pareto chart

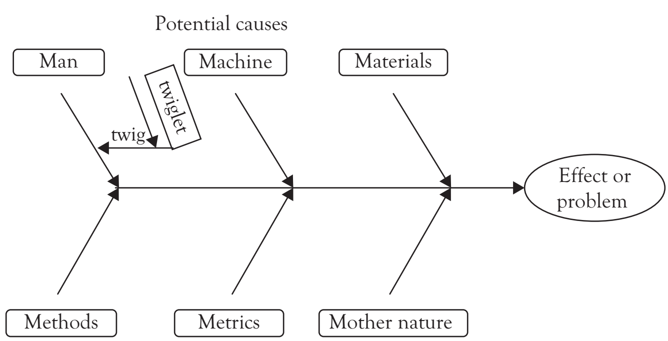


Figure 6.5 Example cause-and-effect diagram

machine, **m**aterials, **m**ethods, **m**etrics, and **M**other Nature). An example is shown in Figure 6.5.

One of the six primary causes is often the root cause or source of the problem. *Man* may refer to various effects such as inadequate training or low morale. *Machine* may refer to various effects such as worn tooling or incorrect settings. *Materials* may refer to effects such as inferior quality of material elements or a component from a vendor that is out of specification. *Methods* may refer to work that does not follow standards or the proper sequence. *Metrics* typically encourage behaviors, so it may refer to the use of the wrong measurements being used to encourage appropriate outcomes. *Mother Nature* refers to elements in the environment that may lead to assignable variability such as humidity or the level of lighting.

Emanating off the six primary cause branches, you will find secondary causes. These are typically referred to as twigs. In turn, these may have emanating tertiary branches commonly referred to as twiglets. This dissection or decomposition of the issue continues until the root cause problem source has been clearly identified.

A *check sheet* is a useful tool for data collection. It typically summarizes historical information often by date, time, location, and issue. An example is shown in the following text as Figure 6.6. Keeping a running tally of the issue or defect type by date, time, process location, part number, operator, or other diagnostic statistic enables relative issue frequencies, trends, or other meaningful patterns to be determined early in order to direct resources for improvement efforts.

A *scatter diagram* is a graphical portrayal of the relationship between two variables. It is useful for depicting the correlation that may exist between the two variables. An example is shown in Figure 6.7. It can depict how one variable (e.g., humidity) may impact the outcome of a process. However, the user should remember that there may be additional variables that impact outcomes. Furthermore, correlation does not necessarily relate to causality.

		Type of defect					
Day	Time	Missing label	Off-center	Smeared print	Loose or folded	Other	Total
M	8-9	IIII	II				6
	9-10		III				3
	10-11	I	III	I			5
	11-12		I		I	I (Torn)	3
	1-2		I				1
	2-3		II	III	I		6
	3-4		II	~~IIII~~I			8
Total		5	14	10	2	1	32

Figure 6.6 Example check sheet

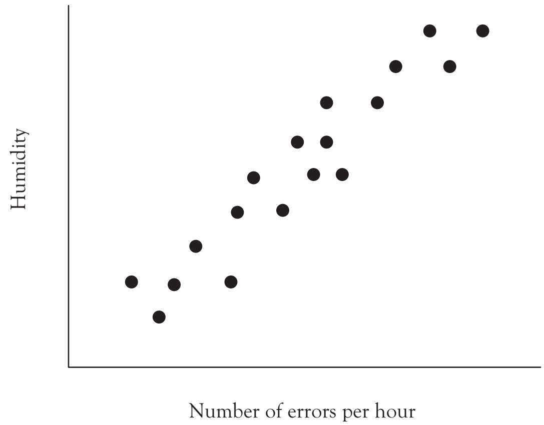


Figure 6.7 Example scatter diagram

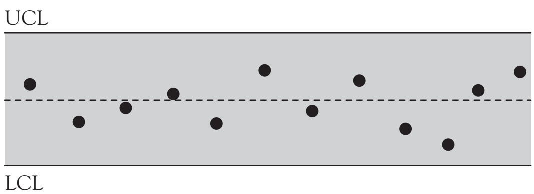


Figure 6.8 Generic control chart*

Statistical Process Control Tools

The second category of quality improvement tools may be divided into two subclasses: control charts and acceptance plans. Each of these subcategories is discussed in the following text.

The *control chart* was developed by Walter Shewhart in the 1920s. It is a graphical tool for describing and monitoring the state of control, typically for repetitive processes. The basic control charts consists of three elements: a center line (CL), which represents the process target level or process mean while in a state of statistical control (shown as the dashed line in Figure 6.8), and upper control limit (UCL) and lower control limit (LCL). Although the details for the construction of control charts goes beyond the intent of this book, the UCL and LCL of the chart are typically established as some equal number of process standard deviations above and below the process mean (CL), regardless of the type of

* *Abbreviations*: LCL, lower control limit; UCL, upper control limit.

control chart being used. Over time, sample values are used to monitor process performance. An example of a generic control chart is depicted in Figure 6.8.

The construction of a control chart varies with two general data types. Some data is measured over a continuous (variable) scale such as ounces or inches. For continuous data, a means ($\bar{x}$) chart, which is used to monitor if a process is operating near its target level (central tendency), and a range (R) chart, which is used to monitor process variability, may be used to assess performance.

The other data type is attribute (0, 1) in nature. An example is a light bulb, which either works correctly or is defective. For attribute data, several chart types may be used to assess performance. Two charts assess performance for items that either meet specifications (good) or do not (defective or nonconformity). These two charts are known as a p-chart, for monitoring the proportion defective in a sample, and an np-chart for monitoring the number defective in a sample. Two additional control charts for attribute data monitor nonconformities when multiple defects are possible per unit of output in the sample. Furthermore, although an item may possess nonconformities, it may not be a defective item unless the number of nonconformities exceeds a hurdle value. These two charts, useful when multiple nonconformities may occur per unit of output, include the c-chart for monitoring the total number of nonconformities in a sample and a u-chart for monitoring the average number of nonconformities in a sample.

As noted earlier, control charts are useful for describing and monitoring the state of control typically for repetitive processes. Variability in these processes is derived from two causes: random and assignable causes. Random causes cannot be eliminated as they are simply inherent and always will be. Assignable variation suggests that the variation may be assigned to a particular cause and thereby eliminated by improvement efforts.

A process is deemed to be in a state of statistical control if all of the variability is attributable to random causes. Whenever assignable variation is present, the process is deemed to be out of control. Example causes of assignable variation include incorrect machine settings, operator error, and out-of-specification materials. In the presence of assignable variation, the quality statistic being monitored will typically exhibit greater variability or some other pattern. The chart is used to detect various conditions in order to signal the need for further investigation.

Control charts can reveal many conditions that suggest the need for deeper investigation. Any one of four general scenarios could suggest the need for further investigation. First, one should compare the actual versus the expected number of observations falling outside of the control limits. If the actual number varies significantly from expectations, an investigation may be suggested. Second, plotted data points should depict a random pattern if all of the variability is attributable to chance causes. Plotted data points that reflect patterns such as a trend are not random. Patterns suggest the need for further investigation. Third, the extent of variability reflected in the sample data points is preferably low. If a large degree of variability is reflected in the sample data points, there may be assignable causes of variation present. Finally, there should not be any evidence of *runs* in the data. A run is defined as a significant number of observations lying on the same side of the CL. In all four of these scenarios, any condition suggesting the need to conduct an investigation must be coupled with one's judgment and experience and tempered by the cost of conducting an investigation versus the benefit of reducing defects being passed downstream.

These four scenarios may lead to an interpretation needing further investigation. However, they do not necessarily mean assignable variation is present. The decision maker may conclude the process is out of control when in reality it is in control, or that a process is in control when there is assignable variable and the process truly is out of control. The common operating hypothesis is that a process is in a state of statistical control. A *type I error* occurs when a decision is made to conduct an investigation looking for a source of assignable variation when in reality the process has none. This is sometimes referred to as *producer's risk*. The cost associated with a type I error may be lost production time and the cost of testing for an absent problem. On the other hand, a *type II error* occurs when a process continues to be deemed in control when in reality assignable variation is present. This is sometimes referred to as *consumer's risk*. The cost associated with a type II error includes potential scrap, rework, as well as possible after-the-sale service costs, which can be difficult to measure.

Acceptance plans are typically used to assess the quality of a batch of items. It is common to use this tool to make an "accept" or "reject" decision (*lot sentencing*) upon receipt if the incoming quality of a batch is suspect or just prior to a batch shipment to a customer. It is also used for lot sentencing in lower-volume batch processes as batch orders flow from operation to operation. If applied during the flow path of a batch, it is more common to make a decision regarding the disposition of a lot just prior to a costly, irreversible, or covering operation.

While performing acceptance sampling, it is important to understand that the disposition decision made does not typically grade the level of quality. Rather, a decision to accept or reject is simply made. Acceptance sampling may be viewed as a means of auditing quality or providing assurance that specifications are being met. It is a less expensive alternative to 100 percent inspection but when applied, introduces the risk of accepting inferior lots and rejecting superior lots.

Although the details for the development of an acceptance plan go beyond the intent of this book, there are several characteristics of these plans that are noteworthy. First, acceptance plans may be devised for either continuous measures or attribute data. Second, there are plan variations that utilize single, double, or multiple samples in order to make a disposition decision. Third, in order to apply acceptance sampling, the user must determine several parameters, including the sample size, number of samples to be drawn, and the acceptance or rejection criterion. These parameters will determine the plan's discriminatory power. It is important that this power ensure that the customer's lowest acceptable quality level is being met.

If a lot is rejected, corrective action is warranted. This may include actions such as the return of the complete lot to the vendor or further inspection of the remaining items not previously evaluated. In either case, it is desirable to know why acceptable quality was not achieved so that preventative action(s) may be taken.

Summary

The TQM tools noted in the preceding sections are not meant to represent an exhaustive list. Many others exist such as various Six Sigma practices including the use of statistical tools and tests (e.g., regression analysis, paired comparisons, rank order tests, analysis of variance, failure modes and effects analysis), Dorian Shainin's contributions (e.g., Lot Plots and the Red X effect), Taguchi's contributions (e.g., his off-line quality control strategy consisting of three stages: system design, parameter design, and tolerance design; as well as the Taguchi Loss Function), TRIZ (or TIPS: the theory of inventive problem solving) consisting of generalized patterns and distinguishing characteristics, which may be used to solve problems, and others.

Is must be remembered that TQM is a complementary and inseparable continuous improvement program sharing the same objectives of lean management. Both possess a customer-driven philosophy for organizationwide continuous or ongoing improvement. Both possess a systematic perspective consisting of leadership, culture, and teamwork as well as a methodical foundation of numerous principles and tools, experimentation, scientific analysis, and problem solving.

Similar to lean management, effective management of quality follows with a systems approach. TQM involves the execution of three interdependent planning stages, each comprising various activities. These three planning stages discussed earlier are strategic quality planning, tactical quality assurance, and operational quality management, control, and improvement. It is during the third phase that many of the TQM tools examined earlier are applied.

To reiterate, a fundamental understanding must exist that quality is free. Although there may be increased prevention costs, well-executed TQM programs pay for themselves in the form of decreased internal and external failure costs resulting in lower total system costs.

CHAPTER 7

Lean Productivity Enhancements and Waste Elimination Through Emerging Technology

The past three decades have witnessed the concept of lean as a systematic transformation process philosophy gain greater understanding. It is well understood that lean is a systematic philosophy for achieving productivity enhancements through waste elimination.[1] Benefits achieved through application of the lean principles, practices, and tools are well documented. Oft-cited benefits attributed to lean applications are lower costs, higher quality, faster order response times, and enhanced transformation process flexibility.[2]

The true understanding of lean's originations has been somewhat distorted by some suggesting that the roots of lean emanated from individuals (e.g., Toyoda, Ohno, Shingo, Imai, and others) within Toyota in the 1950s. Rather, lean represents an evolving body of knowledge dedicated to achieving productivity enhancements through waste elimination.

The true roots of the lean body of knowledge go back centuries. Individuals at Toyota acknowledged contributions to the lean body of knowledge by numerous predecessors. For example, the Egyptians used an assembly line (flow) practice and divided labor to enhance productivity and speed in the building of the pyramids.[3] The field of ergonomics contributes important lean practices as well. The foundation of ergonomics appears to have emerged in ancient Greece. Evidence indicates that the Hellenic civilization in the fifth century BC used ergonomic principles in the design of their tools, jobs, and workplaces.[4] It is estimated that as early as 1104, the Venetian Arsenal utilized a vertically integrated flow process consisting of dedicated workstations to assemble standardized parts into galley ships. This practice of a vertically integrated flow approach combined with standardized parts enhanced ship assembly productivity.

Other contributors prior to the contributions at Toyota include the introduction of interchangeable parts in the United States in approximately 1798 by Eli Whitney. Industrial engineers such as Frederick Taylor and the Gilbreths contributed practices such as standardized work, time and motion studies, and process charting during the scientific management era of the late 1890s and early 1900s. Starting in about 1910 through the 1920s, Henry Ford extended earlier practices by marrying interchangeable parts with standard work and moving conveyance as well as incorporating vertical integration and behavioral concepts such as worker motivation in order to design a more comprehensive lean system.

The contributions emanating from Toyota in the 1950s, often referred to as the Toyota Production System, built upon earlier contributions and focused on waste elimination. Three wastes are typically identified, often referred to as overburden (*muri*), variation (*mura*), and waste (*muda*). Since the work by many at Toyota, numerous additional contributions may be cited. To put it simply, it must be acknowledged that lean is a philosophy of continuous improvement conducted in a systematic manner and dedicated to productivity improvements and waste elimination. In Chapter 1, it was recognized that as a system, lean comprises four integral components: leadership, organizational culture, and teamwork, as well as the practices and tools identified by many predecessors.

Interestingly, the concept of lean as a systematic philosophy for achieving productivity enhancements through waste elimination is quite broad and somewhat vague. For example, one can eliminate waste in a number of ways, including eliminating avoidable non-value-adding activities, reducing unavoidable non-value-adding activities, sharing information in a more timely and accurate manner, using more efficient resources, and so on.

An emerging theme of lean rests on technological change as a means for achieving significant advancement of productivity enhancement and waste elimination objectives. Increasing anecdotal evidence is emerging, which documents the ability of technology to enable productivity enhancement and waste elimination. Technological applications are impacting every industry, including agriculture, automotive, construction, entertainment, health care, and manufacturing, to name a few. This chapter surveys these industries to recognize and document examples as well as identify reported beneficial evidence of these technological contributions. These technological applications are enabling and they will continue to provide future lean achievements.

Lean Technology Capabilities

Productivity enhancements enabled by technology may be best explained, in part, by four laws. Chronologically, they are Moore's Law, Nielsen's Law, Butters' Law, and Kryder's Law. Moore's Law, offered in 1965, observes that the number of transistors in a dense integrated circuit doubles approximately every 18 months, dramatically enhancing the effect of digital electronics in nearly every segment of the world economy.[5] The capabilities of many digital electronic devices we take for granted these days are strongly linked to Moore's Law. Nielsen's Law, observed in 1998, states that the high-end users' Internet connection speed (bandwidth), and, therefore, the ability to rapidly retrieve or exchange information, doubles approximately every 21 months.[6] While Moore's Law observes that transistors double in speed roughly every 18 months, Butters' Law observes that the amount of data coming out of an optical fiber is doubling approximately every 9 months, further enhancing the speed of information exchange over the Internet.[7] Kryder's Law observes that memory storage density or capacity (magnetic disk areal storage density at the time) is increasing very quickly, faster than Moore's Law at times.[8]

Taken together, these four laws directly contribute to the capabilities of emerging technology and, therefore, the productivity enhancements and waste elimination that will be achieved in coming years. These capabilities are embedded in the emerging technologies impacting every industry. Examples of these technologies as well as cited benefits for industries including agriculture, automotive, construction, entertainment, health care, and manufacturing are discussed in the following subsections.

Agriculture

Technology is promoting lower costs, higher quality, and faster order response times in numerous agricultural applications. Technology has greatly enhanced agricultural practices over the past decade and with the continuing trend for large farms and less labor per acre, it will continue to do so, going forward. One current example is real-time kinematic (RTK) vehicle auto steering capability. RTK provides hands-free steering accuracy measured to the inch for a variety of tasks including listing and bedding up, row crop planting, strip-tilling, ridge-tilling, postemergence spraying, banding fertilizer, side-dressing, and cultivating. This technology provides benefits of repeatability of these tasks day after day or even year after year. It allows one to establish rows in the same spot for several years, promoting controlled traffic systems, drip irrigation, or any other use where one needs to be able to come back to the exact same spot in the field. Benefits cited include significantly reduced driver fatigue, which is best understood after one drives a tractor for several consecutive hours. It offers cost savings over older technology, which can approach $50 per acre through reduced overlap on tillage passes. On a farm of 10,000 acres, that adds up to $500,000 annually.[9]

A second example is drone technology (unmanned aerial vehicle or UAV), which is making its appearance in many industries including real estate, military, distribution, search and rescue, and agricultural applications. UAVs equipped with a multispectral camera can survey crops to detect water and nutrition issues, insect infestations, and fungal infections. UAV technology is being introduced to capture aerial field views for soil-moisture information for more efficient (location and duration) watering applications. UAVs equipped with appropriate camera filters and ground positioning technology (global positioning system [GPS]) can detect nutrient deficiencies by providing an aerial field view. Overlaying this field view on a soil map can lead to the diagnosis of nutrient deficiencies (e.g., nitrogen or phosphorous) based upon crop coloration.[10] The GPS can provide exact field coordinates so that the appropriate treatment can be applied to the corresponding area. This application can be applied during the growing season, promoting yields and avoiding losses. Historically, fertilizer applications are performed before or after the growing season.

UAV technology offers a significant improvement relative to the more common uses of doing it on foot or more expensive and time-consuming airplanes. Human sampling on foot or underground sensors lead to less reliable information, as sampled areas may not be representative of an entire field. UAV information can lead to more efficient fertilizer and water applications, which are particularly appealing for large-scale farms. UAV size, cost, and capabilities promote significant efficiencies, making UAVs useful for a wide range of jobs. One estimate suggests farmers can save $10 to $30 an acre in fertilizers and in related costs by examining the progress of crops while they are still in the ground.[11]

Automotive

Technology has been applied in the automotive industry for decades and this industry will continue to be a leading innovator and adopter of technology in the future. More than 30,000 people died on U.S. roadways in 2014 according to the National Highway Traffic Safety Administration (NHTSA). NHTSA estimates that traffic crashes cost the economy $299.5 billion annually and that approximately 90 percent of crashes can be attributed to human error. Furthermore, it is estimated that Americans waste about three billion gallons of fuel annually due to congestion.[12] These statistics suggest most will agree that safety and traffic congestion are significant issues facing automotive transportation.

One example of emerging technology in the automotive industry is being pursued by Denso, a large, international supplier of advanced technology, systems, and components. The particular innovation is referred to as vehicle-to-vehicle and vehicle-to-infrastructure (V2X) technology. This technology allows vehicles to wirelessly exchange data with other equipped vehicles and roadway infrastructure.[13]

The Federal Communications Commission intends to allow the use of the 5.850 to 5.925 GHz band of radio frequency spectrum, which the U.S. Department of Transportation (DOT) has set aside, for road safety and traffic management. This portion of the radio frequency spectrum is to be used for a variety of dedicated short-range communications (DSRC) uses, including traffic light control, traffic monitoring, travelers' alerts, automatic toll collection, traffic congestion detection, emergency vehicle signal preemption of traffic lights, and electronic inspection of moving trucks. DSRC technology data transmissions will use both onboard and nearby roadside transmission facilities. This is part of the national program of the U.S. DOT's Intelligent Transportation System.

Denso's DSRC system utilizes a two-way, short-range wireless communications technology. The more that vehicles are equipped with DSRC devices, the more effective the technology. When all cars have V2X, it creates a 360-degree situational awareness for each vehicle's surroundings. The embedded computing device on each car can use information about nearby vehicles to calculate current and future positions. This can help predict hazardous situations and alert drivers of precautions to avoid crashes.

V2X technology can be used to give right-of-way to emergency vehicles. When an emergency vehicle is approaching, the technology will change the traffic light at intersections and alert surrounding vehicles to switch lanes.V2X can also support enhanced mobility and environmental responsibility. DSRC technology can provide red or green light timing advisories to in-vehicle systems to compute appropriate speeds for optimized fuel efficiency, reduced vehicle emissions, traffic flow to reduce congestion, and time-saving driving habits. This information-sharing technology has the potential to improve driving quality and save lives, reduce costs, and promote a cleaner environment.

Architecture, Construction, and Engineering

Late in 2011, construction on the 736-foot tall, 52-story Leadenhall Building in downtown London, England, began. This project required many innovative architectural, construction, and engineering (ACE) solutions and significant coordinated cooperation among its numerous stakeholders in order to meet its multiple tight constraints. First, it had an expected construction timetable of two years, which is extraordinarily short for a super skyscraper. Second, there was virtually no logistics support space at the construction location. The storage space for materials was approximately 10 feet wider than the building footprint because it was located immediately downtown in London. With no logistics support space, components and modules arrived during the late evening for consumption during that evening, as storage was not possible. This necessitated exacting component and module specifications to ensure that each could be slotted exactly into position upon arrival. Third, fabrication was not performed on site, which would have allowed for custom fitting as the limited logistic space prevented on-site material and equipment storage. Even a large-scale work force was not feasible, given space constraints. The building components and modules were fabricated off-site at several locations, some of which were hundreds of miles away, such as in Worksop, England, and Enniskillen, Northern Ireland. Some modules were nearly completely outfitted off-site with pipe work, electrics, plumbing, and floor plates and transported to the site again, necessitating exacting component specifications in the off-site fabrication because on-site storage was not possible. Fourth, the building had to adhere to rigorous downtown London planning regulations.

One example of the lean technology contribution is the three-dimensional (3D) modeling (simulation) that was employed. A comprehensive 3D model was created to facilitate construction objectives. This 3D model afforded several waste-eliminating benefits. First, it enabled multiple stakeholders to practice the assembly in a virtual manner. The participants ran the complete simulation to build the Leadenhall Building 37 times. The 3D practice afforded just-in-time delivery of the materials, preventing any violation of the logistics support constraint. These practice sessions ensured that the advance time slot for every delivery of each crane lift, beam, bolt, and cable fix met the rigorous construction timetable. It was estimated that the project would have been impossible to coordinate delivery and component installations with conventional 2D blueprints. Second, the 3D virtual simulation enabled participants to engage in the simulated practice, regardless of their physical location. Third, the asymmetric shape of the building led to the foundations settling differently. The 3D model enabled engineers to plan for settling differences and to provide an innovative solution of jacks and removable steel plate shims to adjust the lean of the building.

In the end, nearly 40,000 components were assembled on-site in under two years, which represents a European construction record for a building of this size. The 3D digital engineering model better enabled project feasibility as well as afforded the project stakeholders the ability to eliminate tremendous wastes typical of a super skyscraper.

By itself, engineering supports numerous industries beyond architecture and construction. Technology is having a noteworthy impact in numerous engineering and manufacturing applications outside of ACE.

Rapid prototyping (RP) is one example. RP is a group of related engineering tools used to quickly fabricate a scale model of a physical part or assembly using 3D computer-aided design (CAD) data quicker, at lower cost, with tremendous ability to offer customization (flexibility), to exacting specifications (quality), and in small batch sizes, thereby eliminating the need for large volumes to achieve economies of scale.

RP has been applied in numerous applications including design visualization (e.g., in the 3D architectural model of the Leadenhall Building noted in the preceding text), CAD prototyping, metal casting (e.g., General Electric's [GE's] use of RP jet engine fabrication discussed in the text that follows), education, geospatial analysis, health care (e.g., fabrication of implants and prosthetic devices), entertainment (e.g., video games), and retail (e.g., eyeglass frames and shoe fabrication).

RP fabrication is typically performed using 3D printing or "additive layer manufacturing" technology. Historical manufacturing processes have employed subtractive methods such as milling, planing, and drilling. The RP process utilizes computer-generated 3D information that is exported to a 3D printer, which then builds up a scale model, layer by layer. The scale model is effectively materialized. One of the advantages of RP is that it allows a testable model to be quickly produced to determine proof of concept for a particular application. Generating a model quickly eliminates waste by determining applicability of an idea or part for its intended use. Additive layer manufacturing greatly reduces the waste incurred in subtractive methods by ensuring that only the material needed is used to fabricate the part.

GE notes that it has developed a fuel nozzle using RP for the Leading Edge Aviation Propulsion (LEAP) jet engine. GE utilizes a direct metal laser melting process enabling groundbreaking customization of multiple LEAP components. Essentially, parts are created directly from a CAD file using layers of fine metal powder and an electron beam or laser. GE claims that this part is up to 25 percent lighter, promoting fuel efficiency, five times more durable than its predecessor, and it is more complex than its counterparts by combining into 1 part what was assembled from as many as 18 parts in a multistep manufacturing process in the past, thereby reducing system throughput time.[14]

An example taken from the construction industry uses concrete printing, which employs highly controlled cement-based mortar extrusion process, which is precisely positioned according to computer data. The additive process has the ability to create custom-shaped construction components (e.g., a wall). The process has the potential to create architecture that is unique in form. Material components do not have to be made from solid material and so can use resources more efficiently than traditional techniques. For instance, allowances can be made for embedded conduits in components to directly accommodate utilities (e.g., electrical, plumbing, or telecommunications).

Additional reported benefits of RP include increasing effective communications (e.g., concurrent engineering) and reducing engineering design, development time, and error costs. RP enhances communications in part through its visualization capability. People tend to be visual learners. The extent to which representatives from functional disciplines such as engineering, manufacturing, marketing, and purchasing can see a rendered virtual model or hold a physical, 3D representation impacts their understanding of final outcomes.

RP has been reported to have the ability to reduce engineering and development time as well as to decrease error costs. RP allows modifications or corrections to be made early in the process when changes are less expensive to make. For instance, scale models can be used for testing (e.g., wind tunnel testing) as well as for tooling and casting purposes. The impact of technology in these additional engineering applications is enabling the benefits of lower costs, higher quality, faster orders response times, and enhanced transformation process flexibility.

Entertainment

Disney Entertainment has recently introduced experimental wearable technology (bracelets) that electronically link visitors to an encrypted big data collection and analysis system. The data collected allows for analysis to promote efficiencies through ride staffing adjustments, restaurant menus, and ride queue information. The wearable technology can also serve as admission tickets, hotel keys, and credit or debit cards. Disney reports that this system helped it accommodate 3,000 additional guests during the Christmas holiday season by reducing theme park congestion, which, it states, results in an enhanced visitor experience.[15]

Health Care

Technology is providing numerous health-related improvement opportunities in electronic health care. Two examples are attributable to the evolution of multidetector computed tomography and magnetic resonance angiography technologies for medical imaging. These technologies have led to less invasive and more informative radiological diagnosis. These technologies promote enhanced higher image quality and therefore interpretive accuracy.[16]

Telecommunication capabilities, along with increased Internet bandwidth, are promoting tremendous growth in another field of medicine, clinical telemedicine. One estimate of the growth rate for this medical field is 18.5 percent annually at least until 2018.[17] A 2012 report from Massachusetts-based market research firm, BCC Research estimates the global telemedicine market will grow from approximately $11.6 billion annually in 2011 to about $27.3 billion annually by 2016, which represents 135 percent growth over five years.

The growth rate of telemedicine can be attributable to numerous benefits, including improving access, especially for homebound people or those located in rural or remote locations, reducing the transmission of infectious diseases or parasites, better resource capacity utilization, shortening report turnaround times, as well as improving the satisfaction of both patients and health care providers.[18] It goes without saying that the drivers for the growth of this health care technology are largely overall cost savings, speed, and flexibility, all as a result of productivity enhancements and waste reductions.

There are many specific examples of telemedicine. Some are conducted using asynchronous communication capabilities such as the transmission of electronic medical records and radiological reports and images. Some are conducted using synchronous communication capabilities over phone or mobile devices such as online video consultations. Other forms rely upon various alternative technological devices such as teleconferencing, robotic surgery, or remote monitoring.

There have been disadvantages cited for telemedicine as well. Included among these disadvantages are the costs of telecommunications equipment and medical personnel training, concerns over the protection of patient health information, potential for increased errors, possible decreased personal interactions, which may be more revealing than remote interactions, and others. Needless to say, these exist in the presence or absence of the technology.

Manufacturing, Warehousing, and Supply Chains

New technologies are continually being applied and enhancing lean capabilities in numerous ways in order to drive sustained improvement efforts in manufacturing, warehousing, and supply chains. Technological innovation is enabling timely and accurate information exchanges among multiple locations throughout in distributed supply chain networks.[19] Examples of these innovative development investments include wireless network capabilities (e.g., bluetooth and wireless local area networks), auto identification technologies (e.g., radio frequency identification or RFID and bar coding), laser-guided vehicle technology, pallet shuttles, and cloud-based computing applications. These innovations offer numerous real-time supply chain benefits, including traceability, stock visibility, enhanced data accuracy and timeliness, reduced shrinkage, and real-time system monitoring.[20]

RFID technology enhances information visibility and traceability.[21] RFID technology has become economically feasible for most firms. RFID system element (e.g., tags, readers, and antennae) costs vary, depending upon the application. RFID tag pricing is variable and based upon many factors such as purchase volumes, tag memory bits, tag packaging (e.g., whether it is encased in plastic or embedded in a label), its active or passive nature, and wave frequency. Passive RFID tags maybe cost as little as \$0.07 to \$0.15. Active tags may range from \$20 to in excess of \$100 as one chooses potential features such as protective housing, battery life, or sensors (e.g., temperature, humidity, etc.). Similarly, RFID reader cost is variable and based upon many factors, including active or passive nature and high or low frequency. Reader costs largely begin at \$100 and go upward.

One important feature regarding RFID applications is reading range. Low wave frequency (LF) readers and tags have a shorter reading range (often less than 3 feet) and slower data transfer rate. Although LF systems may only read short distances, shorter-range capability does offer the advantage of reducing cross talk occurrences or the reading of an unintended tag at nearby upstream or downstream workstations instead of the intended target tag.

One example pilot implementation for a multiechelon clothing manufacturer integrated LF RFID and cloud technologies within an intelligent decision support system architecture for the monitoring and capture of real-time workstation production information.[22] This information was used to assist the generation of optimal production schedules in a distributed manufacturing environment. Prior to the implementation, manual recordings were used to collect production information. This resulted in a significant time to read and analyze what were considered outdated and unreliable daily summary reports. Three reported benefits of the pilot implementation were observed. First, a 25 percent increase in production efficiency was achieved. This was attributed to greater visibility and transparency of production operations as well as the improved production-scheduling effectiveness. Second, a 12 percent reduction in production waste was achieved. The enhanced production transparency reduced overproduction, defects, and unnecessary inventories. Third, an 8 percent reduction in labor and system costs was achieved largely through the elimination of the need to input job tickets, the need for fewer computer servers due to the cloud-based approach, and lower installation and maintenance costs. Intangible benefits of more timely production reports, more effective production-scheduling performance, and faster throughput times were also observed.

Summary

It should be evident that the industries noted in the preceding subsections are but a small sample of the many pursuing the enabling advantages that technology offers. Technology applications might start out within a localized portion of a process or it might enable global supply chain trading partners to collaborate on design issues using a 3D virtual model while being located on different continents. The application scale of technological applications being adopted is quite varied. Regardless of the application scale, technology is enabling lean benefits including reduced costs, faster response times, higher quality, and greater flexibility, all through enhanced productivity and reduced waste. Technology represents an exciting frontier of lean.

CHAPTER 8

Lean Supply Chain Management

A noted study of the U.S. food industry estimated that poor coordination among supply chain partners was wasting $30 billion annually.[1] This study further noted that supply chains in many other industries suffer from an excess of some products and a shortage of others owing to an inability to predict demand accurately and in a timely fashion. In all likelihood, this is a conservative estimate today, given that supply chains have become more complex and global, which exacerbates the costs of poor supply chain coordination.

The supply chain management (SCM) concept emerged in the early 1980s as firms began to realize that coordinated efforts among trading partners may provide a competitive advantage. At the time, it was referred to as *just-in-time*. SCM refers to the integration of upstream and downstream material and information flows among vendors, producers (manufacturing and services), resellers, and final consumers. In an overly simplistic view, SCM encompasses three principal processes: (1) sourcing and procurement, (2) transformation (e.g., fabrication and assembly activities), and (3) logistical management or the distribution of materials, including inbound, outbound, and reverse logistical flows as well as the supportive and necessary two-way information flows. These processes occur at multiple echelons and nodes across the typical supply chain.

Two prominent stimuli for the emergence of SCM are globalization, which is served by a nearly worldwide distribution network, and the advancement in information technology. Information technology has promoted the ability to integrate upstream and downstream material and information flows. Technology has enabled fast, cost-effective communications. The advent of the Internet has enabled the necessary information access for even small businesses and individuals. The advancement in information technology offers tremendous leverage for customers of all sizes in the form of the global marketplace. Customers are aware and expect that available information be provided with near-real-time speed and details. The global marketplace coupled with global distribution networks have led to greater market access but also fierce global competition in the form of greater product variety, lower product and service costs, higher quality, and shorter delivery times. These stimuli have driven the advent of lean supply chain management (LSCM). This chapter examines current LSCM practices that focus on multiechelon supply chain connections and flows that promote the elimination of non-value-added activities.

Supply Chain Activities: Sourcing and Procurement, Transformation, and Logistics

The typical *supply chain* is configured with multiple echelons and various components: external suppliers (Tier 1, Tier 2, Tier 3, etc.), original equipment manufacturers, distributors, warehouses, and retailers that work together to create product and service value. A simplified example of these components depicted as nodes and representing a wide variety of potential relationships is shown in Figure 8.1.

Supply chain sourcing and procurement processes focus on a variety of activities. These activities include vendor identification (including requisite material design and vendor performance specifications), vendor capability assessment, proposal or quote evaluation criteria, total cost analyses

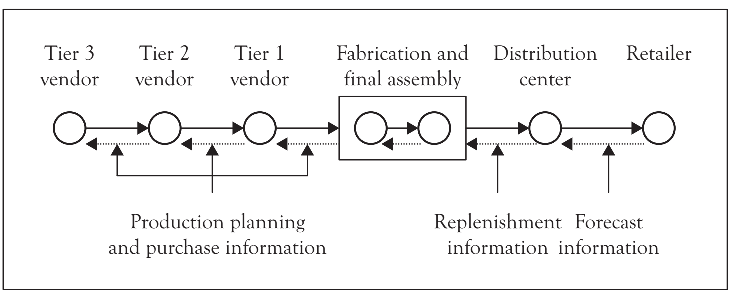


Figure 8.1 Multiechelon supply chain

Note: Dark arrows represent material flows; light arrows represent information flows.

(including choice of make vs. buy), contract negotiations (contract type, prices, service levels, geographical coverage, payment terms, delivery schedules, etc.), risk assessment, specification of change request processes, vendor solicitation method, and others.

Supply chain transformation activities create value at multiple supply chain nodes. Fabrication and assembly are example activities performed at transformative supply chain nodes. Additional support activities including production scheduling, order processing, and inventory management are also performed. Although not necessarily perceived as value adding, support activities are not avoidable as they plan, staff, direct, and control value-adding fabrication and assembly activities.

Supply chain logistical management, or the physical distribution of materials, includes inbound, outbound, and reverse logistical flows as well as the supportive and necessary two-way information flows for planning, staffing, directing, and controlling a variety of SCM processes. Transportation equipment, labor, and knowledge of regulations (local, state, federal, and international) are resources required to move materials. The logistics function also makes significant contributions to sustainable practices such as recycling, remanufacturing, refurbishing, and reusing of products and materials.

Lean Supply Chain Management

LSCM emphasizes the value-added nature of the activities comprising supply chain network processes with a focus on the elimination of non-value-added activities. Given the independent ownership across supply chains, LSCM emphasizes the connections and flows between supply chain links and their respective resources. Integrative supply chain networks require cooperative trading partner relationships, which are critical for achieving waste reductions.

The elimination of non-value-added SCM activities may be viewed as enriching the customer. This entails a quick understanding of the unique requirements of each individual customer and rapidly providing it. The set of objectives that guide individual facility lean efforts are the same that guide multiechelon LSCM efforts. The goal is to achieve a competitive advantage through lower costs (e.g., higher inventory turnover), enhanced quality (e.g., exacting specifications), faster order response speed (e.g., reductions in manufacturing cycle times and faster delivery times), flexibility (e.g., reliance upon global intermodal transport supporting no-touch processes that can automate and eliminate purchase orders, invoices, and movements between different transport mode containers), and sustainability (e.g., reductions and recycling of packaging materials). LSCM emphasizes strategies built upon the lean principles of earlier chapters. Some of the LSCM strategies are specific to the three principal SCM processes noted earlier: (1) sourcing and procurement, (2) transformation (e.g., fabrication and assembly activities), and (3) logistical management or the distribution of materials, while others are employed across the entire supply chain. A sampling of best practice LSCM strategies are listed in Table 8.1 and more fully explored throughout the remainder of this chapter.

Various strategies, which focus on synchronizing flows across the supply chain, can have a profound impact on trading partners' ability to promote productivity and eliminate waste. Strategies, which focus on promoting collaborative relationships, enhancing transaction visibility and transparency, aligning trading partner core competencies, fostering innovation, as well as best practice knowledge sharing can better enable trading partners to prioritize work that addresses current customer needs as well as eliminate non-value-adding resources and activities.

LSCM Sourcing and Procurement

In an effort primarily directed toward achieving lower production costs, *off-shoring*, or international sourcing, increased significantly since the year 2000. More recently, local sources of supply are taking on increasing importance within sourcing and procurement. Companies sourcing overseas face significant supply chain risks, given possible miscommunication regarding specifications such as quality. Local sources promote face-to-face communications and reduce miscommunication risks. They allow for more immediate delivery in the event of a supply shortage. Local sources allow for smaller purchase quantities as more frequent deliveries are easily justified. This allows for the maintenance of smaller buyer inventories.

Table 8.1 Example LSCM strategies

Lean Sourcing and Procurement

1. Supplementation of international sources with local sources
2. Reliance upon numerous procurement metrics for vendor identification and assessment
3. Maintenance of a set of few but reliable vendors
4. Reduced purchase quantities
5. Longer-term contracts
6. Greater focus on total cost of ownership (e.g., make vs. buy choices)
7. Reduced transaction costs

Transformation

1. Various lean tools: for example, value stream mapping, shared *kaizen* events, and A3 problem-solving frameworks
2. Information exchanges

Logistical Management

1. Smaller vehicles
2. Frequent deliveries
3. Intermodal capabilities
4. Postponement (e.g., assembly, mixing, labeling, packaging)
5. Colocate with customers
6. Utilize radio frequency identification (RFID)

Global Supply Chain Management Strategies

1. Supply chain trading partner cooperation
2. Leveraging the impact of people, information, and technology
3. Centralization of common functions
4. Outsourcing of nonessential functions
5. Managing shared trading partner risks
6. Sustainability initiatives

Increasingly, firms are identifying, selecting, and working with vendors based upon performance on a variety of quantitative as well as qualitative lean performance metrics. Lean metrics used to assess vendor performance reflect more than acquisition costs. Vendors are being identified on the basis of long-term *target costing* or an agreed-upon process for determining and achieving a life cycle cost at which a proposed product with complete specifications (functionality, performance, quality, etc.) must be produced in order to generate the desired profitability at its anticipated selling price.[2] Additional vendor identification and ongoing assessment metrics include delivery lead times, timeliness of delivery (variance from expected delivery time), frequency of delivery, delivery quantities, vendor design and production capabilities, certified process capability and delivery quality, returns policy, payment terms, locality, commitment to improvement, information technology and systems capabilities, vendor financial stability, as well as target costs. Reliance upon metrics beyond a competitive price reflects a trend toward reliance upon numerous procurement metrics for vendor identification and assessment.

The time needed to assemble all of the information required to create a complete solicitation package including detailed specifications necessary for a request for quotation and then to subsequently vet prospective vendors is of questionable value at best. As a result, best practice suggests maintaining a smaller set of proven, stable vendors. Once proven, long-term contracts are being used to reward and partner with vendors as well as reduce the time to maintain long vendor lists.

Lean procurement also focuses on the total cost of ownership. This consideration takes into account the costs associated with ownership of specialized equipment, necessary labor to operate it, and costs to maintain it over time. Firms realize that over the long term, it may be less expensive to purchase custom as well as standard items if volume does not justify long-term total costs of ownership in make-versus-buy choices. This may enable the firm to avoid dedicated investments that are not justified.

There is a heightened focus on the number of transactions throughout the procurement process. One example of this is the number of paper documents created, signed, and stored. These are often perceived by many as possessing little to no value. Allowing vendors to monitor inventory and authorizing an agreed-upon replenishment quantity once a threshold inventory level has been passed reduces non-value-adding paper-based transactions.

LSCM Transformation

A vigilant focus from a customer perspective on the performance value of all activities may better enable producers within each supply chain node to achieve waste reductions. Each supply chain transformation node must extend the internal lean principles and practices of previous chapters into external initiatives. For example, reliance upon lean tools such as value stream mapping, shared kaizen events, and an A3 problem-solving framework may enable a reduction in the number of supply chain transactions as well as transaction and production cost reductions.

One external initiative, synchronizing flows across supply chain, represents the single largest opportunity for supply chain productivity improvements and waste reductions. Synchronized flows can be achieved with various strategies, which focus on promoting collaborative relationships, enhancing transaction visibility and transparency, aligning trading partner core competencies, fostering innovation, as well as best practices knowledge sharing. These strategies extend the transformation capabilities of a single firm, serve to integrate the transformation capabilities of many companies, and improve performance throughout a supply chain. Many of these external SCM initiatives integrate materials, organizations, and information, often through advances in technology.

More advanced supply chain trading partners have recently begun to engage in the exchange of information and best practices knowledge sharing. An early and accurate exchange of information regarding external demands in order to synchronize internal planning and execution better enables companies to attain the productivity benefits and waste reductions cited in many lean initiatives. The exchange of accurate and timely information between supply chain trading partners can lead to significant economic, social, and environmental benefits.

The timely exchange of accurate information with trading partners, given potentially volatile demands and other market signals, can promote forecast accuracy, the ability to construct production schedules capable of meeting demand when demand occurs, as well as timely and accurate purchase and replenishment plans across an entire global supply chain. This must be an initiative of any world-class lean organization. Global markets and more competitors have moved supply chain systems toward universal participation by all supply chain members in an effort to cut costs.[3] The increasingly innovative nature of products or the shortening length of most product life cycles and the duration of retail trends make it imperative to get products to market quickly. Otherwise, lost revenues and markdown prices are experienced. For instance, the life cycle of some garments in the apparel industry is six months or less. Yet, manufacturers of these garments typically require up-front commitments from retailers that may exceed six months, making long-term fashion forecasts risky.

Anecdotal evidence of the benefits of demand visibility for synchronized supply chain efforts are abundant and include increased sales; higher service levels; faster order response times; lower inventories, obsolescence, and deterioration; reduced capacity requirements; direct material flows (reduced number of stocking points); and lower total system expenses.[4] A Collaborative Planning, Forecasting, and Replenishment (CPFR) pilot study by Nabisco and Wegman Foods produced a supply chain sales increase of 36 to 50 percent through a more efficient deployment of inventory.[5] A survey concerning the frequency and the benefits derived from information exchange noted manufacturers citing significant improvements in cycle time and inventory turns while retailers indicated order response times as short as 6 days for domestic durables and 14 days for nondurables. Four out of 10 survey respondents cited at least at 10 percent improvement in both response times and inventory turns. Forty-two percent of survey respondents indicated at least a 10 percent reduction in total inventory in the past 12 months. Forty-five percent of respondents cited reductions of at least 10 percent in associated costs.[6] In supply chain collaboration pilot tests conducted with several vendors, Proctor and Gamble (P&G) experienced cycle time reductions of 12 to 20 percent.[7] At the time, P&G estimated that greater supply chain collaboration and integration would result in an annual savings of $1.5 to $2 billion, largely reflecting the reduction in pipeline inventory.[8]

In 1996, approximately $700 billion of the $2.3 trillion retail supply chain inventory was in safety stock alone.[9] Supply chain inventory may be as great as $800 billion of safety stock being held by second- and third-tier suppliers required to provide rapid delivery to their larger customers.[10] According to the U.S. Department of Commerce, there is $1 trillion worth of goods in the supply chain at any given time.[11] Even a small reduction in supply chain safety stocks is a sizeable dollar figure.

Almost immediately after its initial efforts to collaborate on supply chain forecast development, Heineken's North American distribution operations experienced a 15 percent reduction in its forecast errors and cut order lead times in half.[12] As order lead times are lowered, order response time improves. Anecdotal evidence has noted 15 to 20 percent increases in fill rates and half the number of out-of-stock occurrences.[13] Enhanced knowledge of future events (e.g., promotions and pricing actions), past events (e.g., weather-related phenomena), internal events (e.g., point-of-sales [POS] data and warehouse withdrawals), and a larger skillset gained from collaboration may all contribute to enhance forecast accuracy.[14]

Supply chain collaboration should also result in lower product obsolescence and deterioration. Riverwood International Corporation, a major producer of paperboard and packaging products has worked to establish collaborative relationships with customers in order to make production scheduling and inventory control less risky.[15] This company sought to balance the need to stock up on inventory for sudden demand surges against the fact that paperboard starts to break down after 90 days. With a higher degree of collaboration and a timelier sharing of information between retailer and manufacturer, greater stability and accuracy in production schedules resulted, making inventory planning more accurate. Furthermore, as production schedules more accurately reflected the needs of the retailer to satisfy near-term demand, reductions in manufacturer capacity requirements were possible.

The potential supply chain synchronization benefits underscore the importance of sharing accurate and timely information. A framework, which is being used to synchronize planning between trading partners, is developed in the following text.

Current technologies offer supply chain partners the ability to develop collaborative plans in a "pull" manner. Advancements in technology allow for the capturing of retail-level demand and the exchange of demand information upstream in real time. This information offers the dual prospect of reducing excess inventories and enabling supply chain partners to plan production and coordinate purchasing of items needed to meet current demands. Web-based communication is faster and is available at a price most trading partners can afford. Although still used by some firms today, it is well known that older communication techniques (e.g., fax technology) are slower, typically require a more error-prone manual entering of identical data by both trading partners, may be unaffordable by some supply chain trading partners, and may be done in batch file transfer mode, which further delays the exchange of information.

The knowledge and information exchange should emanate from the point farthest downstream in the supply chain where consumer demand originates, typically the retail level, in order to effectively achieve a pull approach to production planning within transformation processes across the supply chain. All other points where demand occurs should simply represent purchase orders for inventory replenishment if information sharing is done in a transparent, accurate, and timely manner. In most instances, this suggests a single supply chain forecast is needed and it should originate at the retail level, as depicted in Figure 8.1. Then, working back upstream, demand information may be shared through the supply chain. The process of sharing demand and generating demand forecasts is simply repeated in sequential fashion for each unique pair of upstream trading partners.

The design of a supply chain information-sharing framework has the potential to eliminate enormous wastes. Initially, at the retail-level POS, technology can capture demand as it occurs. Data mining can detect the early onset of demand patterns. CPFR can be used between any two supply chain trading partners for communicating demand information, the creation of an agreed-upon shared forecast, and the creation of a production plan for replenishment planning purposes.[16] POS, data mining, and CPFR technologies can better enable supply chain partners to share demand information, agree upon joint forecasts, and to ultimately synchronize production planning, purchasing, and inventory allocation decisions across a supply chain. These technologies offer an enhanced ability for supply chain trading partners to operate in a lean manner.

Since forecasts or expectations of demand form the basis for all planning activities, collaborative efforts should drive all partner planning activities in a highly coordinated, tightly integrated lean supply chain. The importance of timely and accurate forecasts cannot be overemphasized, especially for products with long supplier capacity reservation standards such as clothing, trendy items with short life cycles such as toys, low-margin items such as foodstuffs, or longer lead time items sourced overseas. For all of these items, time to market is critical. Therefore, timely and accurate forecast information is essential to competitive success.

Ideally, a collaborative supply chain forecast would accomplish several objectives. It is imperative that the approach have characteristics of affordability, accuracy, timeliness, flexibility, and simplicity. First, it should integrate all members of the supply chain. The sharing of selected internal information on a secure, shared web server between trading partners can lower implementation costs and increase accessibility. Second, as depicted in the simplified supply chain of Figure 8.1, the origination point of collaboration should be the demand forecast farthest downstream. This can then be used to synchronize order replenishment, production scheduling, purchase plans, and inventory positioning in a sequential fashion upstream for the entire supply chain. This will promote greater accuracy. Third, a web-based exchange of information can increase speed relative to older existing means of communication. Fourth, flexibility can be enhanced if it is able to incorporate a variety of supply chain structures and company-specific forecast procedures. In order to accomplish the noted objectives, a five-step framework is outlined in the following text.

Step One: Creation of a front-end partnership agreement. As a minimum, this agreement should specify objectives (e.g., inventory reductions, lost sale elimination, lower product obsolescence) to be gained through collaboration; resource requirements (e.g., hardware, software, performance metrics) necessary for the collaboration; and expectations of confidentiality concerning the prerequisite trust necessary to share sensitive company information. This trust represents a major implementation obstacle.

Step Two: Joint business planning. Typically, partners identify and coalesce around individual corporate strategies to create partnership strategies; design a joint calendar identifying the sequence of planning activities to follow, which affect product flows; and specify exception criteria for handling planning variances between the demand forecasts of trading partners. Among other things, this calendar must specify the frequency and interval of forecast collaboration. A 1998 pilot study conducted between Wegman Foods and Nabisco to develop weekly collaborative forecasts for 22 Planters peanut products took approximately five months to complete steps one and two.[17]

Step Three: Development of collaborative forecasts. Forecast development should allow for unique company procedures to be followed affording flexibility. Supply chain trading partners should generate independent forecasts allowing for explicit recognition and inclusion of expert knowledge concerning internal operations and external factors. Given the frequency of forecast generation and the potential for vast numbers of items requiring forecast preparation, simple forecast techniques easily used in conjunction with expert knowledge of promotional, pricing, or other factors to modify forecast values accordingly could be used. Retailers must play a critical role as shared POS data permits the development of accurate and timely expectations for both retailers and vendors.

Hierarchical forecasting (HF) can provide the suggested framework structure for including all supply chain partners in the collaborative pull knowledge and information-sharing process. HF has been shown to have the ability to improve forecast accuracy and support improved decision making.[18] To date, several studies have offered practical guidelines concerning system parameters and strategic choices, which allow for custom configurations of HF systems within a single firm.[19] Furthermore, HF is able to provide decision support information to many users within a single firm, each representing different management levels and organizational functions.[20] Consequently, HF is increasingly being commercially offered as an integral framework of the enterprise planning software.

Initial applications of the HF approach have been used to provide forecast information based upon a strategy of grouping items into product families, similar to the example depicted in Figure 8.2 for a garment retailer.[21] The typical firm's product line possesses a similar arborescent structure shown in this figure. As depicted in Figure 8.3, the typical supply chain also possesses a treelike structure with upstream nodes typically supplying inventory to multiple downstream nodes. Therefore, extending HF to an arborescent supply chain structure in order to provide the pull forecast framework is readily done.

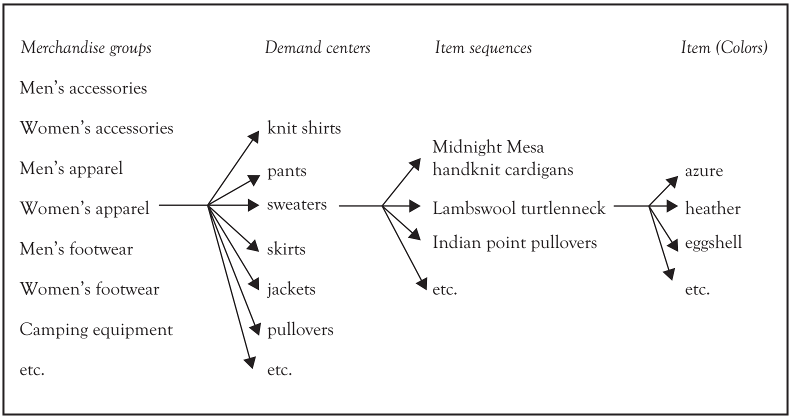


Figure 8.2 Garment retailer product line hierarchical structure

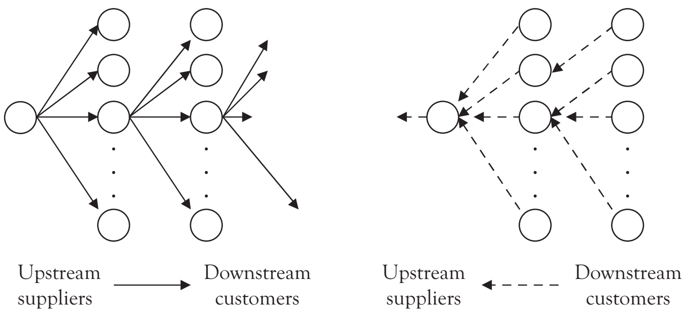


Figure 8.3 Example supply chain arborescent structure

Note: Solid arrows represent material flows; dashed arrows represent demand and forecast information flows; all nodes and links not depicted.

The process begins at the farthest point downstream. Consumer demand is captured and demand information is shared upstream between supply chain partners. This process is successively repeated for each echelon comprising any multiechelon supply chain structure. Web-based technology enables real-time posting of supply chain exchange partner's demand values on a secure, shared web server to accomplish the demand aggregation process.

After demand aggregation is performed, demand forecast generation takes place. These forecasts are generated independently by each partner allowing for explicit recognition and inclusion of expert knowledge concerning internal operations and external factors. Since the typical supply chain consists of many echelons, this shared two-step process of demand aggregation and forecast generation is repeated for each echelon in sequential fashion upstream through the supply chain.

Step Four: Sharing forecasts. Each pair of downstream customer and upstream vendor would then electronically post their respective, independently generated forecasts on a dedicated server. At this point, consensus forecasts between trading partners are not likely to exist, given the independent forecast development. An exception notice could be issued for any forecast pair where the difference exceeds a preestablished safety margin (e.g., a 5 percent variance). If the safety margin is exceeded, planners from both firms may collaborate or a rules-based system response could be devised to derive a consensus forecast. If the safety margin is not exceeded, a simple agreed-upon rule could be devised to rectify minimal differences.

Resultant forecasts of this process are then used for synchronized planning. These forecasts would be consistent between upstream and downstream supply chain echelons. It is these forecasts that could be used to eliminate significant value stream waste.

Step Five: Inventory replenishment. Once the corresponding forecasts are in agreement, the order forecast becomes an actual order, which commences the replenishment process. Each of these steps is then repeated iteratively in a continuous cycle, at varying times, by individual products and the calendar of events established between trading partners. For example, trading partners may review the front-end partnership agreement annually, evaluate the joint business plans quarterly, develop forecasts weekly to monthly, and replenish daily.

The application of the technology within information exchanges in the framework suggested in the preceding text should go a long way in eliminating the *bullwhip effect*.[22] In a simple explanation, the bullwhip effect refers to a trend of increasingly variable swings in order size, production planning, and consequential inventory as one proceeds upstream in the supply chain. This effect occurs for various reasons. The most notable reasons are: (1) each sequential upstream trading partner acting independently (forecasting demand, planning production, and ordering) from its downstream customer; (2) order batching at any one supply chain node, which amplifies variability; (3) anticipated price fluctuations, which further encourage order batching; and (4) rationing and shortage gaming, which also encourage order batching, further exacerbating variable upstream demands.

No discussion of a supply chain knowledge-sharing framework would be complete without recognition of anticipated barriers to adoption and implementation. As practiced by Taiichi Ohno, obstacles let you know where to begin lean initiatives. As with most initiatives, there will be skepticism and resistance to change. Several of the anticipated obstacles to implementation are noted in Table 8.2 and discussed in the following text.

One of the largest hurdles hindering collaboration is the lack of trust over complete information sharing between supply chain partners.[23] The conflicting objective between the profit-maximizing vendor and cost-minimizing customer gives rise to the adversarial supply chain relationship. Sharing sensitive operating data may enable one trading partner to take advantage of the other. Similarly, there is the potential loss of control as a barrier to implementation. Some companies are rightfully concerned about the idea of placing strategic data such as demand forecasts, financial reports, manufacturing schedules, or inventory values online. Companies open themselves to security breaches.[24] However, in a survey of 257 U.S. manufacturing and service companies, only 16 percent

Table 8.2 Expected barriers to supply chain knowledge and information sharing

1. Lack of trust and loss of control in sharing sensitive information
2. Lack of internal and external forecast collaboration interest
3. Availability and cost of technology/expertise
4. Fragmented information-sharing standards
5. Aggregation concerns (number of forecasts and frequency of generation)
6. Fear of collusion
7. Inexperience/lack of skills at retail level

of respondents who were established participants in a business-to-business trading exchange cited security and trust problems.[25] Another study found 96 percent of retailers already sharing information "regularly" with their suppliers, with almost half sharing information with manufacturing partners on a daily basis.[26] The front-end partnership agreements, nondisclosure agreements, and limited information access may help overcome these fears. The potential cost savings will also clearly help.

A second hurdle hindering collaboration is a cultural stumbling block. An unprecedented level of internal and external cooperation is required in order to attain the benefits offered by collaboration. Each firm has its own traditional practices and procedures. A survey of senior managers identified that the second biggest barrier to innovation is a lack of coordination.[27] If multifunctional internal operations can be synchronized, then it may be possible to pursue collaborative efforts between trading partners.

Similarly, there must be a certain degree of compatibility in the abilities between supply chain trading partners. The availability and cost of technology, the lack of technical expertise, and the lack of integration capabilities of current technology across the supply chain present a third potential barrier to implementation.[28] The collaborative process design must integrate skills and procedures that cut across business functions, distribution channels, key customers, and geographic locations.

The necessary "bandwidth" and the associated reliability of technology is a fourth potential barrier. Some companies may not have the supporting network infrastructure. If the necessary trust in the relationship can be developed, synchronizing trading partner business processes with consumer demand need not be overly time-consuming or costly. In order for this to be possible, emerging standards need widespread adoption as opposed to numerous, fragmented standards. Widespread sharing and leveraging of existing knowledge and information across functions within an organization and between enterprises comprising the supply chain may be possible. Common emerging standards will be necessary to promote collaborative supply chain efforts. Attaining a "critical mass" of companies willing to adopt these standards will be important in determining the ultimate success of collaborative practices. The cost of establishing and maintaining collaborative processes without common interfaces will limit the number of relationships each participant is willing to invest in.

However, as the ability to collaborate is made easier, the number of supply chain trading partners wanting to collaborate will increase.

A fifth potential obstacle to adoption and implementation concerns two aspects of data aggregation: the number of forecasts and the frequency of forecast generation.[29] Bar code-scanning technology provides retailers the ability to capture POS data by store, whereas suppliers typically forecast orders at point of shipment such as warehouse. The POS store data is more detailed as it represents daily, shelf-level demands for individual stores. Point of shipment data represents the aggregate of all stores served by one warehouse, typically measured over a longer interval of time, such as a week. In the pilot study by Wegman Foods and Nabisco, 22 weekly forecasts for individual products were developed collaboratively. In a full-blown collaboration for store-level planning, the number of daily collaborative forecasts would increase to 1,250 for Planters peanuts alone.[30] It is not uncommon for large retail stores to stock 75,000 or more items, supplied by 2,000 to 3,000 trading partners.[31] This obstacle must be coupled with the vast potential of exception reporting, given forecast variances. Given the frequency of forecast variance review and the large number of potential exceptions that may occur, a rules-based approach to automatically resolve trading partner forecast variances will be required. In the development of synchronized plans, these aggregation concerns will need to be resolved. One means to synchronize business processes and overcome these obstacles is reliance upon the HF approach.[32]

An anticipated sixth obstacle to implementation focuses on the fear of collusion leading to higher prices. It is possible that two or more suppliers or two or more retailers may conspire and share information harmful to the trading partner. Frequently this fear arises when the item being purchased is custom made or possessing a proprietary nature, making it less readily available. Long-term supplier partnerships between mutually trustworthy partners can reduce the potential for collusive activities.

A final potential obstacle to implementation recognizes the important role retailers must play in the process. However, in many industries, the employee turnover rate at the retail level coupled with its consequential impact on the experience and skillsets of retail employees may result in an important barrier to implementation efforts. However, with all initiatives, success encourages adoption. Anecdotal evidence of the potential benefits attributable to collaborative supply chain collaboration will overcome these adoption barriers.

Many companies have successfully standardized their internal financial and transactional processes. The next step for these companies is engaging supply chain partners using Internet technologies to standardize external financial and transactional processes. Although simplistic, the five-step framework identified in this section addresses interenterprise collaborative efforts.

In a survey of 200 information technology executives using or deploying an enterprise resource planning (ERP) system, 52 percent of the respondents indicated current involvement or future plans to create a business supply chain using ERP software.[33] The concept is to enable suppliers, partners, distributors, and consumers real-time system access via an extranet. Whether it is managed within an ERP system or it is a stand-alone approach, significant potential is emerging for advanced decision support and enterprise execution systems to focus on integrating and optimizing cross functional, intraorganizational, and interorganizational planning activities and transactions.

The future evolution of this idealistic five-step framework will permit an automatic, electronic transference of supply chain partner knowledge and information into the development of demand forecasts, production schedules, accounting (accounts receivable and payable), human resource requirements, and supply chain planning applications such as the warehousing and inventory control applications. Benefits to be realized for all participants will include the mitigation of the supply chain bullwhip effect through better collaboration, increased sales, lower operational costs, higher customer service levels, and reduced cycle times, among a host of others.

LSCM Logistical Management

As noted earlier, one lean procurement practice gaining acceptance is reliance upon a greater number of local sources. This promotes smaller purchase quantities as more frequent deliveries are easily justified. One consequence of smaller purchase quantities is smaller buyer inventories. If buyers purchase smaller quantities more often, larger capacity, less fuel-efficient vehicles are no longer required. A current trend in lean transportation is the reliance upon smaller capacity, more fuel-efficient vehicles. This trend is further supported by truck manufacturers offering vehicles designed to operate on potentially more efficient alternative fuels.

In light of off-shoring procurement, intermodal freight transportation capabilities are critical for achieving supply chain transport time, cost, and flexibility objectives. Intermodal transportation relies upon an intermodal container or vehicle capable of being exchanged among multiple modes of transportation (e.g., rail, ship, and truck), without direct handling of the goods themselves when changing modes. The method reduces the extent of cargo handling, and while doing so, improves freight security, reduces loss and damage, and promotes shorter transportation times.

Various postponement strategies (e.g., assembly, mixing, labeling, and packaging), also referred to as delayed differentiation, are commonly used throughout supply chains today. These strategies allow for the last-minute customization of final products. Assembly postponement requires some degree of assembly at the final shipping destination. It promotes costs reductions attributable to greater cube carry capacity utilization of containers or the avoidance of some import taxes, given lower sales price. The return of collapsible containers promotes assembly postponement. The extent of assembly required depends on the customer preferences and technical abilities. One example of mixing postponement is POS paint color mixing. Vendors are able to stock a small quantity of paint tint bases and colorants and mix them to meet exact customer demand. Resultant benefits include the opportunity for customers to select from a large variety of colors mixed within minutes, higher order fulfillment, higher customer satisfaction, lower inventory costs, and decreased floor space requirements. Examples of both labeling and packaging postponement can be found in the food industry's use of deferred packaging at regional warehouses near the destination markets, given the potential for alternative customers (e.g., Albertsons, Kroger, Walmart, etc.) and its reliance upon packaging postponement, given the potential for alternative package sizes found in destinations such as vending machines, convenience stores, and supermarkets.

Postponement is an adaptive supply chain strategy that enables companies to reduce inventory while improving customer service. Postponement strategies take out the risk and uncertainty associated with having undesirable products, thereby reducing associated inventory costs including investment, obsolescence, deterioration, spoilage, and others. Postponement improves order fill rates.

A recent strategy in lean logistics management is the colocation of trading partners. Sometimes referred to as supplier parks, the auto industry has been an early developer of the concept. This relationship is often one of module or component suppliers locating a facility in the immediate vicinity of the vehicle assembly plant. Ford Motor Company developed an early example in Chicago, Illinois, where nine suppliers initially colocated with Ford. These suppliers provide stampings, suspension components, instrument panels, fuel tanks, engine coolant components, wiring systems, injected and blow-molded plastics, door components, and manufactured items. Numerous anecdotal benefits have been attributed to colocation.[34] Included among these benefits are reduced transportation costs, increased delivery reliability, enhanced ability to cope with demand uncertainty, demonstrated partnership commitment, increased face-to-face contact allowing for quicker response to customer preferences, increased organizational and technological supply chain integration, increased availability of public incentives (e.g., tax breaks and shared infrastructure build and operational costs), inventory carrying cost reductions attributable to shorter delivery distances, as well as allowing each partner to focus on its core competencies.

Reliance upon technological innovations is also promoting LSCM objectives. Use of radio frequency identification (RFID) can reduce labor costs, and proactive information-sharing capabilities such as advance shipping notices (ASNs) promote information visibility and supply chain traceability, which customers expect, given the technological capability.

Global SCM Strategies

In additional to the various SCM strategies noted in the preceding sections, there exist a variety of LSCM strategies, which are not specific to the three principal processes of sourcing and procurement, transformation, and logistical management. The six examples identified in Table 8.1 are discussed in the following text.

The success of the supply chain is dependent upon all supply chain trading partners. There must be recognition of long-term win–win relations in all exchanges. This requires collaboration and cooperation. This cooperation includes better intraorganizational functional cooperation as well as interorganizational cooperation such as partnerships with suppliers and newer, emerging virtual relationships. Functional disciplines within firms as well as trading partners across a supply chain must work seamlessly across borders and differing cultures. This should recognize that at times, a firm may partner with firms in one supply chain while competing with the same firms in another supply chain. Supply chain networks are increasingly weblike where supply chain success is dependent upon all trading partners' contributions.

Most people recognize the most important asset of any firm is the human asset. This recognition of employee importance places greater emphasis on the development of this asset through education, training, and empowerment. Effective leaders recognize the value of leveraging the impact of people. Critical to this practice is providing the human asset access to information, training with technological tools, and the necessary authority so that employees can make decisions to complete their assignments. Data-driven analysis is a significant emerging theme in industry. Correct decisions and subsequent commitments are critical in lean environments. Examples of technology discussed earlier include RFID, POS data collection, data mining for the early detection of emerging demand patterns, CPFR, and proactive information sharing such as ASNs. Many external SCM initiatives integrate materials, organizations, people, and information, often through advances in technology. These technologies enhance information visibility and traceability as well as promote intelligent decision making, therefore providing value to supply chain trading partners. These are largely affordable technologies for most, if not all, supply chain trading partners, which can be used to enhance LSCM efforts.

Centralization of common functions is a strategy commonly pursued in order to avoid redundancies and promote greater efficiencies. One example of this strategy is the recent trend to merge the procurement and logistical functions as one department. Given functional commonalities such as the need to transport purchased materials, these historically separate disciplines are being called upon to promote collaboration. Although some suggest centralization is less customer-friendly, it does offer the ability to achieve lean objectives, in particular lower costs, given higher productivity and waste elimination.

LSCM increasingly encourages placing greater reliance upon outsourcing of nonessential (less value-adding tasks and resources) functions or activities. The point of this strategy is to avoid being a "jack-of-all-trades" and to focus upon being a master of those functions or activities one does perform. Numerous examples of commonly outsourced activities are available, including transportation management functions (e.g., relying upon third-party transportation providers to avoid owning transportation equipment with the associated labor to operate and maintain it as well as keep abreast of local, state, federal, and international regulations), warehousing, procurements, data management, freight forwarding, and reverse logistics to identify a few. Vendors can offer specialized efficiencies in numerous logistical activities. Specific examples include packaging, labeling, assembly, delivery, and manufacturing at a point closer to the consumer. Companies producing foodstuffs often partner with contract packagers or third-party logistics providers to perform that activity off-line. By leveraging the capabilities and processes of logistics service providers, firms can promote LSCM objectives.

Risks have grown dramatically in the increasingly complex, interdependent, global lean supply chain networks that have emerged. Consequently, a premium is now being placed upon managing shared trading partner risks to promote quick response capabilities. Faster response capabilities can be achieved through the flexibility and agility strategies discussed in an earlier chapter. Risk management strategies (e.g., avoidance, mitigation, and transference) refer to proactive, precautionary measures taken to minimize risk, which can ultimately promote faster response capabilities. A host of risk types, including strategic, operational, financial, compliance or regulatory, reputational, and safety are promoting firms to address systematic planning efforts to address risk. These risk-planning efforts address risk identification, both qualitative and quantitative risk analysis (probabilities and impacts), risk response planning (avoidance, mitigation, transference, and acceptance), and finally risk monitoring and control.

Customers and social trends are increasingly demanding the promotion of sustainability initiatives throughout distribution networks. Sustainability is a long-term objective that goes beyond internal improvements and waste reduction by extending Ohno's seven principles externally across the supply chain. Sustainability reinforces Ohno's seven principles as an integral element of an organization's culture. To date, there exist three broad categories of supply chain sustainability initiatives: product and process life cycle considerations; environmental stewardship; and facilities design, construction, environmental control, and maintenance. These categories are discussed in the following text.

Sustainability commonly refers to the characteristic of a process or state, which can be maintained at a certain level indefinitely. The World Commission on Environment and Development articulated what has now become a widely accepted definition of sustainability, "to meet the needs of the present without compromising the ability of future generations to meet their own needs."[35] Sustainability addresses how processes and operations can last longer and have less impact on ecological systems. It is the conservation of resources, natural or otherwise, through sustainable activities and processes across a value chain. In particular, this relates to the societal concern over major global problems of climate change and resource depletion. Global problems and resource depletion can be addressed simultaneously through an examination of supply chain activities aimed at improvement, waste reduction, reduced resource consumption, and a reduction of transformation by various reclamation practices.

To date, most documented lean improvement efforts have looked internally first, going after readily attainable improvements within a single transformation process possibly within a work center or department. Only if internal efforts are successful, have organizations focused on external initiatives. While sustainability promotes internal improvement and waste reduction within a single transformation process, it also encourages external improvement and waste reduction across the value chain. Furthermore, sustainability addresses waste reduction that may lead to improved social conditions on a global basis. Namely, sustainability is an integral cultural characteristic of an organization.

It should be clear that non-value-adding activities that consume resources are wasteful and, over the long run, are not economically sustainable. If an activity does not add value, it should be reduced or eliminated if possible. Processes and operations are less likely to be sustainable without improvement and waste reduction as resources are typically increasingly scarce.

Many organizations, including, for example, Ford, General Electric, Toyota, Walmart, and others, have now included sustainability as part of their corporate objectives. Ford's "vision for the 21st century is to provide sustainable transportation that is affordable in every sense of the word: socially, environmentally and economically."* World-class organizations understand that they must continually reinvent themselves in order to maintain a competitive advantage.[36] World-class sustainability initiatives must anticipate and preempt customer demands and changing environmental regulations.[37] Even when it becomes known that a world-class organization's capabilities provide it with a competitive advantage, lagging competitors are typically slow to address this performance gap as they are inextricably wed to their existing approaches and processes. Once a firm achieves a competitive advantage based upon particular competencies, it is difficult for competitors to replicate without going through the same long-term learning process.[38]

Sustainability is a capability that can enhance the value of a company.[39] Sustainable companies conduct their businesses so that benefits accrue to all supply chain stakeholders; this includes employees, customers, vending partners, the communities in which they operate, and, of course, shareholders.

Although sustainability may have come about largely due to regulatory compliance requirements, a rising ratio of material-to-labor costs, as well the opportunity to improve corporate image and community and customer relations, it has evolved into a much larger initiative. There are eight economic drivers for sustainability initiatives.[40] These drivers, shown in Figure 8.4 may be broadly identified as enhancing image; compliance with regulations; future liability concerns; community relations; employee health and safety concerns; customer relations; cost reduction or avoidance; and quality improvement. These drivers have encouraged firms to

* http://www.ford.com/microsites/sustainability-report-2007-08/default

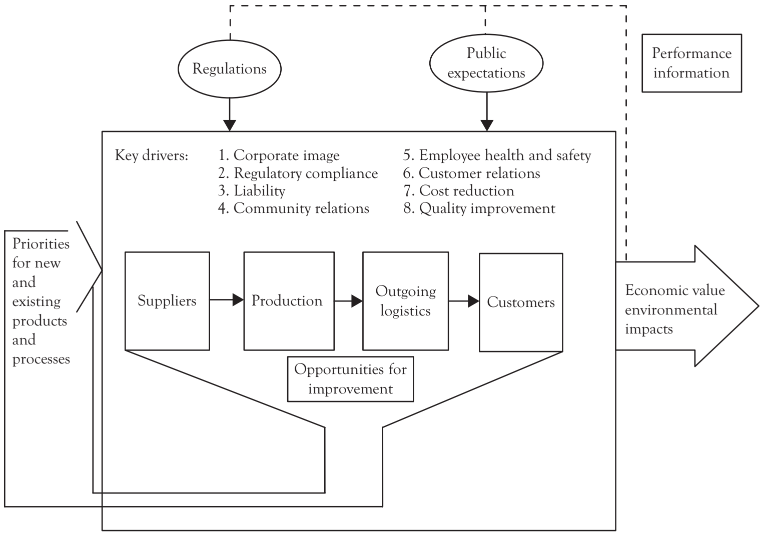


Figure 8.4 Sustainability and the extended supply chain

enlarge transformation process objectives beyond low cost, quality, speed of delivery, and flexibility to include a focus on social responsibility and employees.

Given these eight economic drivers, recent literature provides abundant examples of supply chain sustainability initiatives and their associated benefits. These initiatives have focused on three broad categories: (1) product and process life cycle considerations, (2) environmental stewardship, and (3) facilities design, construction, environmental control, and maintenance. Each of these is discussed in the following text with the use of industry examples and benefits achieved.

Product and process life cycle considerations examine ways to achieve sustainability objectives over the entire life cycle of a product. This includes practices affecting the design, development, manufacture, as well as reverse logistical flow of items in a closed-loop value chain. Two points regarding activities within this category need emphasis. First, firms implementing initiatives within this category often have more mature or advanced sustainability programs. Second, it should be emphasized that sustainability initiatives in this category often look externally, beyond the boundaries of a single transformation process for partners across the entire value chain. The external focus of this initiative increases the economic returns capability for any one firm.

Firms are realizing that closing the supply chain loop with various reclamation activities for products at the end of their life cycle offers economic, social, and environmental value, often referred to as the *triple bottom line*.[41] A change from the typical cradle-to-grave manufacturing model to a cradle-to-cradle approach, where new products are designed to help restore nature and eliminate disposal has been proposed.[42] The idea is to design products for extended use, reuse, reclamation, refurbishing, remanufacturing, and eventual recycling. Use of these practices has been encouraged in part due to rising energy, commodity, and other material costs.

As an example, Ford has applied the triple bottom line concept in parts applications. Annually, Ford has reclaimed and reused 10.6 million pounds of crumb rubber in parts such as air dams, floor mats, trunk mats, and sound absorbers. This saved Ford $4.8 million in parts costs alone in just one year.[43]

The eco-design concept was introduced in 2001.[44] Eco-design views sustainable solutions as products, services, hybrids, or system changes that minimize negative and maximize positive sustainability impacts, including economic, environmental, social, and ethical impacts throughout and beyond the life cycle of existing products or solutions, while fulfilling acceptable societal demands or needs. Eco-efficiency can be said to encompass the concepts of dematerialization, increased resource productivity, reduced toxicity, increased recyclability, and extended product life spans.

Examples of eco-efficiency are numerous. One simple example of dematerialization is the use of less packaging in shipping. A second example is reliance upon engineered returnable packaging and dunnage solutions. A third example is Toyota's belief that hybrid technologies will play a central role in achieving "sustainable mobility." Partnering with many value chain participants, Toyota has made considerable efforts to promote the use of hybrid vehicles. By November 2007, Toyota achieved global cumulative sales of 1.25 million hybrid vehicles. The estimated resulting reduction in carbon dioxide emissions was five million tons. A fourth example is Toyota's efforts toward the development and production of lithium-ion batteries. These batteries offer the advantages of greater energy and output densities than nickel-metal hydride batteries in current hybrid vehicles.

Caterpillar has accrued financial benefits from recycling and remanufacturing tractor components like engines and gears. Its tractor components remanufacturing division, which has become its fastest-growing unit in the recent decade, has annual revenues, which top $1 billion. Furthermore, this division is estimated to grow 20 percent a year while reclaiming components that might otherwise be discarded.[45]

Sustainability initiatives include eliminating the production of process by-products or finding uses for process by-products. Tracking waste generation is a first step to by-product elimination. Knowledge of the source and the reason for the generation of waste will assist its elimination. Eliminating by-products can be achieved through a variety of strategies, including material substitution, alternatives disposition such as the creation of a commodity possessing value (e.g., reworking, composting, converting), or possible inclusion of a third party to assist solution identification.

From these examples, it should be understood that reclaiming value from end-of-lease, end-of-use, and end-of-life product returns is achievable through closed-loop value chains. Reuse, reclamation, recycling, refurbishing, and remanufacturing eliminate waste by reducing the number of times various transformation tasks are performed again. These practices reuse considerable portions of a product in a number of successive product generations leading to waste elimination and enhanced environmental performance.

The second category of supply chain sustainability initiatives increasingly being pursued in industry is environmental stewardship. One significant change in the corporate practices over recent years is due to increasing demand for social responsibility as the result of environmental concerns including global warming, resource depletion, energy and water shortages, solid waste disposal, and others. These concerns are increasingly attracting worldwide attention and, as a result, corporate stewardship of the environment is becoming a more important issue.

A growing awareness is emerging for the environmental stewardship role that business must assume. One industry example is provided by Toyota, which is emphasizing the role of nature in creating production sites that are in harmony with their natural surroundings. Toyota is increasingly using renewable energy, including biomass and natural energy sources (solar and wind power), and contributing to the local community and conserving the environment by planting trees in and around manufacturing plants.

Enhanced environmental performance has reduced waste and improved processes, products, and profitability at several companies.[46] Enhanced environmental performance may lead to superior quality and ultimately improved profitability through higher customer satisfaction and loyalty.[47] Simply put, there is a clear link between environmental management systems (EMSs), practices, and operational performance.[48]

Various practices have emerged, which emphasize this environmental stewardship role. Examples include industry-specific voluntary programs such as the Environmental Protection Agency's 33/50 Program and the International Organization for Standardization (ISO) 14000 EMS standards program. Formerly adopted in 1996, ISO 14000 represents a framework to lead organizations to improved environmental performance. Results of a large-scale survey of manufacturers provide evidence that ISO 14000 can positively impact both the performance of a firm's EMS as well as overall corporate performance.[49] The survey results suggest plants can be both more environmentally responsible and more efficient with ISO 14000 certification.

Given the relative newness of this category of sustainability, it should not be surprising that the EMSs in many firms have not been proactive but rather reactive in nature. Findings suggest that the EMS is typically driven by changes in environmental regulations and that EMSs typically identify neither qualitative nor quantitative costs associated with environmental performance. Furthermore, environmental stewardship issues are typically internal initiatives, confined to a single facility and are seldom extended to the value chain for activities such as supplier selection, retention, and evaluation.[50]

Increasingly, the activities of facility design, construction, operation, and maintenance are being conducted with an eye toward waste reduction and greater sustainability. One significant example of this third category of sustainability initiatives is the Bank of America's One Bryant Park, the first skyscraper designed to attain a Platinum Leadership in Energy and Environmental Design certification. The design of the building was environmentally friendly.[51] It used technologies such as floor-to-ceiling insulated glass to reduce thermal loss and maximize natural light, thereby lowering energy consumption. A gray water system, which captures rainwater runoff and nonindustrial wastewater, provided water for the building's cooling tower and toilets. Waterless urinals are estimated to save millions of gallons of water annually. The building was made largely of recycled and recyclable materials with construction using a 55 percent concrete, 45 percent slag mixture (a recycled blast furnace by-product), which lowers greenhouse gas emissions through a reduced concrete production requirement. The air temperature cooling system produced and stored ice during off-peak hours, and then used this ice to help cool the building during peak load. The building even included on-site power generation, thereby reducing significant electrical transmission losses that are typical of centralized power station production plants.

Walmart is incorporating various sustainable concepts in its retail building design, construction, environmental control, and maintenance. It is reducing the height of stores as well as tenant space, which reduces facility energy consumption. As a substitute for portland cement, the concrete used in the construction of the floors of its buildings incorporates 15 to 20 percent fly ash, a byproduct of coal combustion produced by utility companies. It is specifying the use of the recycled fly ash, which makes the concrete stronger, reduces landfill waste, reduces the demand for virgin materials, and substitutes materials that may be energy-intensive to create. Walmart is utilizing various environmental control systems such as natural daylight–dimming controls and electricity-generating photovoltaic cells in clerestories and skylights to sense and automatically regulate indoor lighting, heating, and cooling. At one retail installation, the skylights alone allowed lights to be turned off in the lawn and garden center for up to 10 hours per day contributing to a $30,000 savings.[52] Increasingly Walmart requires its vendors to have a proactive sustainability management plan.

Ford provides a third example of a company utilizing various sustainable concepts in building design, construction, environmental control, and maintenance. Ford's River Rouge plant has a 10-acre green roof that uses sedum, a succulent plant, to soak up four million gallons of storm water a year and to release it into a nearby wetland. It is estimated that this will double the length of the roof life, provide insulation, and will save Ford millions of dollars it would have had to invest in a water treatment facility.[53]

One should question why sustainability is not progressing at a faster rate among corporations today, given the wealth of benefits cited in the preceding text and in the literature. Keep in mind that peoples' behavior toward adopting innovation occurs at varying rates. Innovations often require a lengthy period, sometimes years before they are widely adopted.[54] Consumers largely drive the economic behavior of firms. Although the concept of recycling has been practiced for centuries, to date, there are apparently still relatively few "innovators" and "early adopters" of this practice. Seemingly, the importance of this practice has yet to be fully understood by the majority of consumers. However, as the price of resources and the cost of proper disposal continue to rise, sustainable supply chain practices will naturally gain greater acceptance.

A second reason why sustainability initiatives are not as visible is that many initiatives are still only internal and have not included widespread value chain participation. The development of a world-class sustainable program typically proceeds in a stepwise manner.[55] First, process-based capabilities are instilled internally in a single set (vertically) of transformation activities. Second, once mastered, the firm will seek to integrate and coordinate these capabilities across several activities (horizontally) or systems within the firm. Embedding these capabilities within the routines and knowledge of the firm making them multifunctional, organizational-based capabilities follows as the third phase. Finally, world-class firms will seek to make these network-based capabilities that reach outside the limits of the transformation process in order to encompass the value chain network. Increasingly, firms must reach outside their transformation process and include value chain partners in sustainability initiatives.

An interesting summary offering a staged taxonomy of sustainability initiatives has been proposed.[56] The years 1970 to 1985 have been identified as the "resistant adaptation" years where organizations found the least expensive means to minimally comply with environmental legislation. The second stage, the mid-1980s, has been identified as companies "embracing environmental issues without innovating." The third stage of the late 1980s consisted of "reactive" organizations using "end-of-pipe" solutions for treating waste but with little effort to prevent waste production. In the "receptive" stage, the early 1990s, organizations began to see environmental considerations as a source of competitive advantage. Organizational "policy entrepreneurs" focused company efforts on being more socially responsible. Due to continuing environmental pressures, the mid- 1990s, witnessed the "constructive" stage when organizations began to adopt a "resource-productivity framework to maximize benefits attained from environmental initiatives." In this stage, companies began to look at product and process design to achieve sustainability objectives.

As firms matured and learned more about lean, it evolved. The emergence of sustainable supply chain initiatives is the emerging evolutionary stage of lean. Sustainability is an extension of lean principles. World-class companies such as Ford are acting in a proactive manner, creating a new vision for the whole system that includes all organizational personnel as well as value chain suppliers and customers. These firms are using value chain partnerships to look externally in order to apply lean principles in a sustainable manner to generate increasing economic value. Once consumers signal they are ready to adopt sustainable purchasing behaviors, world-class firms understand they must have sustainable practices already developed and in place.

Although there has been debate on whether synergies exist between profits and sustainable practices, the industry data in the examples cited earlier illustrate that sustainable practices offer the ability to reduce costs. Non-value-adding activities consume resources and therefore over the long run are not economically sustainable. If an activity does not add value, it should be reduced or eliminated if possible. Without waste reduction and elimination, processes and operations are less likely to be sustainable as resources are typically increasingly scarce.

To date, most lean initiatives have looked internally and have not had an objective to reduce, lessen, or eliminate ecological impacts. Environmental performance gains or savings are typically not included in an assessment for undertaking lean improvement activities. These gains or savings are typically not quantified in the financial justification. This is especially true when considering the entire value chain. As world-class firms mature, they begin to understand lean practices can be extended externally to the value chain. Consequently, strategic practices utilizing closed-loop value chains to achieve both waste elimination and enhanced environmental performance are beginning to emerge. These points demonstrate that sustainability is a significant lean objective.

Lean and sustainability initiatives promote the ability to reduce resource or capacity requirements through conservation and reclamation activities and the ability to capture resources for a cost that is less than the value recovered. There is no doubt that cost reduction has enhanced bottom-line performance through lean and sustainability initiatives. Also, firms have improved their image through socially beneficial practices.

In the future, lean and sustainability initiatives must increasingly reflect shared value chain objectives that simultaneously lessen environmental impacts, achieve cost savings, enhance corporate image, and also drive additional revenues. Opportunities exist to simultaneously reduce cost as well as drive additional revenues. For example, some retailers sell canvas shopping bags, which are reusable from shopping trip to shopping trip. The sale reduces the expense of plastic and paper bags while providing a revenue stream of canvas bag sales.

In the future, lean and sustainable practices must enhance the bottom line from both cost reduction as well as profit generation. Firms must look for opportunities to reclaim or capture resources for a cost that is less than the value recovered as well as drive future revenues. Once firms learn to capture the value of reclaimed products, future revenues will increase as the cost savings may be passed along to consumers providing a significant competitive advantage and further driving future revenues. Sustainability looks beyond the boundaries of a single transformation process. Now world-class firms must view sustainability over the entire value chain for opportunities to reduce costs as well as drive future revenue streams.

Summary: The Future of Collaborative Supply Chain Knowledge and Information

Poor coordination among supply chain partners reduces productivity and results in waste. Coordinated efforts to integrate upstream and downstream material and information flows among vendors, producers (manufacturing and services), resellers, and final consumers can provide a competitive advantage. This chapter has identified a host of strategies focused on the three principal SCM processes: (1) sourcing and procurement, (2) transformation (e.g., fabrication and assembly activities), and (3) logistical management or the distribution of materials, including inbound, outbound, and reverse logistical flows as well as the supportive and necessary two-way information flows.

Globalization and the advancement in information technology place a premium on firms' LSCM efforts to achieve this competitive advantage. Demonstrable evidence exists that technology offers the ability for trading partner efforts to integrate upstream and downstream material and information flows. The advancement in information technology and the information revolution offers fast, cost-effective communications as well as leverage for customer of all sizes in the form of the global marketplace. Customers are aware and expect available information be provided with near-real-time speed and details. The global marketplace, distribution networks, and competition have led to customer expectations of greater product variety, lower product and service costs, higher quality, and shorter delivery times. This has driven the advent of LSCM. This chapter identifies numerous current LSCM strategies and practices, which focus on multiechelon supply chain connections and flows that promote the elimination of non-value-added activities.

CHAPTER 9

The Evolutionary Constructs of Flexibility, Agility, and Lean

Linguistic confusion often arises when multiple terms may refer to the same idea or construct. Terms sometimes possess subtle nuances making it difficult to differentiate among them. For example, a single term may ambiguously refer to more than one idea or construct, or linguistic confusion may simply arise, given evolutionary change attributable to acquired learning. This observation can be made today with respect to the management philosophies, constructs, or paradigms of "flexibility," "agility," and "lean."

Numerous manuscripts explaining and contrasting as well as extolling the virtues of attaining these constructs have appeared for more than 40 years. Authors have praised the virtues of each of these three constructs and painstakingly attempted to explain the nuances that differentiate the three. Yet confusion exists within each of these constructs, let alone among the three. The literature on the flexibility construct alone clearly identifies it as a complex, multidimensional, and hard-to-capture idea.[1]

Many different terms for various types of flexibilities are referenced in the literature. At times, several terms are used to refer to the same type of flexibility. And, at times, terms are not always clear and precise or even in agreement. The literature regarding agility has often suggested it is different from flexibility and lean on the basis of whether environmental uncertainties are anticipated or unanticipated.

Each of the three constructs is complex and multidimensional. Taken as a whole, the preponderance of the research for the three constructs suggests there are differences among them; yet there exists confusion and inconsistency associated with their use, which leads to difficulty differentiating among them. This confusion among the constructs exists for several reasons. First, authors often examine these constructs solely in a pairwise manner. Second, these constructs are typically examined in an evolutionary manner. Agility has often been compared to its predecessor flexibility, and efforts often attempt to differentiate it from flexibility on the simple basis of an external versus internal system viewpoint. Similarly, lean is often compared to its predecessor agility, and efforts often attempt to differentiate it from agility on the basis of a philosophical or systems point of view. Third, some research utilizes empirical testing of inexact and imprecise concepts leading to slightly different aspects of the same underlying construct being masked only by different terminology. For instance, survey results from a 1986 study of 214 Japanese manufacturers suggests investments including "the introduction of flexible manufacturing systems, the reduction of the lead times in production, the development of new processes for new products, the reduction of set-up times and giving workers a broader range of tasks all point in the same direction: flexibility."* Interestingly, these investments are often cited as enablers in the subsequent agile and lean bodies of literature. For instance, it is observed that the "flexibility to respond quickly to customer needs is a hallmark of lean manufacturing."†

If theory and empirical work are to continue to advance in this area, semantic differences among the three constructs must be identified and resolved. Although many would suggest there is presently a preferred conceptual definition of each, to some, the explanation for each of these differing terms seem to possess the same meaning, given the wealth of alternative enablers or simply the system reference point (e.g., internal or external system perspectives) that have been used in the literature. This may possibly be attributed to the observation of the approach often taken in each investigative study of contrasting these constructs only in a pairwise manner making it difficult to triangulate among the three.

Although a conceptual definition for each of these three terms has been largely agreed upon in the literature, understanding the difference

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* DeMeyer et al. (1987, 6).

† Kennedy and Widener (2008, 304).

among the three is still tenuous at best. In part, this may be attributed to a number of alternative enablers or simply the system reference point. Further compounding this difficulty of discerning differences among the three is the dearth of evidence regarding the efficacy of agility.

Comprehensive literature reviews exist for each one of the constructs. However, there is an absence of a comparative review of the literature that assists one's effort to differentiate among the three constructs. This chapter provides a comprehensive, yet sufficiently concise summary review of the literature for the three constructs, flexibility, agility, and lean. In doing so, it lays the foundation to define each term and delineate differences among the three terms so that semantic confusion among them may be dispelled. Seminal works for each construct using a historical evolutionary perspective to trace construct development, principal components, and enablers, as well as differences among the three are identified. In doing so, this chapter offers the following contributions. First, it begins with a concise review of seminal literature for each construct. There is a chronological overlap in the development of this literature. However, one could argue these three constructs appeared chronologically as flexibility, agility, followed by lean. This ordered appearance is used for the discussion in the following text. Noted in this review are the cited principal enablers as well as an explanation of the differences among the three constructs. There are distinct differences among these three paradigms, albeit these differences are subtle, which has led to the linguistic confusion and inconsistency among the three. The single, most important conclusion among the three constructs is how the later constructs of agility and lean have expanded upon and enveloped flexibility. The three constructs of flexibility, agility, and lean actually represent an evolutionary path of continuous improvement. This chapter attempts to address the confusion and inconsistency associated with "flexibility," "agility," and "lean" as transformation process constructs.

In order to better to understand these three constructs, a modified framework for them is borrowed from Gerwin.[2] This framework is used to unify as well as differentiate the literature for each of the three constructs. This framework is depicted in Figure 9.1 with the modified differences depicted in bold print.

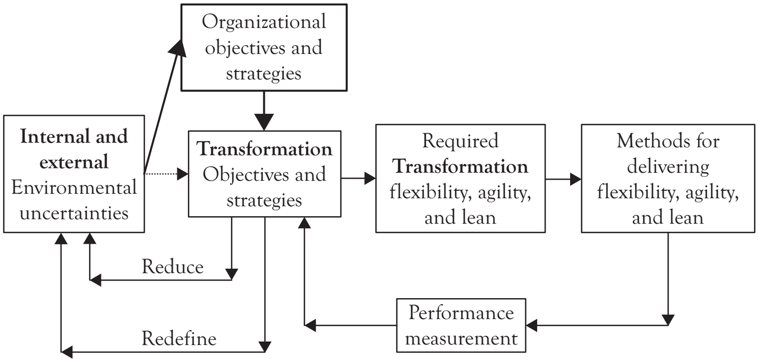

Figure 9.1 Flexibility, agility, and lean conceptual framework

The framework depicted in Figure 9.1 adapts Gerwin's framework to include all three constructs in four ways. First, a box labeled "Organizational objectives and strategies" is added. This addition is necessary, as each construct does not solely apply within manufacturing industries. Further, each construct may derive strategies or practices from both organizational objectives as well as functional (transformation) objectives. Second, the box titled "Environmental uncertainties" has been modified to recognize the source, which may be either internal (e.g., machine breakdown) or external (e.g., technological change) to the organization. Third, an arrow emanating from "Internal and external environmental uncertainties" and terminating at "Organizational objectives and strategies" is added. This arrow is necessary, as environmental uncertainties may alter an organization's objectives, or more directly, environmental uncertainties may alter transformational objectives. Fourth, the term "Transformation" is used to replace "Manufacturing," as flexibility, agility, and lean refer equally well to both service and manufacturing systems.

Flexibility

An early working definition of flexibility is the "ability to respond effectively to changing circumstances."* The construct of flexibility, as it is understood today, began to emerge in the late 1970s. Flexibility may be

* Gerwin (1993, 396).

defined for various organizational levels, including a level as small as a machine or as large as the entire transformation process.[3] This is one issue, which partially explains linguistic confusion among the flexibility, agility, and lean constructs as each is applied at various levels by differing authors.

One author identifies seven alternative types of flexibility, including process (ability to produce a variety of existing products), product (ability to add new or subtract old products), product customization, routing, process volume, material, and sequencing flexibility.[4] The author suggests these flexibility types are important due to both internal and external system uncertainties. As one would expect, these flexibility types can be operationalized with tactics such as the ability for substituting materials, the number of components of processes each machine can accommodate, periodic volume or sequence change accommodations, workforce or equipment capabilities, and so on. The author also postulates that the capability to augment flexibility is enabled by technology.

Flexibility of a transformation process was promoted in large part for three reasons: (1) technological advancement, (2) a desire to enhance capabilities beyond cost and productivity objectives, and (3) an unstable and unpredictable business environment.[5] This author observes that technological evolution leading to flexible manufacturing systems and robotics has significantly enhanced production equipment capabilities, enabling the promotion of flexibility (as well as traditional objectives of reduced cost and greater productivity) as a desirable operational attribute. The author suggests that the instability and unpredictability of the environment have prompted this incentive for transformation processes to adapt.

Another author noted that flexibility refers to volume and product mix changes as well as the ability to accommodate customers' special requests.[6] This author observed that the strategic manufacturing decisions comprise a collective pattern of decisions, including decisions regarding capacities, facilities, technologies, and workforce capabilities. These four transformation components are often cited in later literature as enablers of flexibility, agility, and lean.

A 1986 survey of more than 500 global manufacturing corporations observed planning differences regarding the recent strategic importance of costs, quality, speed, and flexibility over the prior four-year history.[7]

Japanese manufacturers were seen to have focused on cost-efficient flexibility as their priority and were further down the road regarding flexibility as a transformation objective. European manufacturers focused upon cost pressures with large investments in technology, automation, and production and inventory control systems. North American manufacturers focused primarily on quality, with flexibility not yet being a major competitive priority. Further, these authors suggest that manufacturing has to have a minimum level of quality, dependability, and cost efficiency in order to become flexible. These authors suggest the "Japanese paradigm considers quality, dependability, cost and flexibility as priorities which a firm addresses sequentially over time, rather than as alternative points of emphasis."*

In another publication,[8] it is noted that "the Japanese are ahead in recognizing the growing salience of flexibility."† The author suggests that the Japanese began to focus on flexibility as a strategic objective after overcoming quality issues. Like several earlier publications, it is observed that flexibility is normally considered as a means to adapt to environmental uncertainty. This author identifies means for achieving adaptation including small setup times, part standardization, and technology investments. This may represent the first instance of the evolutionary path emergence of flexibility, agility, and lean as constructs, as these strategies are also enablers often cited of agility and lean. Interestingly, the author also observes that some means for achieving agility lead to "waste." Some of the noted examples include investments in excess capacity and floor space, slack time, as well as routing flexibility, which may discourage machine downtime reduction efforts.

A more recent review of the flexibility literature notes that flexibility "reflects the ability of firms to respond to changes in their customers' needs, as well as to unanticipated changes stemming from competitive pressures."‡ These authors suggest that flexibility offers the ability to respond to unanticipated *external* forces.[9] It is noteworthy to observe at this point that the body of agile literature (discussed in the following sections) argues that the principal difference between agility and lean is

* DeMeyer et al. (1987, 6).

† Gerwin (1993, 395).

‡ Vokurka and O'Leary-Kelly (2000, 485).

simply that agility offers the ability to respond to unanticipated external forces, while lean does not.

These authors further observe that flexibility does not refer to a single decision variable, but rather to a general class of variables. Fifteen drivers (facilitators), or variable classes of flexibility, are identified, built upon earlier authors' contributions.[10] These 15 classes have one of two source characteristics, which spur a firm to achieve flexibility: (1) internal, based upon a specific resource capability or a collection of system attributes attributable to various unspecified resources, or (2) based upon an external source. These flexibility drivers coupled with a short description are noted in Table 9.1. It is noteworthy that only 2 of these 15 classes have an external source characteristic.

Table 9.1 Flexibility drivers (facilitators) and source characteristics

Flexibility driver (facilitator)	Source characteristic	
	Internal resources	External driver
Automation: provided by computerization of technologies	√	
Delivery: ability to respond to delivery change requests		√
Expansion: ease of altering capacity	√	
Labor: range of operator capabilities	√	
Machine: range of machine capabilities	√	
Market: ability to adapt to external changes		√
Material handling: range of materials handling parts capabilities	√	
New design: new product introduction ease	√	
Operations: range of alternative processing capabilities	√	
Process: range of alternative parts processing capabilities	√	
Product: ease of introducing new parts	√	
Production: range of production parts	√	
Program: unattended system function time	√	
Routing: alternative path processing capabilities	√	
Volume: range of profitable system volume output	√	

Agility

The construct or "paradigm" of agility was first described in 1991 by a group of researchers at Lehigh University's Iacocca Institute.[11] Their report led to an early working definition of agile: the ability to meet changing marketplace needs quickly. The Iacocca Institute report subsequently encouraged several authors to promote agile as a new, evolving paradigm.

An early pioneering work resulting from the 1991 Iacocca Institute report suggests that incremental improvement of the currently existing mass production system was no longer able to provide American manufacturing with a competitive dominance.[12] Subsequently, numerous authors largely agree that the principal motivator of agility as a paradigm has been marketplace turbulence, an *external* systematic source of uncertainty requiring organizations to develop an inherent ability to continuously adapt.[13]

The agile body of literature cites numerous *external* drivers attributable to the agile paradigm emergence, including, but not limited to, rapidly changing customer demands, competitive challenges, technological and communications development, as well as cultural and social change. A simplified summary of the principal drivers for agile development noted in the earliest agile manuscripts are shown in Table 9.2. It is interesting to note that one manuscript identifies the principal driving force behind agility as simply the need for change.[14]

Since its emergence in the literature, various discipline-specific manuscripts have promoted agility as an important emerging business paradigm. One interesting observation of the agile body of literature is its multidisciplinary nature. From an evolutionary point of view, authors initially examined agility from a manufacturing perspective. This was followed by contributions examining agility from engineering, software development, supply chain management, marketing, and, most recently, project management perspectives. Taken as a whole, since approximately 1990, this body of work has synthesized common drivers and strategies for achieving agility across these various areas. The multidisciplinary nature of this body of literature clearly represents a key criterion for judging the merits of agility.

Table 9.2 Commonly noted agile development drivers

Agile driver	Kidd (1994)	Kumar and Motwani (1995)	Fliedner and Vokurka (1997)	Gunasekaran (1998)	Yusuf, Sarhadi, and Gunasekaran (1999)	Sharp, Irani, and Desai (1999)
Marketplace requests for mass customization			√			
Supply chain stakeholders' perceived value of information enrichment and partnerships			√	√	√	√
Information technology (e.g., the ability to provide real-time information operationally to the factory floor, internally across transformative functions, and externally across supply chains)	√	√	√	√	√	√
The ability for technology to enhance innovation, product design, and development	√	√	√	√	√	√
Competitor-driven responses (e.g., capabilities such as quality, flexibility, fast response times, and lower costs)	√	√	√	√	√	√
Social and cultural change (e.g., responsiveness to social and environmental issues)					√	√
Human resource (team-based) investments (e.g., skills, welfare, decentralized authority)	√	√	√	√		√

Agile Manufacturing Literature

Possibly the first reference to agile manufacturing occurred in 1991 as an outcome of Lehigh University's Iacocca Institute study.[15] From what is possibly the earliest use of the term agility as a business paradigm, the participants focused on the different capabilities of agility and flexibility in manufacturing applications. They suggest agility requires strategies, which integrate flexible technologies of production with the skill base of a knowledgeable workforce and with flexible management structures that stimulate cooperative initiatives within and between firms. The participants observe that the agile manufacturing enterprise is capable of designing, developing, and producing new products quickly as well as assimilating field experience and technological innovation easily into existing products. An important aspect of these participants' definition of agility is the inclusion of flexibility. This may represent flexibility in product offerings (e.g., product mix or specification changes), process capabilities (e.g., quick machine changeover or mixed scheduling), or volume changes (e.g., varying output levels) in order to respond quickly to varying marketplace demands.

Using Kuhn's model of paradigmatic change,* agile manufacturing is suggested to be an emerging paradigm.[16] This author attempts to draw connections between agile manufacturing and previous production paradigms of craft and mass production. A staged model representing an evolutionary path toward achieving agility is suggested through various mechanisms including business process reengineering or redesign and business network redesign.

An early definition of agility is the capability of operating profitably in a competitive environment of continually, and unpredictably, changing customer opportunities.[17] These authors elaborate extensively upon this definition and expand upon the earlier explanations of agility by noting that the key difference between agility and flexibility is the ability to respond quickly to unanticipated marketplace changes. In their elaboration, these authors also note that the journey to agility is never completed due to an ever-changing marketplace.

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* Kuhn (1962).

An early exploration observed that agility should be considered from a systematic viewpoint.[18] The author suggests agility is attained through distinctive core capabilities (e.g., diverse technologies) possessed by contributing partners, which enable rapid adaptation. The author suggests the emphasis is on leveraging the skills and knowledge of people in combined (supply chain) organizations.

An agility index, derived from 21 influencing factors, was developed in 1995.[19] Two of the influencing factors commonly cited in subsequent literature include information technologies and organizational or human resource factors.

A 1997 study defined agility as the ability to successfully market low-cost, high-quality products with short lead times and in varying volumes that provide enhanced customer value through customization capabilities.[20] These authors note this ability must be able to respond to changes in market demands, regardless of the source. Namely, agile firms manage change as a matter of routine.

In approximately 1998, the body of agile manufacturing literature began to focus on the difference between agility and flexibility. One study differentiates agility from flexibility by noting that flexible changes are responses to known situations where the procedures are already in place to manage the change.[21] These authors suggest that agility extends the capability of flexibility by requiring the ability to respond to unpredictable changes in market or customer demands.

Also in approximately 1998, the body of agile manufacturing literature began to focus on the difference between agility and lean. Four dimensions are used to define the agile manufacturing enterprise: (1) value-based pricing strategies that enrich the customer, (2) cooperation that enhances competitiveness, (3) organizational mastery of change and uncertainty, and (4) investments that leverage the impact of people and information.[22] The author asserts that agile and lean are not synonymous. However, only an example of supplier relationship differences used to distinguish between the two is provided. The contribution of this manuscript lies with its identification of agile enablers and the conceptual model illustrating the enabling strategies.

A 1999 study suggests differences between agility and lean.[23] These authors note that agile firms must be lean and flexible and have the ability to respond quickly to changing situations. These authors also add that despite having these abilities, agile firms will not likely possess all of the necessary resources and will increasingly need to rely upon supply chain partners. A theoretical model, built upon the drivers of Table 9.2, consisting of 10 key agile enablers is offered: (1) core competencies, (2) virtual enterprises, (3) rapid prototyping, (4) concurrent engineering, (5) multiskilled workforce, (6) continuous improvement commitment, (7) teamwork, (8) change and risk management, (9) information technology, and (10) employee empowerment. Although these authors strongly suggest significant differences exist between agile and lean, they observe that "there are no simple metrics or indices currently available" to explain agility or how it can be measured.*

An observation made in 1999 notes that agile manufacturing has sometimes been confused with flexibility and lean manufacturing.[24] These authors note that agile manufacturing goes "beyond" the latter two "thought schools of manufacturing management" of flexibility and lean. These authors suggest that agility comprises two main factors: (1) responding to change, either anticipated or unexpected and (2) exploiting changes as opportunities. A large survey of (1) electrical and electronics, (2) aerospace, and (3) vehicle parts manufacturing was conducted. Although varying by industry, their findings suggest that (1) environmental disturbances are a key agility driver, (2) a customer focus is consistently important across all three industries, (3) information systems and technology are major differentiators of agile systems compared to traditional systems, (4) organization and personnel are keys to success, (5) customization capabilities is an emerging differentiator, and (6) virtual organizations, mass customization, and Internet capabilities are not as important as expected.

Building upon predecessors' research noted in the preceding text, a more contemporary definition of agility and identification of agile drivers was promoted in 1999.[25] The collective insights of the agile body of literature were extended to identify 10 decision domains comprising 32 attributes of agile organizations that should be explored in future research. The 10 decision domains identified leading to agility included (1) integration of

* Sharp, Irani, and Desai (1999, 161).

enterprise information capabilities, (2) intraorganizational and interorganizational supply chain competencies, (3) the team-building nature of empowering employees, (4) technology, (5) quality, (6) receptiveness to change, (7) effective partnerships, (8) market focus, (9) employee investments, and (10) employee welfare.

A framework proposed in 2007 for agile implementation comprised seven agile capabilities.[26] Utilizing a taxonomical approach based upon cluster analysis, three distinct types of agile strategies, "quick, responsive, and proactive players" were identified in various U.K. manufacturing sectors. Factor analysis and canonical discriminant analysis were used to investigate the differences among the underlying dimensions of these three groupings. The "quick" participants were characterized as possessing a significant customer focus. The "responsive" participants were characterized as emphasizing responsiveness to change and a flexible, reactive approach to dealing with change. The "proactive" participants emphasized a proactive and partnering approach to environmental threats and opportunities.

The most comprehensive definition of agility, given its multidisciplinary nature was offered in 2009.[27] Defined in the context of information system development, agility is the "continual readiness . . . to rapidly or inherently create change, proactively or reactively embrace change, and learn from change while contributing to perceived customer value (economy, quality, simplicity), through its collective components and relationships with its environment." The author constructs this definition from agile manufacturing, engineering, software development, and marketing literature. The various definitions proposed over the years are rationalized to all business disciplines. Further, the author suggests there are two distinguishing differences between agility and lean: (1) Agility is better able to cope with variability while lean is not, and (2) agility promotes fast learning while lean does not.

One of the most startling observations to be gleaned from all of the agile literature is that to date, there exists little, if any, research that verifies the efficacy of these agile manufacturing strategies. The vast amount of research identifying agile drivers, concepts, and strategies (enablers) underscores the implied importance of agility. However, there is little if any empirical evidence documenting the value of these agile strategies. Most of the research is speculative rather than evidence based.[28]

Agile Engineering, Software Development, and Project Management

Beyond manufacturing, agile concepts have been reported in engineering, software development, and project management applications as well. Agile engineering, software development, and project management are examined together as they each rely upon an agile strategy for pursuing deliverables (tangible, verifiable work products) in an overlapping, staged manner rather than following a sequential or linear process.

Historical engineering approaches for the design and development of new products have been highly structured, linear processes. Using an overly simplistic explanation, the process initiates with product conceptualization, feasibility assessment, establishment of design requirements, creation of a preliminary design, creation of detailed design specifications, production planning and tool design, and finally production itself. Initial design requirements and the creation of detailed specifications may be identified jointly by the customer, marketing, and engineering. Once detailed requirements have been determined, various contributions from within the engineering function are made, possibly including concept engineering and prototyping, product engineering, as well as manufacturing engineering, all prior to production.

Various strategies within the engineering function have been promoted in order to remain agile. One example is reliance upon quality function deployment (QFD), which has been shown useful for collecting customer requirements (customer attributes) and translating these into detailed specifications (engineering characteristics) in order to clearly articulate stakeholders' wants, needs, and preferences.[29] Furthermore, the use of QFD has been shown to greatly enhance functional collaboration (e.g., marketing and engineering) as well as hasten time to market through a variety of facilitated workshop techniques or interviews.

Significant agile engineering strategies identified in the literature include reliance upon experienced, cross functional teams; heavy emphasis upon technology and the management of product data, information, and knowledge over a product's life; and the ability to share product data intraorganizationally and interorganizationally.[30] Tight integration in product development between an emerging design and the resulting application context is critical.[31] Early test versions must contain the essential specifications providing a baseline for customers to give timely feedback. The architectural design is important in terms of its ability to accept late design changes. These authors found the generational experience of team members to be critical as it led to fewer resources being needed to complete projects and higher quality levels for more complex products. However, the authors note that this experience may not be beneficial in environments characterized by rapidly changing customer requirements.

As much as 80 percent of the cost structure of a product is defined while establishing engineering design requirements, product characteristics, and the information associated with products.[32] A strategy that enables collaborative creation, management, dissemination, and use of product definition information across the extended enterprise (supply chain) is critical. Therefore, enterprisewide and supply chain information systems are critical determinants of agile strategies.

Historical software development methods have emphasized the creation of detailed plans consisting of specified processes and products. The systems development life cycle (SDLC) method, sometimes called plan-based or waterfall model, was one of the original software development methodologies. Planning and execution within SDLC is typically characterized as a linear and sequential process. It is a five-phased model that goes through requirements gathering (planning), analysis, design, implementation, and maintenance, with each phase being completed before the next phase commences. This waterfall approach may be depicted graphically as shown in Figure 9.2.

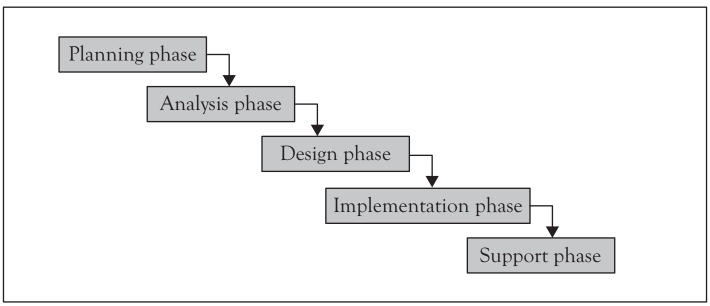

Figure 9.2 Systems development life cycle or waterfall model*

* Shelly and Rosenblatt (2012).

This process begins by determining the functionality required in the software (requirements gathering). During this phase, the customer is involved to convey necessary functionality and requirements. Once the necessary functionality and requirements have been determined, solution analysis begins. Solutions lead to a design or blueprint for the construction phase. Implementation is the actual construction of the system, with the software being deployed at the phase end. The customer is often not involved with analysis, design, or implementation phases. The support phase provides the necessary maintenance over the useful life of the system as the software would be upgraded or enhanced. The customer is often reintroduced during this latter phase for user acceptance testing purposes. This has been the primary means of software development for several decades. It has served to offer stable project requirements over the project life to facilitate project goal attainment.

Enhanced computing capabilities and the growth and continuing development of corporate information systems have led to more complex and interdependent systems over this span of time. Furthermore, significant up-front planning efforts suggest that the environment remains static. In a changing environment, the early assumptions or requirements and consequential specifications may not hold throughout the project. By its very nature, the phased approach of the SDLC is resistant to changing requirements.

Agile software development recognizes that custom-designed and custom-built systems lead to high costs and long installation lead times due to increasingly changing or even volatile environments. Since the early to mid-1990s, agile principles have been integrated into software development efforts. Common agile software development drivers include requirements that tend to evolve very quickly and become obsolete prior to project completion, time-to-market pressures, as well as rapid changes in competitive threats, stakeholder preferences, and software technology.[33]

The Chrysler Comprehensive Compensation project (C3 project) in 1996 is often cited as the seminal Extreme Programming (XP) project fully utilizing the tools and techniques of agile software development throughout the project lifecycle.[34] In 2001, these techniques were formally codified into what has become known as the 12 principles behind the Agile Manifesto. The central ideas include the following: (1) Individuals and interactions may be more important than processes and tools, (2) the development of working software in a timely manner may be more important than comprehensive documentation, (3) customer collaboration is critical to success, and (4) quick responses to change trump following a detailed plan identified at the project outset.

Families of agile methods, which seek to address high costs and long installation times, have emerged over the past two decades. A few of the more popular methods comprising these families include Scrum, XP, Agile Modeling, Rational Unified Process, Crystal Clear, Dynamic Systems Development Method, Lean Development, and Rapid Product Development. These methods utilize various strategies to reduce costs and hasten delivery times, including short iterations and test-driven development; frequent releases based upon highest priority or most critical features; simpler designs; peer reviews and collective code ownership; as well as various communication tools such as prototyping, piloting applications, on-site customer participation, review meetings, and acceptance testing, all of which provide fast feedback. Various researchers provide detailed discussions complete with citations of these alternative strategies.[35]

Rather than suggesting differences between agility and lean, some suggest that lean practices are applicable to the design, development, deployment, and validation of software projects.[36] These authors have gained acclaim for emphasizing waste elimination, bureaucracy reduction, and enhanced learning with short cycles, frequent builds, and fast iterations with frequent feedback pulling changes into products. Seven principles of lean software development, similar to agile strategies of other functional areas, are promoted, including (1) optimizing the whole (systems perspective), (2) eliminating waste (e.g., unnecessary code and functionality, using smaller teams with less staff), (3) building quality into designs (considering that earlier testing and later specification identification can reduce waste), (4) learning constantly, (5) delivering fast, (6) engaging everyone, and (7) improving continuously.

However, to date, there exists little, if any, research that verifies the efficacy of these agile software development strategies. The vast amount of research identifying agile drivers, concepts, and strategies (enablers) underscores the implied importance of agility. However, there is little, if any, empirical evidence documenting the value of these agile strategies.

Few studies have empirically confirmed the benefits of agile methods. It has been suggested that the following software development strategies provide positive results: Share an early, low-functionality version ("micro-project") with customers for feedback followed with an iterative approach to adding functionality, all the while using an experienced development team and a product architecture that offers flexibility. However, these research findings did not directly compare the iterative approach with a traditional waterfall method. Rather, results achieved were compared to historical project results.[37] Subsequently it has been noted that most of the research is speculative rather than evidence based.[38]

Traditional project management planning promotes a hierarchical planning approach including clearly defined, well-documented and planned project specifications, budgets, and schedules. Traditional project management planning promotes a five-phase approach consisting of initiating, planning, executing, monitoring and control, and closing. Although time-consuming, this hierarchical decomposition approach to planning facilitates subsequent execution. Decomposition is similar in concept to the SDLC method of software development. Decomposition is a hierarchical and sequential division of work, possibly into stages. As each stage is completed, there is typically an assessment performed. This breaking down process enhances communication, estimating accuracy, monitoring and control, as well as stakeholder understanding and motivation.

Over the past 30 years, numerous strategies have been developed to promote the faster accomplishment of project objectives. One of these time-saving strategies is *fast tracking*, the deliberate overlapping of sequential tasks so successor tasks may commence sooner rather than later. Within the realm of project management, agile is a recent term being used to refer to a more advanced set of strategies to achieve a faster response to quickly changing environmental conditions. As noted in the project management literature, agile project management (APM) emphasizes

1. A team approach with frequent interpersonal interaction and communications and greater stakeholder involvement and communications to facilitate a rapid approval process for new specification adoption as well as process and product change orders;

2. Simultaneous or parallel task execution emulating the effects of fast tracking; and
3. Decomposition of specifications of deliverables into stages.

To date, APM relates largely to the management and control of software projects. APM principles may be applicable to projects of any type. The emphasis on people and the desire to remain flexible and adaptive is critically important in light of project uncertainty and complexity. Attempts have been made to widen the scope of APM to projects with different characteristics, for example, construction projects. Potential exists for gains to be made from the adoption of APM in the predesign and design phases of construction as the iterative and incremental development approach of agile methods can promote creative solutions, particularly in an environment with complex and uncertain requirements.[39]

Most of the research contrasts traditional project management with APM. Three important differences are noted: (1) Traditional projects are clearly articulated with well-documented and planned project specifications, budgets, and schedules, whereas APM discovers complete project requirements iteratively; (2) traditional projects manage and control with the budget, schedule, and project scope, whereas APM focuses more on deliverables and value offerings with budgets and timelines being secondary; (3) traditional projects distribute work to teams and specialists by matching well-defined requirements with capabilities, whereas APM requires colocation of team and staff members to promote faster responses to change order requests and to produce incremental accomplishments.[40]

The literature offers an intriguing five-phased approach for APM, consisting of (1) envisioning, (2) speculating, (3) exploring, (4) adapting, and (5) closing.[41] The underlying concept of these five phases for projects with complex and possibly uncertain requirements is for team members to explore different avenues to achieve outcomes, test, and adapt the more acceptable solutions in an ongoing iterative manner, until project requirements are achieved. This appears to be a less structured environment relying upon greater flexibility, informal communications, and evolving requirements. Results documenting its use would be welcome.

Similar to agile manufacturing, the shift toward APM has been driven by increased environmental turbulence and the shortcomings in traditional project-based approaches. Future development of APM strategies based upon organizational improvisation will occur as project timetables continue to compress. Seven key APM constructs have been identified to promote future APM strategy development: (1) creativity, (2) intuition, (3) bricolage, (4) adaption, (5) compression, (6) innovation, and (7) learning.[42] The author suggests that more experienced project managers who are able to adapt their style based upon these constructs or the components of APM may be better positioned to resolve ambiguities and shorten delivery times.

Agile Supply Chain Management

Despite suggestions in the literature that lean and agile are different paradigms developed in the manufacturing sector, a suggestion has been offered that they should not be viewed separately within a supply chain. Rather, the suggestion is to combine these paradigms to form a total supply chain strategy utilizing market knowledge and positioning of inventory to establish a "decoupling point."[43] Supply chain inventory serves as a decoupling point or as a point of postponement at which a product may be differentiated. The decoupling point may be used to buffer upstream lean manufacturing, which benefits from potential waste elimination afforded by a stable, level schedule, from the downstream satisfaction of fluctuating demands in a volatile marketplace, thus providing agility. This concept has been referred to as *leagility*. The view of these authors is supported by consideration of a personal computer supply chain case study.

The *leagile* concept has been extended by suggesting that businesses must first identify and fully understand marketplace requirements, including product variety demands and the extent of demand variability. This understanding promotes the supply chain's information enrichment capability. The authors argue that this knowledge must be used in conjunction with the *decoupling point* to achieve leagility.[44]

Another author attempts to distinguish between lean and agility by suggesting that lean is best restricted to waste elimination in factories within high-volume, low-variation environments, while agility refers to the ability to respond rapidly to volatility in demand, from either volume or variety.[45] The author notes several strategies that promote agility, including (1) capturing of real-time customer demand and its exchange among supply chain partners to drive planning responses, (2) the use of a decoupling point, prior to which inventory is held in a delayed configuration, and (3) leveraging supplier relations with fewer, trusted strategic partners, which permits the collaborative exchange of sensitive information.

The agile supply chain literature offers a clear consensus of various strategies that promote supply chain agility. Included among these are: (1) information technology and information exchanges, both intra- and interorganizationally, which enable the capture of real-time demand, which promotes a fast response capability to marketplace volatility; (2) the use of a decoupling point, prior to which inventory is held in a delayed configuration; and (3) investing and leveraging supply chain partner capabilities in order to promote the integration of business processes throughout the chain.

Agile Marketing Management

The idea promoted within the agile marketing literature is best described as "agile competitors precipitate change, creating new markets and new customers out of their understanding of the directions in which new markets and customer requirements are evolving."* Agile marketing has been indirectly described as "opportunistic actions in capturing new markets and responding to new customer requirements," which is necessary for success, given the drivers in Table 9.1.†

Developed principally as a marketing concept to facilitate customer needs assessment, product development, and quality management, as noted earlier, QFD can be viewed as a significant agile methodology. QFD has been shown useful for collecting customer requirements (customer attributes) and translating these into detailed specifications (engineering characteristics) in order to clearly articulate stakeholders' wants, needs, and preferences. QFD has the ability to significantly reduce product time to market.[46] Furthermore, the use of QFD has been shown to greatly

* Goldman, Nagel, and Preiss (1995, 43).

† Sharifi and Zhang (1999, 9).

enhance functional collaboration through a variety of facilitated workshop techniques or interviews. QFD has been successfully applied within various function areas, including marketing, engineering, and even software development.[47]

Agile manufacturing principles for the creation and development of proactive, strategic marketing plans in small- and medium-sized enterprises in the United Kingdom have been examined.[48] These authors promote a three-step, proactive agile marketing framework. First, a bottom-up focus on identifying tactical improvement opportunities within the operating environment is promoted. Second, the identification of responses to address the vulnerabilities identified as an outcome of the first step occurs. These authors contend this creates a robustness of the operating system. Third, once robustness has been achieved, the authors encourage a campaign to better anticipate and even further stimulate marketplace demands. It is noted that stimulating marketplace demands while production systems have weaknesses could lead to the loss of customers. Addressing operational weaknesses can present opportunities to grow one's business. The authors suggest that marketing agility enables companies to reconfigure their marketing efforts on short notice.

The complete body of agile research literature offers three important conclusions. First, regardless of the functional discipline or application (e.g., manufacturing, engineering, software development, project management, supply chain, and marketing), there is widespread agreement in the research literature that agility refers to the ability of a firm to rapidly respond to volatile, unpredictable marketplace demands. Whether the agile paradigm is truly different from the lean paradigm has yet to be proven. There seems to be a consensus in the literature that agile represents a significant paradigmatic change and that agile and lean are different.

Second, there is also widespread agreement within the multidisciplinary agile research suggesting a common body of strategies for achieving agility. The five agile strategies most often cited are:

1. Organizational mastery of uncertainty and swift responses, given rapid marketplace change. The ability to innovate, given marketplace volatility and uncertainty, is essential.

2. Investing and empowering one's team (possibly small and inclusive of all stakeholders) in order to leverage their ensuing capabilities. Agility requires speed to react to changing market conditions and the ability to deliver value to the customer. Investing in one's team better positions the enterprise to achieve rapid response and value delivery proposition.
3. A systems viewpoint and reliance upon cooperation that enhances competitiveness. This includes both intraorganizational as well as interorganizational cooperation. Reliance upon a shared vision and the integration of whole business processes across a supply chain, including virtual organizations, partnerships, or other forms of cooperation are essential.
4. Intraorganizational and interorganizational information technology and exchanges. Technology and the ability to capture real-time information and rapidly share vast amounts of information in a virtual manner across a supply chain offers value. The timely exchange of this information is essential.
5. The incremental development of product offerings, given swiftly changing marketplace demands. It is critical to constantly assess customer demands and to have the ability to rapidly alter current product configurations.

Third, the focus of this multidisciplinary body of agile research literature is on (1) defining agility, (2) identifying the drivers for agility, (3) discussing agile concepts, and (4) identifying the strategies (enablers) for achieving agility. To date, there exists little, if any, research that verifies the efficacy of agile strategies. The vast amount of research identifying agile drivers, concepts, and strategies (enablers) underscores the implied importance of agility. However, there is little, if any, empirical evidence documenting the value of these agile strategies. As noted earlier, most of the research promoting agility is speculative rather than evidence based. To date, there exists scant empirical evidence regarding the efficacy of agile strategies, which leads to confusion regarding the arguments that agility is different from lean.

Lean

Whereas contributions to the flexibility and agility bodies of literature have largely remained unchanged since approximately the year 2000, the body of lean knowledge continues to experience considerable contributions since the early reference to just-in-time terminology began to emerge in the late 1970s and early 1980s. Lean has been a prominent business construct or philosophy over the past several decades.[49]

The term *lean* was originally coined in 1988.[50] Much of the lean body of literature has evolved subsequent to 1988, with the vast majority of this body of knowledge being promoted since 1995. Therefore, the chronological presentation of its body of literature in this manuscript appears subsequent to the agile body of literature.

Although much of the lean body of literature has evolved subsequent to 1988, it should be recognized that the body of lean knowledge has been evolving for millennia. The practices of specialized work, division of work, flow lines, ergonomics, process charts, time studies, and others are fundamental lean practices, with some being used for thousands of years. Lean represents a systematic body of knowledge devoted to a continuous journey seeking improvements in productivity and quality, lowered cost, shortened delivery time, enhanced safety, improved environment, and fortified morale, all of which may be refined to a single objective of best practices devoted to continuous improvement.[51]

Some authors suggest the principal difference between lean and agility is simply whether one examines system capability internally (lean) or externally (agility). Others suggest a primary differentiator between the two constructs being agile's ability to respond quickly to unpredictable markets, whereas lean only offers the ability to respond quickly to anticipated events. One might observe that early agile manuscripts portray lean in a shortsighted manner, given its evolutionary development since 1995. For instance, one manuscript notes that while there are similarities between agile and lean, there are fundamental differences, including the following points:

- Lean production is regarded by many as simply an enhancement of mass production, while agility offers the capability for more highly customized products in varying batch sizes.

- Lean strives for economies of scale (savings attributable to larger lot sizes of specific items), while agility pursues economies of scope (savings attributable to larger volumes achieved through a diversification of items).
- Lean focuses solely internally on the factory floor, while agility looks both internally and externally recognizing a holistic or systematic viewpoint.
- Lean is a single company pursuit, while agility pursues supply chain partnerships or virtual relationships.
- Lean pursues simple objectives of productivity and cost efficiencies, while agile pursues additional objectives of speed and learning.[52]

Hopefully, one recognizes that the evolutionary development of the lean body of knowledge dispels each of these fundamental differences. For instance, single-minute exchange of dies (SMED)[53] recognizes that if setup times can be reduced, the consequential lot size and inventory can likewise be reduced. Flexibility, an objective emphasized by lean and pursued with strategies such as multiskilled workers and general-purpose equipment, affords economies of scope (efficiencies wrought by variety) as well as economies of scale. Lean does possess a systematic viewpoint, especially in light of the integral system elements of leadership, culture, teamwork, as well as practices and tools.[54] The emergence of supply chain management concepts since approximately 1980 has witnessed significant interorganizational efforts to extend lean concepts to supply chain partnerships and virtual relationships. Finally, there can be no doubt that lean acknowledges *kaizen* efforts, which require learning.

One intriguing observation when one contrasts the lean and agile bodies of literature is the complete absence within the agile literature of encouraging waste elimination. Although one author does suggest that lean is best restricted to waste elimination in factories within high-volume, low-variation environments, ultimately however, waste elimination emphasis is overlooked when the distinguishing feature of agility is noted to be its ability to respond rapidly to volatility in demand, from either volume or variety.[55] Therefore, one significant difference between the lean and agile literature is the absence of waste reduction or elimination within agile strategies.

Rather than reiterate content identified in earlier chapters, suffice it to say that an emergent theme in the flexibility, agility, and lean bodies of literature is the recognition of the need for adaptability and fast responses, given the instability and unpredictability of the environment due to either internal or external concerns. Much of this instability and unpredictability in the environment may be attributed to rapid technological development and change. The later constructs of agility and lean have expanded upon and enveloped flexibility. The three constructs of flexibility, agility, and lean actually represent an evolutionary path of continuous improvement.

CHAPTER 10

Lean Performance Metrics, Lean Accounting, and Financial Controls

Performance metrics are collected and used for two principal purposes. First, they enable a better understanding and monitoring of the current system state. Second, they are used for control activities, which include external reporting as well as continuous improvement efforts. Various metrics have been devised to assist the lean practitioner. It is important to recognize that each of these metrics should help focus monitor and control efforts to better assist the attainment of improvements in system objectives regarding time, cost, quality, flexibility, sustainability, safety, and morale as noted in Chapter 1.

This chapter focuses on identifying various metrics lean practitioners use to assess firm performance and on the accounting practices that underlie the determination of some of these metrics. The content of this chapter is not to suggest a better means of accounting, but rather to identify potential shortcomings of current accounting practices, which may lead to future improvement efforts.

Lean Performance Metrics

Lean performance metrics, or key performance indicators (KPIs), may be categorized by the objective they recognize, based on time, cost, quality, flexibility, sustainability, or safety and morale. Alternatively, a KPI may be categorized by the portion of the system it monitors, ranging from a measure as small as a machine, to a complete process, to the entire organization itself. Although not meant to be an exhaustive list, frequently encountered lean metrics categorized by objective are identified in Table 10.1.

The vast majority of research demonstrates that firms commonly rely on nonfinancial information and metrics when employing lean.[1] It is desirable to rely upon a variety of metrics possessing various characteristics. For instance, metrics that are visual enhance understanding and communication capabilities. Visual management techniques employed within a lean management system have the ability to convey a lot of information quickly. Furthermore, people remember information better when it is represented and learned verbally and visually. Data that is conveyed in financial terms is also better understood. People easily understand the value of a dollar.

Many of the metrics noted in Table 10.1 lack a direct financial nature. As an example, the amount of inventory (e.g., days of inventory outstanding) expresses the number of days that would be expected for demand to consume the existing number of units of inventory. However, a critical element of many business choices relates to the financial bottom line. Financial implications of strategic choices and tactical decisions can materially affect lean practices. Simply put, many common lean performance metrics may be converted into financial terms; however, they are not directly financially focused.

Often the application point for the lean microscope differs, depending upon the environment. For example, in lower-volume, batch environments, the examination of connections and flows between resources is critical for waste reductions. This is true due to downstream arrival delays, given longer upstream process times of batches. Therefore, it is important for system drumbeat or takt times and pitch times to be consistent between connecting process resources. Alternatively, in higher-volume, repetitive processes, it is assumed that processes are initially designed with a common takt time across system resources. Therefore, a greater focus on the productivity of the resources themselves should be pursued. In particular, a measure such as overall equipment effectiveness (OEE) and the six big losses of equipment utilization, which focuses on equipment availability (equipment failure, setup, and adjustment), equipment speed loss (idling, minor stoppages, and reduced speeds), and output loss due to lower quality (defects and reduced yields) are useful.[2] It should be evident that OEE focuses upon more than one objective. The point is, not all lean metrics or KPIs are useful

Table 10.1 Example lean performance metrics

Lean metric nature	Lean performance metric examples
Time based	• Total order throughput time • Average system order throughput time • Process velocity = throughput time/value-added time • Net operating time available = total operating time available – production and maintenance downtime • Plant availability = total operating time available/net operating time available • Number of process steps; machine setups; material touches
Cost based	• Number of process or system employees • Inventory turnover = cost of goods sold/average inventory • Days of inventory outstanding = 365 days/inventory turnover • Efficiency = actual output/standard output • Utilization = total resource time usage/total resource time availability • Yield = (units produced–defective units)/units produced • Process step efficiency = (order batch size × *takt* time)/ total process step operating time • Labor productivity = units of output/units of labor
Quality based	• Number of defects (defect rates) • Scrap rates • First time through = (order batch size – number of defects in order)/order batch size
Flexibility based	• Setup times (possibly as a portion of pitch times) • Range of worker task capabilities • Range of machine task capabilities • Routing alternatives
Sustainability based	• Extent of energy requirements supplied by renewable/ alternative energy sources • Waste to landfill (indexed to net sales) • Volatile air emissions (indexed to net sales) • Environmental protection agency toxic release inventory (indexed to net sales)
Safety and morale based	• Number of job accidents • Employee satisfaction • Staff retention

for all types of transformation processes. Given their varied nature, lean practitioners should rely upon a variety of metrics, both financial and nonfinancial.

Lean Accounting

Financial accounting is commonly thought of as having an external reporting focus. As an integral business function though, accounting serves both internal and external cost-reporting purposes. Financial accounting measures and records transactions and contributes to various documents, primarily financial in nature, based upon generally accepted accounting principles (GAAPs).

Anecdotal evidence suggests financial accounting performance metrics do not always serve lean practitioners well for several reasons. First, financial accounting performance metrics provide late information. In particular, measures calculated at the end of a period such as a month may delay or prevent proactive actions. Second, financial accounting performance metrics, which are vague, such as the allocation of indirect overhead costs to a line of products, do not represent accurate system performance. Third, measures, which are primarily financial in nature (e.g., standard costs) do not relate to the customer's perspective of value-added tasks for specific products. This confounds process improvement activities. Consequently, the term *lean accounting* has emerged, given the potential deficiencies current financial accounting practices may result in when attempting to assess system performance. Lean accounting attempts to rationalize the necessity to track, allocate, and monitor financial metrics at numerous, pinpoint locations within operation processes. Lean accounting recognizes that voluminous transaction processing attributable to standard costing and overhead allocation practices does not add value to well-understood, stable processes. Rather, many of the financial transactions focused on tracking, allocating, and monitoring financial metrics may be unnecessary and eliminated.

A sound understanding of financial accounting practices and financial metrics is important for lean practitioners' comprehension of lean accounting and for choices both in the boardroom and on the factory floor. These practices and metrics may reflect data that are financial in nature or they may reflect data that concern defects due to unmet specifications including length, width, height, weight, or volume. Alternatively, the data may reflect flow interruptions due to late materials, poor machine reliability, missing tools, unavailable operators, and so on. The point is lean practitioners benefit from the knowledge of a broad set of performance assessment tools with the frequency of data collection being determined by the value of the data itself. Highly stable operations require less data collection and transaction processing.

Ideally, lean practitioners will rely upon a broad set of performance measures possessing numerous characteristics. These characteristics can include (1) financial metrics, (2) current, or real-time, system performance, (3) a depiction of the current state of the process relative to the planned or expected state, (4) engaging the individual(s) close to the process and those individuals who are responsible for maintaining and correcting the process, (5) relying, if possible, upon multiple sensory functions (e.g., coupling audio signals with visual signals) simultaneously, (6) utilization of smaller time increments between data capture points enabling issues being brought to light sooner and more easily, highlighting the introduction of assignable sources of variation, (7) use for accountability regarding investigative results, and (8) utilization of various colors in order to depict multiple-state conditions. Some of the more significant accounting practices and financial metrics topics impacting lean practitioners' choices both in the boardroom and on the factory floor are identified in the following sections.

Cost Accounting

Cost accounting provides much of the information used for financial accounting reporting purposes. Cost accounting is used to provide information for internal decision making. Cost accounting typically collects, analyzes, and disseminates financial and nonfinancial information related to the costs of resource acquisition and consumption supporting transformation processes for both internal and external decision making.

Cost allocation is used to describe the assignment of indirect costs (e.g., lease, overhead, insurance, taxes, and quality control) to particular cost objects (e.g., individual jobs, orders, a product, department, machine, or material). The objective of allocating indirect costs to an object is to measure the underlying usage of indirect resources by objects. Cost accounting relies upon individuals within responsibility centers to provide estimates of resource usage for cost allocation purposes. Resource usage often cuts across multiple departments making accurate estimates difficult at best. Indirect costs, costs that are assumed to be related to an object such as a part, machine, or an order, cannot be directly or easily traced to it. Indirect costs are nonetheless attributed to the object despite the difficulty tracing costs.

Indirect costs can comprise a significant portion of overall costs assigned to objects. The historical practice of allocating indirect costs in this manner has been done for several reasons. First, it assumes this information is necessary for economic decision making, such as determining a selling price for a product. However, in a product's inception, the selling price may not sufficiently cover production costs, as production volumes are commonly low relative to later periods. Leaders should always examine decisions from a systematic point of view; otherwise, some products assessed as being successful in later life cycle stages may never initially go into production. Second, full cost disclosure, even though one may be relying upon inaccurate cost estimates, can be used to motivate employees to alter designs. Various strategies, including simplicity from fewer parts, the use of standardized components, or possibly alternative materials or technologies can be followed to alter designs. Third, estimates for reasonable reimbursement rates may be required. Fourth, external information reporting is often necessary.

Unfortunately, indirect cost estimates can be wrong to a great extent, leading to poor decision making. This sometimes occurs because indirect costs are often accounted for with definitive time periods (e.g., a week or month). However, indirect costs may be incurred beyond these discreet time periods. Furthermore, indirect costs are often assumed to be incurred at a linear rate such as the incurrence of monthly rent. Yet not all months have the same number of working days. And, there may be variable (seasonal) aspects to some indirect costs, further reducing the effectiveness of estimates.

An additional cost allocation issue is whether indirect costs are controllable, minimally influenced, or uncontrollable. This issue is similar to non-value-adding activities. Most would agree that non-value-adding activities should be eliminated, as they are wasteful. Unfortunately, not all non-value-adding activities can be eliminated, as they may not be avoidable. Some costs that are allocated to objects are uncontrollable. Examples of uncontrollable costs include depreciation, workspace charges, general and administrative overhead allocations, and even direct labor during periods of low demands as the labor may not be transferred or eliminated. Uncontrollable costs should be recognized so that managers do not pursue matters beyond their immediate, direct control.

Choices about (1) the degree of detailed estimation, collection, analysis, and reporting of information; (2) product- or service-costing methods (e.g., variable or absorption costing); (3) job-costing alternatives (e.g., standard costing using sequential tracking or backflush costing); and (4) process costing can each have profound impacts on costs of goods sold and therefore financial reporting implications. These are but a few of the accounting issues confronting the lean practitioner. These ideas are discussed in the following four sections.

Activity-Based Accounting Systems

Emerging lean accounting practices seek to reduce non-value-adding transaction processing, eliminate standard costs in favor of actual costs, and eliminate cost allocations. Activity-based costing (ABC) represents a step in this direction. ABC attempts to improve upon traditional estimating approaches of indirect costs by focusing on less aggregated or more detailed transformation activities, such as actual machine setup times, design activities, or inspection activities for each specific product in order to allocate indirect costs to objects on the basis of specific activities undertaken for each product.

ABC activities may rely upon process flowcharts to more accurately trace and estimate indirect costs. Process flowcharts may provide a more finely structured mapping of transformative activities allowing a more accurate cost tracing and subsequent allocation.

ABC systems commonly use utilize a four-part cost hierarchy.[3] The hierarchies are based upon different types of cost drivers or differing degrees of difficulty in determining cause-and-effect relationships for cost allocations, which may be estimated based upon a process flowcharting investigation. Four-part hierarchies, which determine how indirect costs are allocated are typically related to (1) output unit-level cost measures, (2) order- or batch-level cost measures, (3) product- or service-sustaining cost measures, and (4) facility-sustaining cost measures. Each of these hierarchies is defined in the following text.

Output unit-level cost measures assess indirect costs against resources consumed producing specific products or services. Examples of these activities include electrical consumption and machine maintenance. Costs associated with these activities are assumed to be directly proportionate with the output levels for a product or service. Indirect costs deemed related to unit output levels are allocated directly using a measure such as unit outputs. For example, assume the monthly electric bill for an organization producing 500 units of product A and 250 units of product B is $1,000. In this example, monthly electric costs allocated to product A would be $666.67 (500/750 × $1,000), while $333.33 (250/750 × $1,000) would be allocated to product B.

Order- or batch-level cost measures assess indirect costs against resources consumed producing an order or a batch of a product or a service rather than against unit output levels. Examples of these activities would include item procurement or setup activities. Costs associated with these activities are assumed to be incurred once per order or batch for a product or service. Assume the setup costs associated to produce a batch of product A are estimated to be $250. If five setups are done for product A during the month, the costs allocated for product A setups would be $1,250 (5 × $250).

Product- or service-sustaining cost measures assess indirect costs against resources consumed producing a specific product or service. This assessment does not occur on the basis of units or batches, but rather for the product or service itself. Examples of this would include vendor identification, product design, product engineering, and tooling costs. Each of these activities incurs costs, which cannot be directly traced to unit or batch volumes.

Facility-sustaining cost measures assess indirect costs against resources consumed producing all of the organization's products and services. Examples of these costs include lease, custodial, security, information technology, and other costs. Determining cause-and-effect relationships for these cost allocations are most difficult. Therefore, some organizations deduct these costs from operating income rather than pursuing a product cost allocation approach.

Cost hierarchies used within ABC systems promote identification of cost cause-and-effect relationships. The idea of ABC systems is to promote more accurately tracing and estimating of indirect costs, which may promote efficiency improvements. The cost cause-and-effect relationships promote more accurate indirect cost tracing and estimating, which may allow for waste elimination and efficiency improvements. However, it is important to understand the effort involved in determining detailed identification of cost drivers and cost categories. Detailed ABC systems can be costly to initiate, understand, operate, and maintain. In effect, the lean practitioner must question the value added of the detailed information.

Product or Job Costing: Variable, Absorption, and Throughput Inventory Costing Choices

Reported income is a key metric in the performance evaluation of all managers. There are two historical product approaches for capturing *inventoriable costs*, which refer to the timing of when costs of a product (job) are incurred and reported as cost of goods sold. There are three alternative methods of product (job) costing utilized in lower-volume batch processes. There are two alternative methods process costing commonly uses in higher-volume, line flow processes.

The three alternative product-costing methods are variable, absorption, and throughput costing. Each method impacts reported income differently. It should be noted that among the product-costing methods, GAAP requires absorption costing for external financial reporting.

The first, *variable costing* is an inventory costing method that uses only variable manufacturing costs (both direct and indirect) as inventoriable costs. Fixed manufacturing costs (both direct and indirect) are excluded from inventoriable costs and therefore are treated as an expense in the period in which they are incurred rather than the period in which the product is sold. Variable costing does not delay reporting fixed manufacturing costs in the form of stored inventory until subsequent periods.

Absorption costing is an inventory costing method of expensing all costs associated with manufacturing a particular product. It absorbs, or includes, both variable and fixed manufacturing costs as inventoriable costs. Absorption costing uses the total direct costs and indirect overhead costs associated with manufacturing a product as the cost base. Because absorption-costing inventories fix manufacturing costs as inventoriable, relative to the variable costing method, use of absorption costing can encourage managers to produce more inventory than necessary in order to inflate income in the period. In general, if inventories increase during an accounting period, more operating income will be reported under absorption costing than variable costing. All nonmanufacturing costs are expensed in the period in which they are incurred under both variable- and absorption-costing approaches.

Some suggest that even variable costing promotes the unnecessary buildup of inventories, given a desire to promote current period financial reports. *Throughput costing* treats all costs, except those related to variable direct materials, as expenses of the period in which they are incurred. Namely, only variable direct costs are inventoriable costs.

Although absorption costing is the method most commonly used, there is disagreement as to the favored inventory costing approach. Lean practitioners might consider throughput costing to encourage greater efficiencies. However, throughput costing is not allowed for external reporting if its use results in materially different numbers than those reported by absorption costing. As previously noted, GAAP does not allow throughput costing to be used for external financial reporting for U.S. firms. However, GAAP is not followed globally. Furthermore, there is disagreement among accountants as to a favored product-costing approach. Some accountants suggest variable costing be used for external reporting because the fixed portion of manufacturing costs is more closely related to manufacturing capacity than to the actual production of specific units. Other accountants suggest absorption costing be used for external reporting because inventories should carry both variable and fixed cost components as both are necessary for production.

Traditional Product Costing and Backflush Inventory Costing Choices

Product costing for transformation systems assumes a sequential approach whereby accounting journal entries occur at sequential process stages such as procurement (raw materials inventory), fabrication (work-in-process inventory), final assembly (finished goods inventory), and distribution. Each one of these process stages requires recording journal entries.

An alternative to traditional job costing is backflush inventory costing. It is sometimes used in systems with short throughput times that maintain little in-process inventories or highly stable periodic inventory levels. Although it still reflects a linear process flow, *backflush inventory costing* often omits capturing one or more in-process accounting journal entries, effectively delaying the costing process until final assembly is completed. Costs are then "flushed" back at the end of the production run and assigned to the goods. This eliminates some of the detailed tracking of costs at intermediate production process steps, a feature common to traditional sequential costing systems. The detailed tracking of traditional sequential costing systems may simply not provide the value-added information for monitoring and control purposes.

By eliminating work-in-process accounts and journal entries, backflush costing simplifies the accounting process. However, this simplification and other deviations from traditional costing systems means that backflush costing may not always conform to GAAP. For example, work-in-process inventories may exist but would not be recognized in financial statements. This system also complicates a potential audit trail, as the ability to identify resource consumption at sequential process stages may be eliminated.

Process Costing: Weighted Average and First In, First Out

Variable and absorption product-costing methods are traditional sequential costing methods commonly used in lower-volume batch processes. Accounting in high-volume processes sometimes uses a process-costing approach for financial reporting. It is sometimes assumed that each item consumes similar resources and consequently direct material costs, direct labor costs, and indirect manufacturing costs in systems producing largely identical, mass-produced items. As a result of uniformity, a process-costing approach treats all units produced as equivalent through the adoption of an average production cost per unit to calculate unit costs of products or services.

As a result of equivalent products, rather than having separate journal entries for different products at each stage of the production process (e.g., fabrication work in process or assembly work in process) as product-costing alternatives practice, process-costing methods result in a single journal for each process stage. Process costing relies on two alternative inventory cost flow assumptions, a weighted average and a first in, first out (FIFO) method. Each results in different work-in-process and work-completed costs.

The weighted average process-costing method calculates an equivalent unit cost of work done to date, regardless of the actual period or timing in which the work was completed. It assigns this cost to both the number of equivalent units completed and transferred downstream as well as to the equivalent units transferred to work-in-process inventory at the end of the period. The *weighted average cost* is the total of all costs entering the work-in-process journal account (regardless of timing) divided by total equivalent units of the work done to date.

The FIFO process-costing method may be best explained as a four-step process. First, it assigns the cost of the previous period's equivalent unit ending inventory (current period's equivalent unit work-in-process beginning inventory) to the first units completed and transferred downstream during the current period. Second, it assigns the costs of equivalent units worked on but not finished during the period to the remaining equivalent unit work-in-process beginning inventory. Third, cost assignment proceeds to equivalent units arriving, completed, and transferred downstream during the period. Fourth, cost assignment proceeds to equivalent units arriving and remaining in work-in-process inventory.

The principal differences between these two process-costing procedures include the following observations. First, the weighted average process-costing method aggregates inherited units and costs (work done in prior periods and accounted for as current period beginning inventory) with units and costs of work done during the current period. As a result, the weighted average process-costing method tends to smooth (averages) equivalent unit costs. Second, the weighted average process-costing method is computationally simpler than the four-step FIFO process. Third, the FIFO process-costing method for equivalent unit costs are determined solely for work done during the current period. Therefore the

FIFO method is more transparent with information concerning periodic cost changes, which may enhance one's performance-monitoring ability. Fourth, costs of completed units and, therefore, operating income can be materially different under the two approaches when the direct material or transformation process costs vary greatly from period to period or when there is a dramatic change in periodic work-in-process inventory levels relative to work transferred downstream. This can influence one's understanding of financial reports. Regardless of the method, process-costing approaches are typically used exclusively in high-volume process industries that produce similar items, given their need to determine equivalent units. Otherwise, the average production cost per unit is too broad.

Financial Controls

Beyond cost-based lean metrics, there are additional financial controls and KPIs that lean practitioners should be aware of as well. In any investment decision, various financial considerations should be assessed. Among these are example metrics such as the payback period, return on capital (ROC), discounted or net present value, as well as operating profit.

The *payback period* refers to the length of time it takes to recoup an initial investment from the revenue or free cash flow the investment generates. Consider this example: If a project costs $100,000 and is expected to return $20,000 annually, the payback period will be five years determined as $100,000/$20,000. This is a common investment evaluation measure, which assesses how quickly an investment such as equipment can be repaid. It is a good proxy for risk, but it ignores the time value of money, so its use is better suited for quick repayment periods. Although it is easy to accommodate nonlinear cash inflows, it also ignores cash inflows after the payback period.

ROC is commonly used to assess the rate of return a business is generating on the company's book value. The ROC measure may be used as a hurdle to identify and select capital expenditure projects. ROC is determined as:

$$\frac{\text{Net operating profit after tax}}{(\text{Book value of equity} + \text{book value of debt} - \text{cash and cash equivalents})}$$

The *discounted or net present value* refers to the time it takes to recoup an investment from the revenue or free cash flow it generates by using the value of those cash flows in today's currency by discounting them using an appropriate discount rate. It is determined as

$$PV = FV(1+i)^n \text{ and the } NPV = PV\text{'s} - \text{investment expense}$$

where PV is present value, FV is future value, i is the assumed rate of return, n is the number of periods (e.g., years) ahead, and NPV is the net present value. As an example, assume you have the opportunity to invest a sum of money that will yield $1,000 at the end of two years. The present value of this investment opportunity if you want to achieve a 5 percent rate of return is $907.03, determined as $\$1{,}000/1.05^2$.

Operating profit is the profit realized from carrying on the regular activities of a business or a company. It excludes gains and profits from other investment activities such as real estate and financial investments. Operating profit (operating income) is formally referred to as EBIT (earnings before interest and taxes). EBIT is calculated by subtracting the cost of depreciation and amortization from earnings before interest, taxes, depreciation, and amortization (EBITDA) expenses.

$$EBITDA = \text{revenue} - \text{cost of goods sold} - \text{sales, general, and administrative costs}$$

$$EBIT = EBITA - \text{depreciation expenses} - \text{amortization expenses}$$

It should be apparent that many variables impact the financial accounting KPIs. For instance, material costs, tooling expenditures and the consequential amortization schedule, equipment depreciation schedules, indirect overhead allocation costs, and many other variables impact operating profits. For monitoring, controlling, and improvement activities, the implications of these consequences should be well understood.

Summary

Needless to say, there is a wide array of important lean performance metrics. Some focus on various system objectives (e.g., cost or time), others examine specific system elements (e.g., machine utilization), some are not directly financial in nature (e.g., inventory turns), and others are directly financial (e.g., payback period). Emerging lean transformation system monitoring and control procedures are attempting to focus on recent system or current state performance, social controls (e.g., encouraging worker cross-training), and visualization approaches. Technology is facilitating and will continue to facilitate the identification of more costs as direct rather than as indirect costs. For example, bar code technology can identify consumption of specific parts within an exact stage of a transformation process.

It is important to understand that many variables impact lean performance metrics. This observation is not limited to the financial accounting KPI's. Monitoring, controlling, and improving transformation processes are data driven. The focus, nature, and limitations of each metric should be understood. Lean practitioners benefit from the knowledge of a broad set of performance assessment tools.

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Leading and Managing Lean

Gene Fliedner

Lean is a comprehensive, integral system consisting of four interdependent elements: leadership, culture, team, and practices and tools. This book examines these elements following a systematic, hierarchical orientation and explains their relevance for guiding lean initiatives. This book follows a framework beginning with the identification and establishment of strategic goals, followed with strategy development, and lastly tactical choices. This model framework is cognizant of a firm's relative internal strengths and weaknesses as well as external opportunities and threats.

Each of the four integral lean system elements is explored in depth. The model framework offers a path to develop lean leaders with practical, actionable ideas suited for applications in all industries. Throughout the book, the evolution of the current body of lean knowledge is examined as well as lean's complementary initiative, Total Quality Management. A perspective which views lean as a customer-driven philosophy for organization-wide continuous improvement and waste elimination is maintained throughout the book. This book builds upon Fliedner's earlier book *Leading and Managing the Lean Management Process* with additional lean content focused on technology, supply chain management, flexibility and agility constructs, and accounting. This offering is different from other lean books in three fundamental ways. First, it pursues a comprehensive lean model based on a sound framework. Second, it examines evolutionary lean timeline contributions. Third, it explores topics where future lean contributions will be found.

Dr. Gene Fliedner is an Associate Professor at Oakland University where he has been a member of the Decision and Information Sciences Department within the School of Business Administration since 1995. He received his D.B.A. and M.B.A. in Operations Management from Indiana University and his B.B.A. from Texas Christian University. Dr. Fliedner has published in numerous premier business journals and is a member of several professional societies. In 2010, he received the distinguished Fellows lifetime service award from the Midwest Decision Sciences Institute. In 2011 and again in 2014, he received a three-year Research Fellowship from the Pawley Lean Institute at Oakland University. In 2011, in collaboration with Business Expert Press, he published his book titled *Leading and Managing the Lean Management Process* which received the prestigious Shingo Research and Professional Publication Award.

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