

PLANNING BUSINESS IMPROVEMENT USING ANALYTIC HIERARCHY  
PROCESS (AHP) AND DESIGN STRUCTURE MATRIX (DSM)

By

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## ABSTRACT

Many management system engineering ideas and theories have evolved to help businesses grow and achieve their goals. Applying these ideas and theories to a business system is a strategic planning issue and results in a bewildering array of strategic alternatives for business system improvement. Choosing the appropriate alternatives is a complex and difficult decision. The most appropriate strategic alternative must be executable. To be executable the strategic alternative must not only be technically feasible, but must also overcome social and cultural obstructions.

This research presents a planning approach to select the most appropriate strategic alternative and to plan its implementation. The planning approach is built on a planning framework synthesized from previous research. This framework involves the following planning functions:

1. Determine business strategic alternatives
2. Acquire business knowledge
3. Shape business for strategic advantage
4. Implement plan - operational engagement

The planning approach uses Analytic Hierarchy Process (AHP), Project Management Tools (PMT) and Design Structure Matrix (DSM) to implement these functions and plan business improvements.

This research demonstrates that rational hierarchies appropriate for strategic alternatives analysis using AHP can be constructed. Business scenarios are used to show that AHP method prioritizes alternative strategies differently under different business circumstances. In addition, the data generated by the AHP can be aggregated into statements of work and input into DSM to generate a project plan to implement organizational design changes and achieve strategic intent.

## CHAPTER 1

## INTRODUCTION

Continuous changes in the business environment require business planners to rethink the way they organize and manage their business in order to stay competitive. Staying competitive requires making business system improvements. However, many organizations fail to achieve expected performance results when implementing business system improvements (i.e., total quality management, lean production systems, information technology, etc.) (Griffin 1988, Greene 1993, Harari 1993, Placek 1993, Gagnon 1999). A possible reason for the failure to achieve performance results despite management's desire and best efforts is that such organizations lack the knowledge, skill and appropriate planning practices for engaging and aligning the organization enabling the development of systemic and congruent approaches for implementing improvements and managing organizational change.

#### The Need for Systemic and Congruent Approaches

As systems, business systems are seen as being composed of interdependent components. Systems theory asserts that the performance of a business system emerges as the result of component design and the complex interaction between system components. Business performance as measured by quality, cost / profit, and on time delivery are emergent properties of the system. Each subsystem has an effect on these performance measures. The business system must be designed from a whole system perspective. The likelihood of improved performance is increased if organizational designers have systems thinking skills and apply sound systems theory in their planning and organizational design practices. A metaphor will help illustrate this point.

An automobile is an example of a system. The basic purpose of an automobile is to move people around. The subsystems of the automobile (e.g. engine, chassis, drive train, etc.) interact to achieve the purpose. No one subsystem can achieve the purpose by

itself. This system cannot be subdivided into parts and still achieve its purpose. It loses fundamental properties that make the system work. It requires both the properly operating subsystems and proper interaction between subsystems in order for an automobile to achieve its purpose. Like a car, business systems require properly operating and integrated subsystems to achieve their purpose.

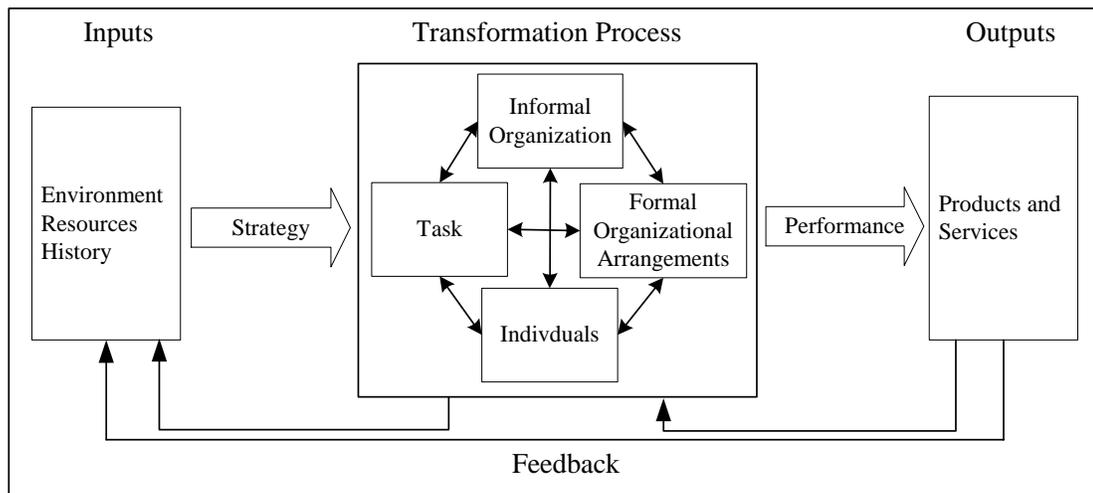
There are performance properties describing how the automobile achieves its purpose. They are specific goals for the system. For example, the automobile must obtain a certain level of fuel efficiency and minimal levels of air pollution. The ability of the system to achieve these goals is mostly determined by the structure and interaction of the subsystems of the automobile. Each subsystem has an effect on these goals and no subsystem has an independent effect on them. The performance of a business system is also determined by the structure and interaction of its subsystems.

Suppose the objective is to design the best car in the world. The best talent is acquired for a design team. The team is tasked with going out and getting the best components from all the best cars. The analysis done shows the rationale behind the selection of the best engine, chassis, drive train, etc. If these parts were assembled, would it produce the best car in the world? It is not even likely that the parts would fit together because the component interfaces are not designed to fit together. Likewise, when designing a business system, it is not likely that the best business system in the world will be built by taking the best parts from other business systems (e.g. Toyota's lean production system, Motorola's quality system, IBM's ERP system, etc.) and trying to integrate them. A more holistic approach is needed to generate systemic and congruent approaches for implementing improvements and managing organizational change.

Consistent with systems theory, a Congruency model (Nadler, Grestein, and Shaw 1992), shown in Figure 1: Congruency Model for Business Systems, provides insight into the interdependence of business system components in business system design. The basic premise behind the congruency model is that business systems will be most effective when their major components are congruent with each other. In other words, problems with organizational effectiveness often stem from poor fit or lack of congruence among business system components.

The system components include inputs, strategy, transformation process, system performance and outputs. Inputs include the environment that presents constraints, demands, and opportunities; resources available to the organization; and history that describes key events and past decisions that influence current performance. Strategy is a set of decisions that define how the business system will compete in the market and matches business system resources with opportunities, demands, and constraints in the environment within the context of history. The transformation process creates products and services as outputs from the inputs with levels of efficiency and effectiveness described as performance. The transformation process includes: the task or work to be done and its inherent critical characteristics; individuals that perform the tasks; the formal arrangements, including various structure, processes and subsystems that are designed to facilitate the performance of business tasks; and informal arrangements, which are neither planned or written, but emerge over time.

Figure 1: Congruency Model for Business Systems (Adapted from Nadler, Grestein, and Shaw 1992)



Tasks, individuals, formal arrangements and informal arrangements interact and comprise a complex system that affects measurable performance and organizational behavior. Formal arrangements and informal arrangements motivate and provide

guidance for the decisions made, and actions taken, by actors in the system. It is through the decisions and actions taken by actors that system performance is achieved.

Formal arrangements are explicit, financial, technical, managerial, or operational in nature and constructed through application of Industrial Engineering and organizational design theory, principles, and practices. Formal arrangements are defined through policies, measurements, and standard operating procedures. They involve supervision, plans, structure, budgets, and compensation systems (O'Reilly and Chatman 1996) and often use quantitative performance measures (e.g. quality, cost, delivery, safety, etc.).

Informal arrangements include patterns of communication, power and influence, values and norms, which characterize how the business actually functions. They provide the desire and willingness to take necessary and appropriate action. Informal arrangements can be implicit or explicit, are psychological in nature, and are socially constructed. Informal arrangements affect individual and organizational behavior in the forms of level of motivation, compliance to cultural norms, sense of obligation, and commitment to organizational goals. In addition, informal arrangements operate on the actor's sense of purpose, belonging, contribution, and meaning (O'Reilly and Chatman 1996).

Informal arrangements are imbedded in the culture of an organization (O'Reilly and Chatman 1996). Organizational culture is the underlying assumptions, beliefs, attitudes, values, and expectations shared by members of an organization that affect their behavior and the behavior of the organization as a whole.

Formal and informal arrangements are linked through organizational culture. It is the underlying assumptions, beliefs, attitudes, values, and expectations of organizational leaders that are translated into policies and structures. The policies and structure drive measurements. Policies and measurements drive organizational behavior and have a major effect on performance.

Adverse Effect of Non-Systemic and Non-Congruent Approaches to Implementing Improvements

When implementing improvements, organizational change can fail due to a number of reasons. The following are examples from my personal experience that demonstrate a lack of systems thinking resulting in non-congruence within the transformation process of a large manufacturing system.

I was a quality engineer early in my career and worked for a large aerospace company located in the northwest United States. In the late 1980's this company was trying to implement Total Quality Management (TQM). I was given an assignment to lead a major part of the implementation effort.

This aerospace company determined that total quality management was of strategic importance in maintaining their competitive position. The president of the company along with directors established an organizational structure, budgets, timelines, and expectations for the TQM implementation project. The directors identified 120 company processes that would be documented, defined and implemented as part of the company's new TQM structure. Through a cascade planning process the TQM implementation project became part of the management's performance measurement system.

The company had a central quality improvement office. I was part of a team organized by this office to support project development and deployment. My primary responsibility was to develop education and training materials to be used during TQM implementation. I was also responsible for providing reports to the office of the president on the progress of the TQM implementation.

There was, however, lack of congruence between the formal and informal arrangements. The formal arrangements were in place to lead the organization through the planning, designing, implementation, and control of a TQM system. However, the company culture and informal arrangements were not considered during project planning. Project activities were greeted with considerable skepticism on the part of those required to participate. Motivation to accomplish project tasks was very low and there was no

sense of obligation or commitment to company goals. This ultimately resulted in the expenditure of considerable resources and an inability to achieve executive expectations and business results.

Another part of the TQM deployment plan was the implementation of statistical process control (SPC) throughout manufacturing. I was tasked to conduct training and facilitate SPC implementation in numerous manufacturing centers over several months. I revisited some of these manufacturing centers a year later and found that the people that had been trained in SPC were transferred elsewhere in the company and the SPC practices were no longer in use. An inquiry revealed that the manufacturing director was being measured on improved labor efficiency and was transferring personnel to adjust labor to work load. The result was skill dilution in the SPC practices and a loss of investment in training with no improvement in quality and cost performance. This is an example of a lack of congruency within the formal arrangements. The management's performance management system did not include appropriate measurements of the manufacturing directors performance to assure the gains were sustained for the SPC investment.

A secondary adverse effect of the SPC implementation failure was on the attitude of shop personnel. They expressed a great deal of dissatisfaction with management's labor practices. SPC empowered groups of people to fix problems they were having locally. This capacity and capability was lost as people were transferred to other manufacturing centers that did not have the SPC skills and support structure. Many shop personnel expressed a lack of trust and believed that management was insincere in their pursuit of improvement. Shop personnel believed management was acting in its own interest and did not care about the effect that management's labor practices had on them. This created even greater non-congruence between the formal and informal arrangements in manufacturing.

On other occasions I had opportunities to facilitate front-line problem-solving teams. One of these teams consisted of front-line quality inspectors. The team charter was to identify and eliminate sources of defects that continued to escape factory detection and were discovered in the paint hangar or by the customers on the flight line. The team

members were highly motivated, deeply vested and committed to achieving their stated goal of delivering a defect free airplane to the paint hangar. This team was very successful and identifying key problems. They came up with countermeasures to these problems along with a comprehensive proposal that was submitted to upper management. However, upper management was unwilling or unable to provide required resources and make necessary organizational structure changes to support the proposal and no action was taken.

In essence, informal arrangements were in place that reinforced the team taking action. There was a high level of motivation, compliance to cultural norms, sense of obligation, and commitment to organizational goals. But, the necessary formal arrangements (e.g., budget, organizational structure, supervision, operating procedures, etc.) were not in place to enable the execution of the improvement plan and nothing was done.

An observation based on these examples is that it is very important to have congruence between system components when implementing organizational change. To achieve results the formal arrangements need to simultaneously support appropriate technical business system improvement solutions, provide needed infrastructure and address the social/cultural issues of the informal arrangements that create a sense of obligation, commitment and motivation toward implementing the change and achieving the results.

### Problem Statement

Many organizations fail to achieve expected performance results when implementing business system improvements. A possible reason for the failure to achieve performance results is that such organizations lack the knowledge, skill and appropriate planning practices for generating systemic and congruent approaches for implementing improvements and managing organizational change. There is a need for a planning system that provides the process and infrastructure to acquire the knowledge and skills needed to plan, design, and implement an organizational change based on strategic intent.

This planning system needs to apply systems thinking principles to engage the organization and assure congruence between business system components.

### Objectives and Scope of Research

The goal of this research was to integrate existing planning theories, methods and tools into a planning approach that engages the organization and increases the likelihood that a business will achieve expected performance results when implementing business system improvements. The design objectives of the proposed planning approach were to:

- Assist business planners in building agreements about strategic direction.
- Encourage reflection on shared attitudes, beliefs, and values that shape policies.
- Account for the formal and informal structures within the organization.
- Provide a disciplined process to translate high-level goals and values into priorities for tactical business initiatives.
- Translate tactical priorities into a workable implementation plan.

Ideally, the planning system would assure congruency by developing strategies and implementation plans that concurrently address the formal and informal arrangements within the business system when planning innovations in business systems infrastructure.

This research is limited to a study involving manufacturing firms whose improvement needs are focused on improving product quality and on time delivery performance while concurrently minimizing cost.

### Organization of Thesis

The remainder of this thesis is organized as follows. Chapter 2 is a literature review that investigates the body of knowledge associated with strategic business planning and organizes it by function, structure, and process. This is followed by a review of important concepts associated with maturing organizational capabilities and with organizational learning. Chapter 2 concludes by summarizing insights from the

literature review. Chapter 3 describes an approach to business planning built on organizational learning theory and using Analytic Hierarchy Process (AHP), Design Structure Matrix (DSM) and project planning methods and tools. Chapter 4 demonstrates the planning system through an illustrative example. Chapter 5 summarizes the work and concludes with recommendations for implementation of the proposed planning system.

## CHAPTER 2

## LITERATURE REVIEW

Continuous changes in the business environment require business planners to rethink the way they organize and manage their business in order to stay competitive. Fundamental changes in the way people think about the nature and structure of businesses, technological innovation, globalization, changes in government regulations, and shifts in cultural values are some of the factors driving changes in the way business systems are organized and managed.

The Ever Changing Business Environment

In the early 1900's, a major source of competitive advantage was mass production. At this stage of industrial development mass production systems were conceived as mindless machines. The systems were very rigid and formalized. They were rationally designed using analytical scientific methods for the interchangeability of parts and labor and had centralized decision-making and control (Scott, 2003). Mass production systems solved the problem of how to produce large quantities of uniform product in a very efficient manner. However, once the problem of mass production was solved, others replicated the solution. The business environment became very competitive as many businesses began serving the same market. This created, early on, the need to identify sources of competitive advantage.

In more recent times, other sources of competitive advantage have been brought into play. In the 1980's, Total Quality Management (TQM) was a source of competitive advantage. But as more and more companies adopted TQM practices this approach to competitive advantage transformed into a basic business requirement. During the same time period Lean Production Systems pioneered by Toyota also were pursued as a source of competitive advantage. During the late 1980s and the 1990's spurred by innovations in

information technology many companies sought to implement fully integrated enterprise wide information systems as a source of competitive advantage. Today, the search for competitive advantage is a major part of modern business planning.

The search for competitive advantage is a strategic issue for business. Strategic planning has become a knowledge rich and complicated activity. Business strategists fall into three camps: 1) operational issues, 2) gazing into the future, and 3) cultural and behavioral approaches (Campbell and Alexander, 1997). Operational issues use process engineering, time based competition, benchmarking, empowerment, and other tools to evaluate effectiveness. Examples include the Total Quality Management, Lean Production System, and Information Technology approaches mentioned earlier. Gazing into the future looks at critical success factors. Examples of ways of looking into the future include Michael Porter's competitive analysis (Porter 1985), scenario planning (Schwartz 1991), business process re-engineering (Hammer and Stanton 1999), and Technology S-Curves (Foster 1986). Cultural and behavioral proponents like Peter Senge (Senge 1990) and Chris Argyris (Argyris 1990) focus on organizational learning and organizational defensive routines. Because of the depth and breadth of strategic alternatives, there is a need to develop formalized methodologies to aid in strategic planning.

Changes in the business environment can be internal as well as external. Organizations have life cycles, just as people do (Smith, Mitchell and Summer 1985). Companies in the latter stages of their life cycles may find the need to reinvent themselves to survive in today's highly competitive markets. Many companies aren't able to accomplish this, as exemplified by the fact that many of the Fortune 500 companies of a few years ago are no longer in existence today (Zey and Swenson 2001). The process for rejuvenating companies often involves an organizational development strategy that involves fundamentally rethinking the underlying assumptions on which the business was originally built. These assumptions are often derived from older paradigms that are not relevant today.

For example, over the course of recent industrial history there have been two major paradigm shifts in the way business systems are designed. One paradigm shift

deals with how we conceptualize organizations (e.g. as machines, uni-minded, or multi-minded social systems). The other paradigm shift deals with how we inquire into the system (e.g. analytical {independent variables} vs. systems approach {interdependent variables}) (Gharajedaghi 1999).

Over the years, business leaders obtained competitive advantage by changing the way they thought about their business systems. First was the paradigm shift from machine (i.e. mindless) to a biological (i.e. single minded) and then to social system (i.e. multi-minded) models. Second was the paradigm shift from an analytical thinking (i.e. independent variables) to a systems thinking approach (i.e. interdependent variables). Today businesses are recognized as complex social systems (Scott 2003). System redesign has evolved as one of the more recent approaches to rejuvenating companies, and to regaining and maintaining competitiveness (Ackoff 1999).

Shifting the paradigms of a business culture is a complex and difficult task. However, this approach to improvement may be driven from strategic necessity. Because of the importance of these strategic alternatives, there is an advantage in developing formalized methodologies to aid this kind of strategic planning.

Today's competitive environment drives accelerated change. Increased customer expectations for variety, quality, and value continue to challenge the delivery systems of many businesses. Innovations in information technology facilitate rapid global reproduction and dissemination of knowledge and information. This enables the replication of delivery system infrastructure that can rapidly compromise a firms' competitive position. Changing government regulations controlling markets also require agile strategic planning. It is important for businesses to be aware of its internal and external environment in order to identify strengths, weaknesses, opportunities, and threats to sustaining a competitive position and assure its survival.

### Strategic Management: Responding to the Business Environment

Strategic management requires specialized knowledge and skill to plan, design, and implement a business system based on strategic intent. Strategic management means

that all individuals in the organization, not just the top executives, think strategically and demonstrate autonomy and responsibility in combining thought, analysis, and action to achieve the strategic intent (O'Shannassy 2003). Strategic management starts with strategic thinking. Strategic thinking provides the theoretical and philosophical foundation for planning and designing business systems. This involves a clear mental picture of the complete system of value creation within the organization and the individual's role within the larger system. Strategic thinking provides a perspective of the big picture and the important issues that encompassed strategic management. Strategic management is understood by looking at strategic management function, structure, and processes.

### The Function of Strategic Management

The function of strategic management has both technical and social-psychological aspects. Strategic management solves strategic problems at the individual and institutional level by combining rational and generative thought processes (O'Shannassy 2003; Senge 1990). It provides a conceptualization of a firm's future with the objective of understanding the conditions under which a firm obtains superior economic performance (Barney 2002). Strategic management provides an understanding of the competitive forces and industry dynamics shaping the industry in which the firm operates and takes into account a wide array of factors to identify opportunities for the firm to succeed (Lippitt, 2003).

The technical function of strategic management involves a critical thinking framework that generates balanced decisions, manages risk, and builds a communications plan. This framework generally focuses on six priorities (Lippitt 2003). These are: 1) keeping products/services up-to-date and/or being state of the art; 2) gaining and maintaining market share and/or serving customers; 3) minimizing confusion by building an infrastructure and systems to establish and sustain high performance; 4) improving processes and procedures for efficiency, quality, and financial return; 5) developing commitment and competent workforce and/or building a supportive environment and

identity; and 6) positioning for the long-term by identifying trends, assumptions, and issues that offer opportunities and present potential threats.

The social-psychological function of strategic management is to build commitment by providing focus, accountability, and discipline to strategic management activities. Strategic management helps develop the prepared mind; that is, to make sure decision makers have a solid understanding of the business, its strategy, and the assumptions behind that strategy (Beinhocker and Kaplan 2002). It provides the strategic thinker with a clear mental picture of the complete system of value creation within the organization and the individual's role within the larger system. It creates clarity out of complex and seemingly disconnected details. (O'Shannassy 2003)

Strategic management exposes the mental models a firm's management uses to articulate its assumptions, premises, and the accepted wisdom by which a firm understands itself and its industry. This managerial frame of reference, to a large extent, drives its competitive strategy (Hamel and Prahalad 1993).

### The Structure of Strategic Management

In order to facilitate the development of knowledge and skill associated with strategic thinking, academics, theorists, and practitioners have developed frameworks that can be applied to strategic management. These frameworks provide a conceptual construct system for the understanding of strategic concepts, content, and processes.

Michael Porter's Strategic Management frameworks were the most noted in the literature. In his books *Competitive Strategy* (Porter 1980) and *Competitive Advantage* (Porter 1985) Porter parameterizes industry attractiveness through the well-known five forces and value chain frameworks. He made empirically testable assertions showing that firms operating in industries characterized by high rivalry, high threat of substitutes, high threat of entry, high buyer power, and high supplier power will perform at a lower level than firms operating in industries without these attributes (Oliver 2002). Porter's work gave real shape to strategy as a critical line management function and provided tools and substantive guidance to those taking an analytical approach to strategy.

The Balanced Scorecard (Kaplan and Norton 2001) complements Porter's work. The Balance Scorecard approach begins with the premise that an exclusive reliance on financial measures in a management system is insufficient. Financial measurements are lag indicators that report on outcomes of past actions. The Balanced Scorecard approach retains the financial performance measures and supplements them with measures on drivers, the lead indicators of future performance. There are four primary measures on the Balanced Scorecard: 1) Financial: the strategy for growth, profitability, and risk viewed from the perspective of the shareholders; 2) Customer: the strategy for creating value and differentiation from the perspective of the customer; 3) Internal business processes: the strategic priorities of various business processes that create customer and shareholder satisfaction; and 4) Learning and growth: the priority to create a climate that supports organizational change, innovation, and growth. The fundamental premise of this framework is that organizational learning drives improvements in business processes that in turn drives customer and shareholder satisfaction that leads to financial performance.

Another leading framework in the area of strategic management is Business Process Re-Engineering (Hammer 2002). This framework is built on the premise that process management is a structured approach to performance improvement centering on the disciplined design and careful execution of a company's end-to-end business processes. The advocates of Business Process Re-Engineering assert that, while there are many improvement initiative frameworks (including ERP implementation, supply chain integration, six sigma, and others) that can improve performance, these improvement initiatives need to be positioned under a process management umbrella if they are to be successfully integrated. Using Business Process Re-Engineering methods allows companies to manage their portfolio of initiatives in an organized way. This ensures a company benefits from these important tools while avoiding the traps of applying them where they do not fit.

Competing on Capabilities (Stalk and Evans-Clark 1993) is a framework that closely parallels Business Process Re-Engineering. Capabilities are sets of business processes that are strategically understood. Capability based competitors identify their key processes, manage them centrally, and invest in them heavily, looking for long-term

payback. These companies combine scale and flexibility to outperform the competition along five dimensions: 1) Speed- the ability to respond quickly to customer or market demands and incorporate new ideas and technologies quickly into products; 2) Consistency- the ability to produce a product that unfailingly satisfies customer expectations; 3) Acuity- the ability to see the competitors environment clearly and thus to anticipate and respond to customers' evolving needs and wants; 4) Agility- the ability to adapt simultaneously to many different business environments; and 5) Innovativeness- the ability to generate new ideas and combine existing elements to create new sources of value.

Core Competencies (Hamel and Prahalad 1993) are related to capabilities and provides another way of structuring strategy. These involve core technologies and the intellectual assets to use them to improve the firms efficiency and effectiveness in ways that competing firms cannot. Core competencies provide strategic focus for a firm's investments in growth and development.

Strategy frameworks based on resource views turn neo-classical price theory upside down by altering one major assumption, that certain kinds of resources and capabilities are inelastic in supply (Barney 2002). The resources based view analyzes the value, rarity, limitability, and exploitation of firm's resources as sources of competitive advantage.

### The Strategic Management Processes

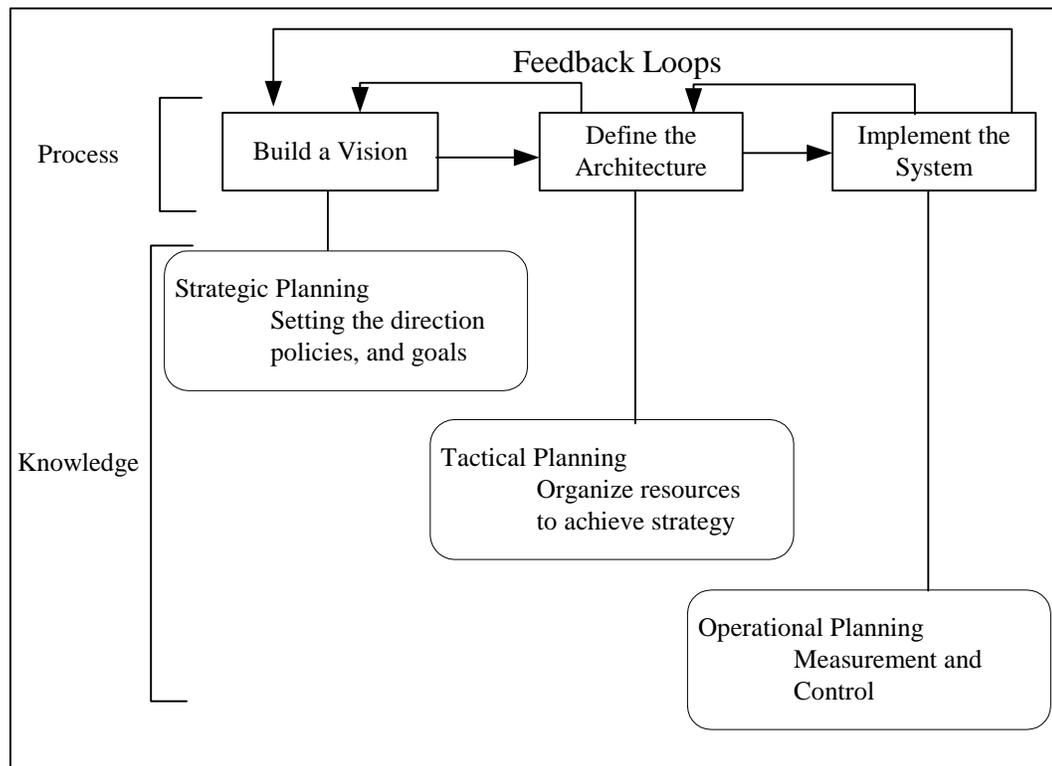
Strategy management processes includes strategy formulation and execution (Katz 2002). Two overarching goals of these processes are acquiring knowledge (the building of the prepared mind) and increasing the innovativeness of a company's strategy (Beinhocker and Kaplan 2002). The strategic management process has three sub-processes as shown in Figure 2: Three Step Planning Process.

Step one involves building a shared vision. The strategic management process starts with building a shared vision. Any effective vision must embody the core ideology of the organization. Core ideology includes core values and a core purpose. Research has

shown that visionary companies have outperformed the general stock market by a factor of 12 since 1925 (Collins and Porras 1996). Companies that enjoy enduring success have core values in a core purpose that remains fixed while their business strategies and practices endlessly adapt to a changing world.

The vision process is one of five disciplines needed to make strategic management successful. These are the disciplines of a learning organization (Senge 1990). The other disciplines are developing common mental models, team learning, personal mastery, and systems thinking. Applying these disciplines enables the strategy process to: 1) translate the strategy into operational terms; 2) align the organization to the strategy; 3) makes strategy everyone's every day job; 4) makes strategy a continual process; and 5) mobilize leadership for change (Kaplan and Norton 2001)

Figure 2: Three Step Planning Process



There are numerous ways in which to add content to the vision process. One approach is called "Idealized Design" (Ackoff 1999). This approach imagines that what exists today has been destroyed. The business planners are free to design anything technically feasible. In this way business planners are free to choose the future they want unconstrained by their perceptions of current realities.

Iterative design provides a methodology for idealized design (Gharajedaghi 1999). The Iterative design process involves four steps: context, functionality, structure, and process. Context examines the environment in which the business components will operate. Functionality defines the output of the components. Structure defines the subsystems that comprise the components. Process describes how the components interact in order to provide the function. The iterative design process is repeated over and over again. New knowledge is acquired with each iteration. This continually improves the design of the organization and over time moves the organization incrementally closer to the ideal design.

Another approach to adding content to the vision process is through capability gap analysis (Coyne 1986). Examples of capability gaps include: 1) business system gap which results from the ability to perform individual functions, such as engineering, more effectively than competitors; 2) a position gap resulting from reputation, customer awareness and trust, and order backlog and are often the result of earlier management generations; 3) regulatory gaps which result from the government's limiting of competitors who perform certain activities. These include patents, operating licenses, and import quotas; 4) organizations or managerial quality gaps resulting from an organization's ability to consistently innovate or adapt more quickly and effectively than its competitors.

Another method for adding content to the vision process is by developing a strategic profile (Kim and Mauborgne 2002). This involves looking at factors affecting competition amongst industry players. The result of this process is a strategy map displaying a firm's market offerings compared to its competitors.

If a firm encounters a threat, several defensive strategies can be used (D'Aveni 2002). These include: 1) containment strategies - blocking in customers or swapping

distribution channels; 2) shaping strategies which might include co-opting the competitors or influencing them through venture capital; 3) absorption strategies - bringing the competitors inside to enhance your existing business; 4) neutralizing strategies - quashing through legal means, giving away the benefits offered by the competitors for free, or continually improving existing products or technologies; and 5) annulment strategies - the leapfrogging the threat with another revolution better suited to the incumbent's strengths.

Step two involves defining architecture. The outcome of the strategic vision process is a commitment to a strategic direction. This involves the communication of policies, goals and objectives. It targets business architecture including functions, processes and infrastructure, and provides guidelines for their development in order to achieve superior economic performance and other strategic objectives. This provides linkage between strategy formulation and strategy execution.

Business system architecture is defined through a set of architectural views (Sowa and Zachman 1992). These views document the functional requirements and design parameters of the components of the business infrastructure. They provide different insights from different perspectives of the business system. A metaphor for business architectural views is the architectural views of a house. A house has functional requirements for the structural frame, electricity, plumbing, heating, and masonry. The design parameter specifications for these functional requirements are documented and provide different views of the house. The views provide guidelines for construction, configuration management, and maintenance of the house. Likewise, business systems have architectural views that document functional requirements and design parameters that are used for construction, configuration management, and maintenance. Common architectural views for a business system include business processes, product and services, management controls, external agents, financial resources, physical resources, human resources, information resources and technology resources.

Step three involves implementing change. Useful concepts for increasing organizational capabilities to manage change have been developed by the Software Engineering Institute. They have developed a Capability Maturity Model (CMM) (Paulk

et al. 2004).). CMM concepts can be use to describe an organizational change management process in terms of:

1. Maturity level that indicates workforce capability
2. Key process areas that define specific goals
3. Common features that address implementation
4. Key practices that describe infrastructure or activities.

A graphical representation of the CMM concepts is shown in Figure 3: Concepts in Capability Maturity Model; the concepts described below.

A maturity level is a well-defined evolutionary plateau that establishes a level of capacity for improving workforce capability. The five maturity levels provide the top-level structure of the CMM. These levels are shown in Figure 4: Capability Maturity Model Maturity Levels.

Workforce capability contributes to an organization's performance and its ability to achieve business objectives. It is an important predictor of business performance. Workforce capability describes the level of knowledge and skills in the organization's workforce and the ability of the workforce to apply them to improving business performance.

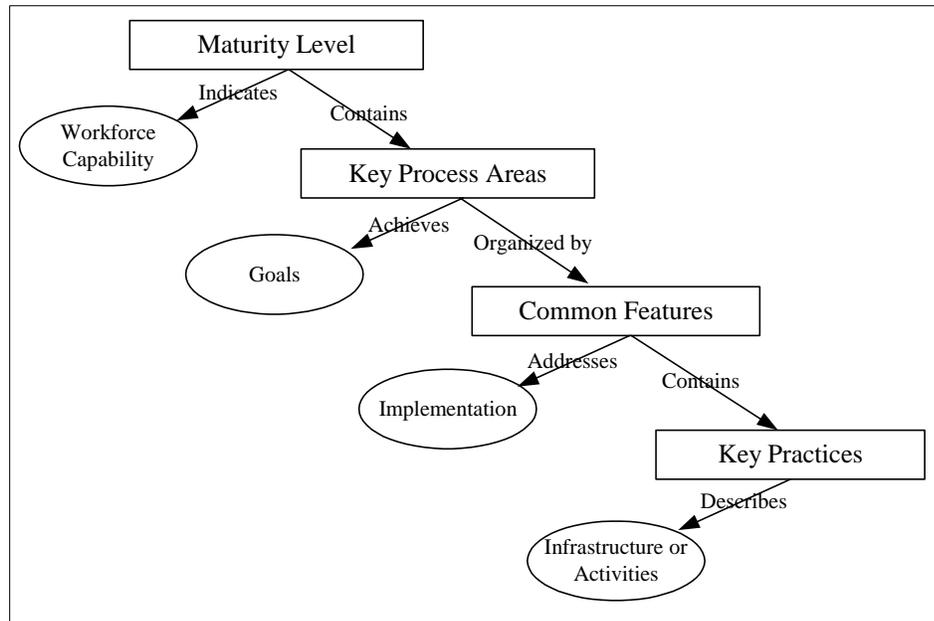
Each maturity level is composed of key process areas. Each key process area contains a set of goals that, when satisfied, establish that key process area's ability to affect workforce capability. Key process areas have been defined to reside at a single maturity level.

The goals of a key process area summarize the states that must exist for that key process area to be implemented in an effective and lasting way. The extent to which the goals have been accomplished is an indicator of how much capability the organization has established at that maturity level. The goals signify the scope, boundaries, and intent of each key process area.

Each key process area is composed from a set of key practices that, when implemented, help to satisfy the goals of that key process area. The key practices describe the elements of infrastructure and workforce practice that contribute most to the effective implementation and institutionalization of their key process area. These key practices

state the fundamental policies, procedures, and activities for the key process area. Sub-practices (also subordinate key practices) describe what one would expect to find implemented for the top-level key practice

Figure 3: Concepts in Capability Maturity Model (Adapted from Paulk et al. 2004).

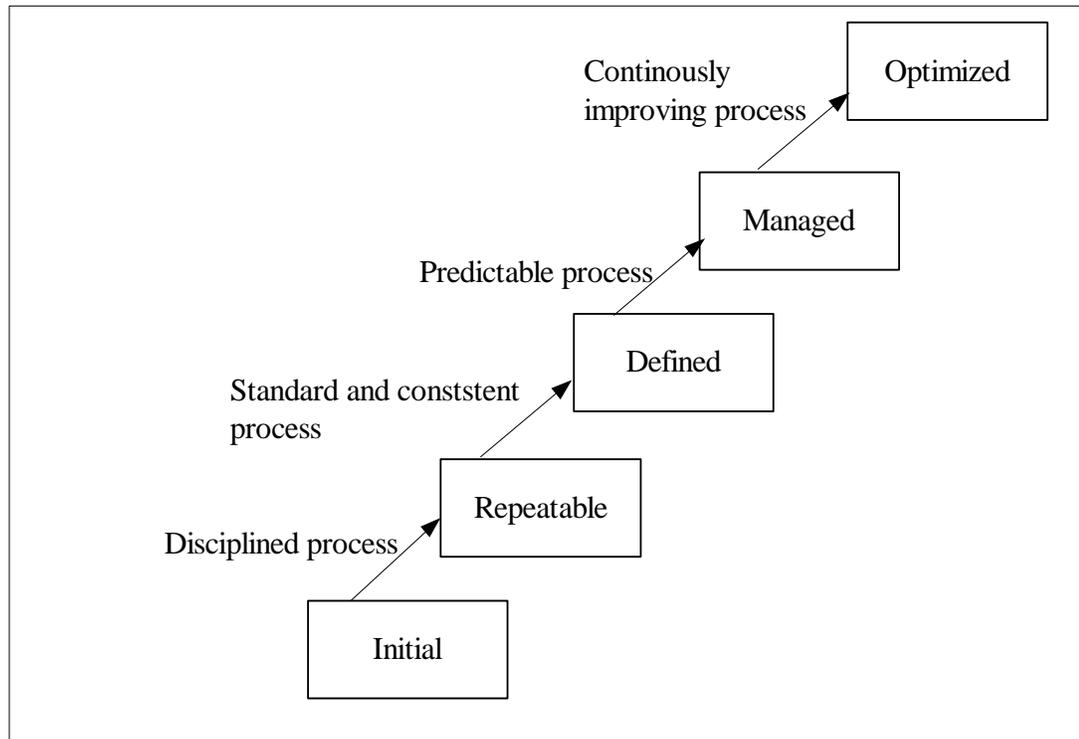


Of particular importance to organizational change management are the common features. The key practices in each key process area are organized by a set of common features. The common features are attributes that indicate whether the implementation and institutionalization of a key process area are effective, repeatable, and lasting. The common features also group and order the key practices in a sequence helpful for organizations using them. The key practices of each key process area are divided into five clusters called common features. The common features include practices that implement and institutionalize a key process area. These five types of common features include:

1. Commitment to Perform
2. Ability to Perform
3. Activities Performed
4. Measurement and Analysis

## 5. Verifying Implementation

Figure 4: Capability Maturity Model Maturity Levels (Adapted from Paulk et al. 2004).



Commitment to Perform describes prerequisites for implementing each key process area and the actions the organization must take to ensure that the activities constituting a key process area are established and will endure. Commitment to Perform typically involves establishing organizational policies and management sponsorship.

Ability to Perform describes the preconditions that must exist in the unit or organization to implement key practices competently. Ability to Perform typically involves resources, organizational structures, and training.

Activities Performed describe the roles and procedures necessary to implement the functions constituting a key process area. Activities Performed typically involve establishing plans and procedures, performing the work, tracking it, and taking corrective

actions as necessary. The key practices describe the processes that should be implemented to establish a workforce capability.

Measurement and Analysis describes the need to measure the key practices and analyze the measurements. Measurement and Analysis typically include examples of measurements that could be taken to determine the status and effectiveness with which the Activities Performed have been implemented.

Verifying Implementation describes the steps to ensure that the activities are performed in compliance with the policies and procedures that have been established. Verification typically encompasses objective reviews and audits by responsible parties.

An integral part of the CMM is the use of project planning and management techniques. The project manager must plan, schedule, and manage projects and resources throughout the project life cycle, assuring compliance with the goals and objectives. The project manager's duties include managing project scope, time, costs, quality, teams (human resources), communications, risks, and procurements (Ghattas and McKee 2001).

### The Importance of Organizational Learning

The business environment is very dynamic. Many management system engineering ideas and theories have evolved to help businesses grow and achieve their goals. Available management system theories provide different vantage points from which to view and improve business systems. These theories help develop new organizational capabilities (Senge 1990), analyze markets and target new sectors (Porter 1980), improve quality (Deming and Walton 1988), implement lean production systems (Jones and Womack 1996), and re-engineer the business to take advantage of the benefits of information technology (Hammer and Stanton 1999). Each of the theories provides a different perspective and develops different insights about the function and structure of a business system.

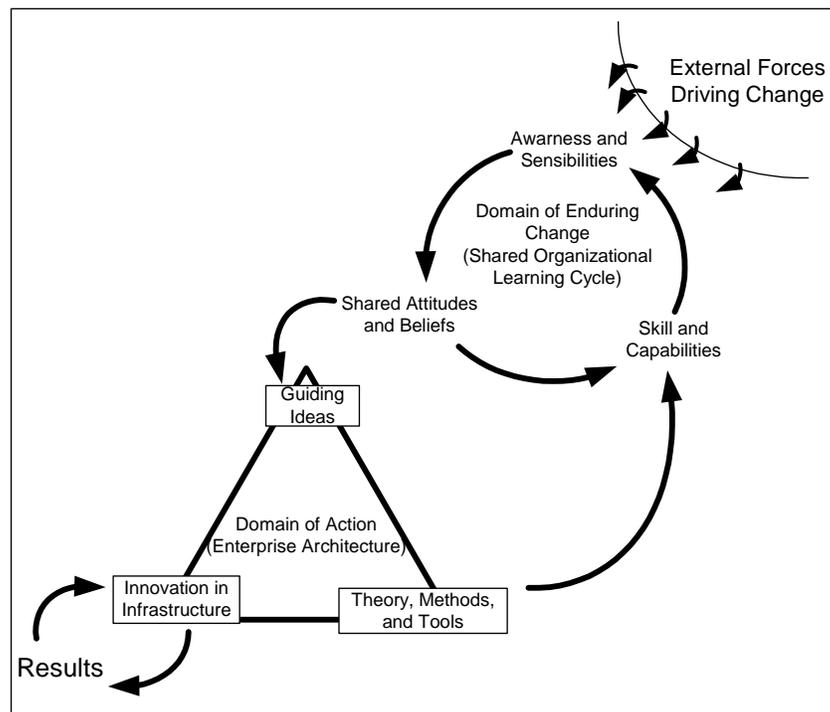
Acquiring knowledge about the sources of competitive advantage these theories offer is an important strategic planning activity. Application of these theories to a business system means evaluating a bewildering array of strategic alternatives for

business systems improvement. In this context, developing a formal planning system that simultaneously selects appropriate technical business system improvement solutions, provides needed infrastructure and addresses the social/cultural issues of the social system is a very complex and difficult problem. An approach for an organization to develop formal planning that addresses this problem can be found in organizational learning theory.

One of the main themes in organizational learning is that an organization's ability to learn is a primary source of sustainable competitive advantage. A learning organization is a group of people continually enhancing their capacity to create what they want to create. Learning in organizations means the continuous testing of experience and the transformation of that experience into knowledge that is accessible to the whole organization and relevant to its core purpose (Senge 1990).

Figure 5 depicts a popular organizational learning cycle (Senge, Kleiner, Roberts, Ross, and Smith 1994).

Figure 5: Graphical Depiction of Organizational Learning Cycle (Adapted form Senge et al. 1994)



The learning cycle begins by examining external forces that are shaping the business environment and driving change. These might include competitive pressure, new customer requirements, government regulations, or environmental issues. An organization, through learning about how these issues affect the business, creates new awareness and changes shared attitudes and beliefs. New guiding ideas evolve that are used to implement innovation in business system infrastructure. The result of these innovations addresses the external forces driving change as well as improves customer satisfaction and financial performance.

This organizational learning process also provides a framework for a set of integrated performance measures. The idea that organizational learning drives innovation in infrastructure that in turn drives the results of improved customer satisfaction and improved financial performance is the basis for a performance management system such as the “Balanced Score Card” (Kaplan and Norton 2001).

During the learning process theories, principles and practices are used to improve the skill and capabilities to learn and innovate. The focus of this thesis is to examine business-planning theory, principles, and practices that will provide structure for the organizational learning process.

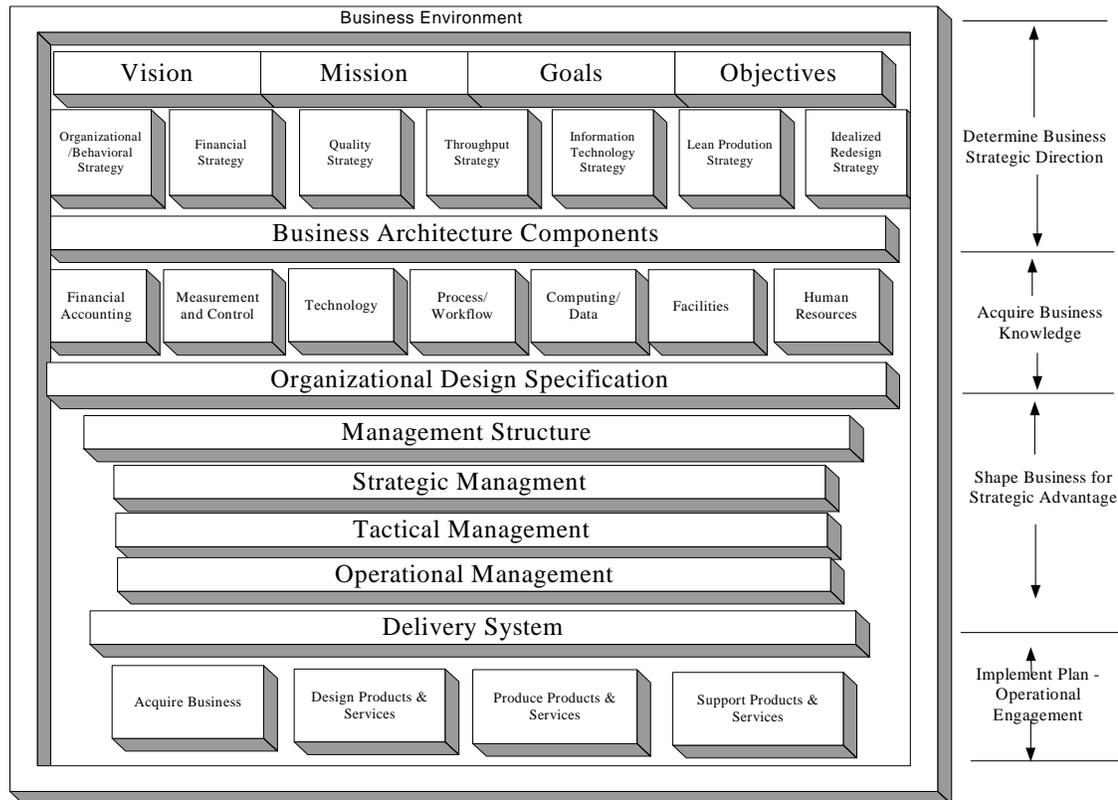
### Insights From Literature Review

This literature review explored some of the vast body of knowledge that can be used to support the organizational learning cycle shown in Figure 5: Graphical Depiction of Organizational Learning Cycle. This body of knowledge provides insights about how to transform the learning cycles into a formal planning system of improving business systems based on strategic intent. This literature review attempted to capture the more prominent theories and practices comprising the function, structure and processes of strategic management. This information provides the foundation for structuring planning practices that characterize an organizational learning cycle. These planning practices

would articulate an organization's core ideology and beliefs, analyze the external and internal business environment, specify the design of the business architecture and infrastructure, and build commitment by embedding modern social engineering in appropriate CMM and project management practices.

The literature review provides the content for the development of a new planning system. It provides planners with things they need to know and the things they need to do to develop improvement plans. The content of the literature review was synthesized into a knowledge base that is graphically depicted in Figure 6.

Figure 6: Components of a Business Planning System



The outer box in Figure 6 represents the boundary between the internal and external business environments. The internal environment includes business culture and leadership (e.g. the vision, mission, goals, and objective), business architecture (e.g. an arrangement of components that delivers business function), and primary delivery system

that provide value to the market. The mission is the fundamental reason the business exists. The vision is a compelling image of the future state of the business. Vision statements often include an affirmation of core values (Senge et al. 1994). The goals and objectives are the means to achieve the vision. Business architecture is a multidimensional conceptual model representing the functional, logical, and physical aspects of the business system. Architecture is often documented in different views (Sowa and Zachman 1992) such as financial, management control, technology resources, business process, computing, facilities, and human resources. The primary delivery system is the set of business processes involved with acquiring new business, and with designing, producing, and supporting products and services.

To determine strategic direction business planners examine the external environment for factors that affect the internal environment. Various strategies are formulated that address these environmental factors in relationship to the vision and business architecture. Applying organizational learning practices, organizational actors acquire knowledge about the impact of the strategies on the business system. This new knowledge is used to target innovation in business architecture to reshape the business for strategic advantage. Implementation plans are developed and changes made through operational engagement.

The implication of this model is that planners need to establish their vision, mission, and goals. They need to know about their internal and external business environment and what alternatives are available to achieve their vision, mission, and goals. This is necessary so that planners can determine the business's strategic direction. Then, if planners know how to apply organizational learning practices, they can acquire business knowledge from across the organization. The organization's collective knowledge is used to specify structural changes to the business architecture enabling planners to shape the business for strategic advantage. Finally, through the use of project planning methods and tools, the innovations in infrastructure are organized into a workable plan so that operational engagement of infrastructure changes is effective.

This research contributes to the business planning body of knowledge by designing a planning method to assist business owners and managers acquire the

knowledge and skills needed to successfully plan, design, and implement changes to business systems based on strategic intent. The method provides a structured process to facilitate determining strategic direction, developing projects to implement the strategic direction and soliciting involvement from key participants. Chapter 3 describes an approach to planning that imbeds organizational learning practices into a series of steps that will allow planners to accomplish the planning functions.

## CHAPTER 3

## AN APPROACH TO PLANNING

The planning approach proposed in this chapter describes a decision process that is designed to engage the organization. This planning approach uses Analytic Hierarchy Process (AHP), Project Management Tools (PMT), and Design Structure Matrix (DSM) to carry out the important planning functions. The following pages outline a proposed approach to planning large-scale organizational change, followed by detailed descriptions of the key technical tools used in the approach. The ensuing chapter illustrates the approach through a hypothetical example based on the author's experience.

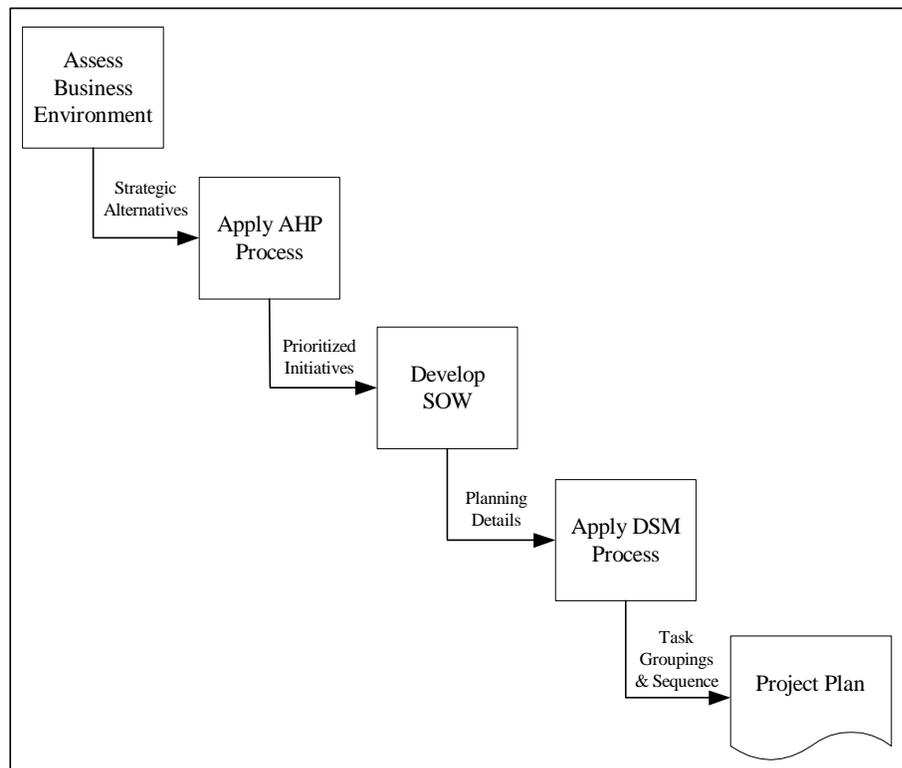
Overview

The major steps in the proposed planning approach are shown in Figure 7: Steps in Planning Approach. The approach begins with an assessment of the external and internal business environment. Planning participants discuss what they know and believe to be true about the business environment. The assessment is intended to create situational awareness. That is, where has the business been in the past, where is it now, and where should it be going. Planners use their preferred assessment methods (e.g. competitive forces (Porter 1985), reengineering (Hammer and Stanton 1999), core competency (Hamel and Prahalad 1993), etc.) to advocate their choice of strategic direction. The assessment results in a set of strategic alternatives that are inputs into the AHP process.

The planners construct a decision hierarchy by discussing the business situation and examining the various strategic proposals. Understanding and applying systems thinking principles is valuable at this stage of the process. It is important to understand how a proposal will be integrated into the existing business system and how it will affect the desired future state of the business. By balancing advocacy with inquiry (a team learning practice), they build agreements about important factors to be included in the

decision hierarchy. A shared vision and common mental models begin to emerge as business knowledge is acquired and shared across the organization during the AHP process. The result of AHP is a set of prioritized initiatives for precipitating organizational change consistent with strategic intent.

Figure 7: Steps in Planning Approach



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process. The result of AHP is a set of prioritized initiatives for precipitating organizational change consistent with strategic intent.

The business knowledge acquired during the discussion provides the basis for specifying changes to business systems allowing the business system to be shaped for strategic advantage. Statements of work (SOW) organize the details of what is learned during the application of AHP. The details from the SOW are input into the DSM process, which organizes the tasks into groups and sequences the groups. The output of the DSM is input into project management tools for scheduling and resourcing. Applying this approach to planning creates an environment for organizational learning, provides a disciplined structured process to facilitate the determination of strategic direction, develops projects to implement the strategic direction, and solicits involvement from key participants throughout the planning process.

#### Analytic Hierarchy Process (AHP)

AHP is a multi-criteria decision method that uses hierarchical structures to solve complicated, unstructured decision problems, especially in situations where there are important qualitative aspects that must be considered in conjunction with various measurable quantitative factors. Applications of AHP include:

1. Developing a business performance evaluation system (Lee, Kwak, and Han 1995)
2. Making strategic decision about equipment replacement (Oeltjenbruns, Lolarik, and Schandi-Kirschner 1995)
3. Choosing manufacturing plant layout (Abdul-Hamid, Kochhar, and Khan 1999)
4. Making management decision about continuous improvement processes (Labib and Shah, 2001)
5. Determining key capabilities of a firm (Hafeez, Zahng, and Malak 2002)
6. Selecting next-generation manufacturing (Alvi and Labib 2003)

7. Developing a design strategy for a re-configurable manufacturing system (Abide and Labib 2003)

AHP has been demonstrated as a powerful and useful method for assisting managers with complicated and difficult decisions.

### AHP Axioms

AHP is founded on the following set of axioms for deriving a scale from fundamental measurements and for hierarchical composition (Saaty 1986).

#### Axiom 1: Reciprocal

If element A is  $x$  times as important than element B, than element B is  $1/x$  times as important then elements A.

#### Axiom 2: Homogeneity

Only comparable elements are compared. Homogeneity is essential for comparing similar things, as errors in judgment become large when comparing widely disparate elements.

#### Axiom 3: Independence

The relative importance of elements at any level does not depend on what elements are included at a lower level.

#### Axiom 4: Expectation

The hierarchy must be complete and include all the criteria and alternatives in the subject being studied. No criteria and alternatives are left out and no excess criteria and alternatives are included

### How it Works: AHP Procedure

Pair wise comparisons among  $n$  elements in each level lead to an approximation of each  $a_{ij}=w_i/w_j$  which is the ratio of the weight of element  $i$  to element  $j$ . The estimated weight vector  $w$  is found by solving the following eigenvector problem:  $\mathbf{A}w=\lambda_{\max}w$ , where the matrix  $\mathbf{A}$  consists of  $a_{ij}$ 's, and  $\lambda_{\max}$  is the principal eigenvalue of  $\mathbf{A}$ . If there is no inconsistency between a pair of elements, then  $a_{ij}$  is equal to  $1/a_{ji}$  for any  $i$  and  $j$ . The

result is that  $\lambda_{\max} = n$  and we have,  $\mathbf{A}w = \mathbf{n}w$ , where  $n$  is the number of elements in each row. Written out more fully this matrix equation looks as follows:

$$\begin{array}{c|cccc}
 & A_1 & A_2 & \dots & A_n \\
 \hline
 A_1 & \frac{w_1}{w_1} & \frac{w_1}{w_2} & \dots & \frac{w_1}{w_n} \\
 A_2 & \frac{w_2}{w_1} & \frac{w_2}{w_2} & \dots & \frac{w_2}{w_n} \\
 \vdots & \vdots & \vdots & & \vdots \\
 \vdots & \vdots & \vdots & & \vdots \\
 A_n & \frac{w_n}{w_1} & \frac{w_n}{w_2} & \dots & \frac{w_n}{w_n}
 \end{array}
 \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}$$

or

$$\begin{array}{c|cccc}
 & A_1 & A_2 & \dots & A_n \\
 \hline
 A_1 & 1 & a_{12} & \dots & a_{1n} \\
 A_2 & \frac{1}{a_{12}} & 1 & \dots & a_{2n} \\
 \vdots & \vdots & \vdots & & \vdots \\
 \vdots & \vdots & \vdots & & \vdots \\
 A_n & \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \dots & 1
 \end{array}
 \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = \lambda_{\max} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}$$

To calculate the  $w$  vector (also called the eigenvector) each column of  $A$  is first normalized and then averaged over its rows. This vector is used to find the relative importance of each element. Observe that since small changes in  $a_{ij}$  imply a small change in  $\lambda_{\max}$ , the deviation of the latter from  $n$  (the number of elements in a row) is a measure of consistency. The consistency ratio (CR) is given by  $(\lambda_{\max} - 1)/(n - 1)$ , which is the variance of the error incurred in estimating the matrix  $A$ . If the inconsistency becomes

more than 10%, the problem and the judgments must be reinvestigated and revise (Saaty 1980).

### Project Management Tools

The Project Management Institute (PMI 2004) identifies project management as having five phases:

1. Initialization: the process of formally recognizing that a new project exists or that a process should continue into the next phase.
2. Planning: the process of developing a written scope statement as the basis for future project decisions including criteria to determine if the project or phase has been successfully completed.
3. Execution: the process of carrying out the project plan by carrying out the activities included therein.
4. Control: the process of monitoring project execution and taking corrective action in order to meet project plan requirements.
5. Closure: the process of closure that consists of verifying and documenting project results to formalize acceptance of the product of the project by the sponsor, client, or customer.

A Statement of Work template developed by the author for managing projects can be used in the initialization and preliminary planning phases of a project. A template is shown in Figure 8.

Figure 8: Statement of Work

Objective: (What is the higher level effect?)	Assigned to: (Who?)
Action: (What to do?)	
Purpose: (Why do it?)	
Work to be performed: (How do I do it?)	
Constraints: (What is going to keep me from getting it done?)	
Measurements: (How do I know I am doing a good job and that the work is achieving the objectives?)	

This template is used to organize the detailed data that is documented during the discussion for building consensus about the weights used in AHP. Project managers can use the templates for implementation planning and control.

### Design Structure Matrix (DSM)

A design structure matrix (DSM) provides a simple, compact, and visual representation of a complex system that supports innovative solutions to decomposition and integration problems. DSM has been applied to facilitate architectural decomposition strategies, integrate organizational structures, model information flow (Browning 2001), improve product development processes (Ahmadi, Roemer, and Wang 2001; Browning, and Eppinger 2002; Chen, Ling, and Chen 2003) and building design and construction projects (Baldwin, Austin, Hassan, and Thorpe 1999; Huovila and Seren 1998).

The activity-based DSM provides a visual format for understanding and analyzing project planning issues by describing the input/output relationships between activities and showing the dependency structure of a project based on the required information flow. This provides a systematic method for designing a data-driven project schedule.

Once constructed the DSM becomes a useful project management tool. With a reasonably accurate DSM, one then uses the DSM to look for improvements. The activity-based DSM can provide insight in several areas. Glancing down a column reveals where the output of an activity goes. An examination of a row shows where an activity gets its information, and, thus, how changing an activity's outputs may affect other activities.

DSM highlights feedbacks that can cause iterations and rework. DSM can also be used to determine which activities can be accomplished in parallel as well as activity precedence. By highlighting dependencies, feedback, and iteration, an activity-based DSM provides planners with a powerful capability for managing complex projects. It enables improved project understanding, which, in turn, leads to project innovation and improvement (Browning 2001).

### How it Works: DSM Procedure

Design Structure Matrix (DSM) is a technique based on representing the from-to relation between any two activities as a binary representation in the matrix cell. The activities in the columns produce outputs that are inputs to activities in a row. By partitioning the matrix, (i.e., re-arranging the rows and columns in such a way that the activity relations are transferred to the lower triangle of the matrix) it is possible to establish sequential, parallel and coupled activities (or activity blocks) in the matrix (Cronemyr, Ronnback, and Eppinger 2001).

Modeling a project using DSM starts with determining the boundary of the project to be modeled and how the project will be decomposed. Second, the modeler collects activity data and builds DSM. To do this the project is broken down into activities. Information flow among activities is documented. Activities are listed in DSM in roughly chronological order, with upstream or early activities listed in the upper rows by decomposing the project into activities. The activities are sequenced into a (generally) maximally feed forward process flow. During this process the modeler is answering the following types of questions: What outputs or products must the activity produce? Where do these outputs go? What inputs does the activity need? Where do these inputs come from?

The following example from Gebala and Eppinger (1991) demonstrates matrix partitioning. Consider a project that is comprised of Activities A through G. They are entered into a matrix shown in Table 1. The “X” entered into the cell, row 1-column 3, indicates that Activity C produces an output that is an input to Activity A. Likewise the “X” entered into the cell, row 3-column 1, indicates that Activity A produces an output that is an input to Activity C. Once all of the activity relationships are documented the matrix can be partitioned.

The objective of partitioning is to rearrange the tasks and eliminate as many feedback loops as possible. This will help avoid rework. There are several approaches used in DSM partitioning. However, they are all similar in how they identify cycles of information. The matrix can be partitioned through identifying loop by path searching

(Steward 1981; Gebala and Eppinger 1991). To begin this process, observe that the Activity F row has no entries in any of the cells (see Table 2: Matrix Partitioning Step 1). This indicates that Activity F does not require input from any other activity and therefore can be scheduled first.

Table 1: Activity Dependency Matrix (Adapted from Gebala and Eppinger 1991)

Task		1	2	3	4	5	6	7
Activity A	1	■		X	X			
Activity B	2		■					X
Activity C	3	X	X	■			X	X
Activity D	4		X		■			
Activity E	5			X		■	X	
Activity F	6						■	
Activity G	7				X		X	■

Table 2: Partitioning Matrix Step 1 (Adapted from Gebala and Eppinger 1991)

Task		1	2	3	4	5	6	7
Activity A	1	■		X	X			
Activity B	2		■					X
Activity C	3	X	X	■			X	X
Activity D	4		X		■			
Activity E	5			X		■	X	
Activity F	6	■	■	■	■	■	■	■
Activity G	7				X		X	■

Next observe that column 5, representing Activity E, has no entries in any of the cells (see Table 3: Matrix Partitioning Step 2). This indicates that Activity E does not provide an input to any other activity and can be scheduled last.

Now there are no more empty rows or columns. Examining Activity A reveals a loop with Activity C. These tasks are compressed into one activity (see Table 4: Matrix Partitioning Step 3). The column 3-1, representing the combined Activities CA is blank indicating it is not part of any other loop and therefore can be moved to the second to last activity.

Table 3: Matrix Partitioning Step 2 (Adapted from Gebala and Eppinger 1991)

Task Name		6	1	2	3	4	7	5
Activity F	6							
Activity A	1				X	X		
Activity B	2						X	
Activity C	3	X	X	X			X	
Activity D	4			X				
Activity G	7	X				X		
Activity E	5	X			X			

Table 4: Matrix Partitioning Step 3 (Adapted from Gebala and Eppinger 1991)

Task		6	3-1	2	4	7	5
Activity F	6						
Activity CA	3-1	X		X	X	X	
Activity B	2					X	
Activity D	4			X			
Activity G	7	X			X		
Activity E	5	X	X				

Next, dependencies are traced starting with any unscheduled task. For example observe that task B depends on task G that depends on task D that depends on task B. This final loop includes all the remaining unscheduled tasks. The finished partitioned matrix is shown in Table 5.

Table 5: Finished Partitioned Matrix (Adapted from Gebala and Eppinger 1991)

Task		6	2	4	7	3	1	5
Activity F	6							
Activity B	2				X			
Activity D	4	X						
Activity G	7	X	X					
Activity C	3	X	X		X		X	
Activity A	1			X		X		
Activity E	5				X			

## CHAPTER 4

## IMPLEMENTATION

The proposed planning approach presented in Chapter 3 uses the knowledge of planning participants to construct a planning hierarchy for use in the AHP process. Building consensus about element weighting during the AHP process creates a shared understanding of business priorities and detailed information about how to address those priorities. The detailed information is organized into statements of work. These statements of work are grouped and sequenced using DSM into an improvement plan.

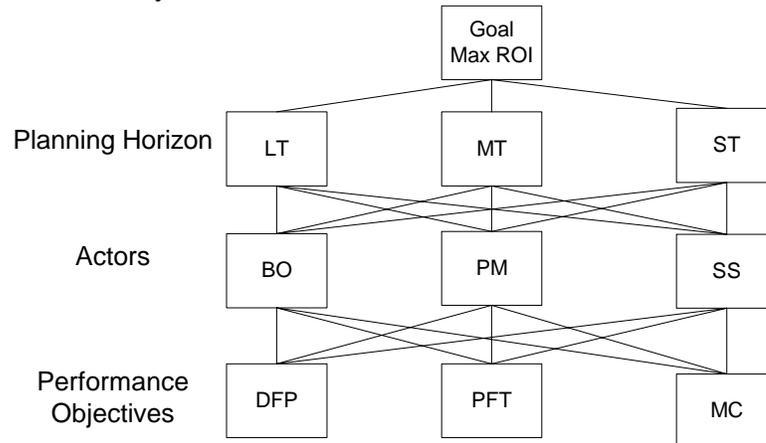
This chapter presents a hypothetical example of the application of the planning approach. An AHP hierarchy is first constructed from the knowledge obtained from the literature review. The hierarchy is then used to examine four different business circumstances referred to as business scenarios. This demonstrates that AHP prioritizes improvement alternatives differently under different business circumstances. Next detailed statements of work are developed for a quality strategy and a lean production strategy. These provide the data for a demonstration of DSM for project plan development.

#### Justification of a Strategic Planning Hierarchy

As noted in the literature review business strategists fall into three groups: 1) gazing into the future, 2) cultural and behavioral approaches, and 3) operational issues (Campbell and Alexander 1997). These three approaches to strategic planning reveal three important topics for inclusion into an AHP hierarchy. Gazing into the future suggests that *planning horizon* should be included. It is strategically important to know what is feasibly possible and in what timeframe. Cultural and behavioral approaches point to the importance of *actor involvement* in the planning process. Operational issues emphasize the physical aspects of the operational system required to implement functional requirements and achieve *performance objectives*. This leads to the

hierarchical structure shown in Figure 9: 4-Level Hierarchy. This hierarchy is similar to and consistent with hierarchies validated in other research (Abide and Labib 2003).

Figure 9: 4-Level Hierarchy

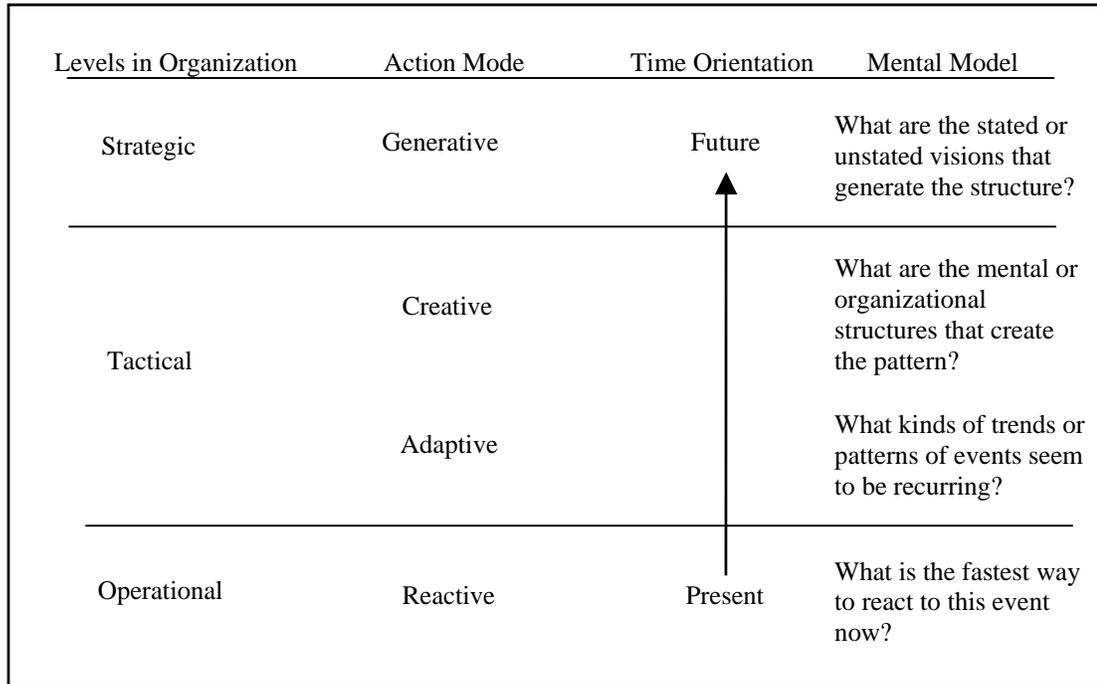


The goal of making more money now and in the future deals with maximizing return on investment (ROI) and is at the top of the hierarchy. The second layer of the hierarchy deals with planning horizon. Planning horizon can be viewed from short term (ST), medium term (MT) and long term (LT) perspectives. The third layer of the hierarchy deals with actor involvement. Actor involvement requires a vertically integrated planning process to assure organizational alignment. Management structures within organizations have three distinctive levels: strategic, tactical, and operational. Each level requires a fundamentally different set of knowledge and skills. The strategic level actor is the business owner (BO) or their representative who is knowledgeable and skilled in markets and capital investment. The tactical level actor is the plant manager (PM) who is knowledgeable and skilled in organizational design and implementation. The operational level actor is the shop supervisor (SS) who is knowledgeable and skilled in measurements and control of systems execution.

These management levels have distinctive viewpoints affecting the mental models people have at different levels. Figure 10: Actors Mental Models (Senge 1990) shows the relationship between management level in the organization and mental models. These mental pictures of how the world works have a significant influence on how these

different actors perceive problems and opportunities, identify courses of action, and make choices.

Figure 10: Actors Mental Models (Adapted from Senge 1990)



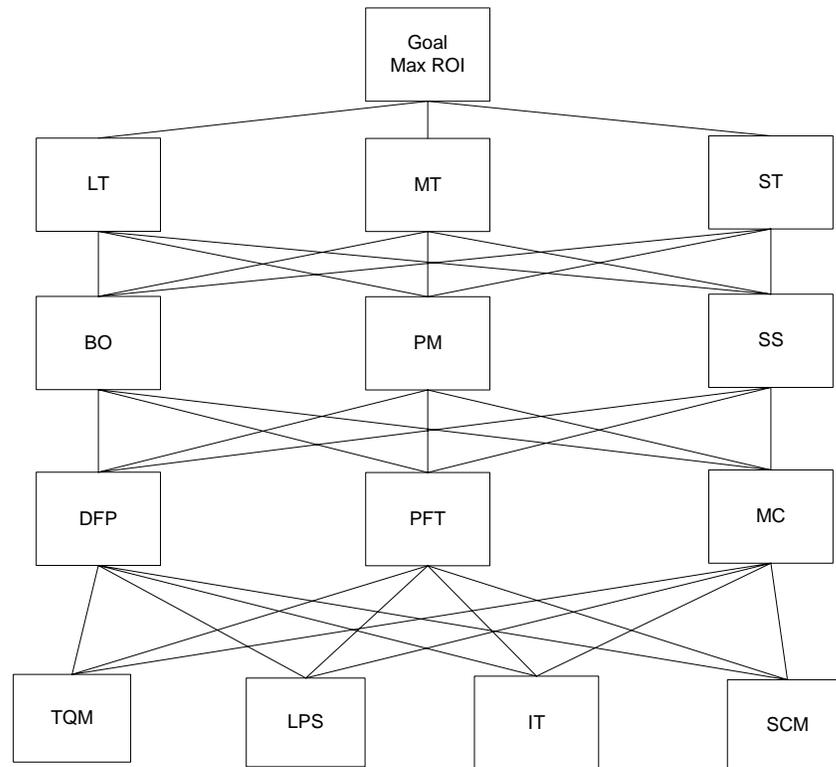
The fourth level of the hierarchy deals with objectives of the system. General objectives for a manufacturing system include defect free production (DFP), predictable flow times (PFT) and minimized costs (MC). This hierarchy is generic and consists of managerial parameters that are strategically valuable to many companies.

The means to achieve these objectives is the next question to be addressed. The literature review in chapter 2 suggests four general areas of strategic development:

1. Total Quality Management (TQM)
2. Lean Production Systems (LPS)
3. Information Technology (IT)
4. Supplier/Supply Chain Management (SCM)

These are added to the previous AHP hierarchy. The resulting structure is shown Figure 11.

Figure 11: 5-Level Hierarchy



The hierarchy is still incomplete, however. To make informed judgments about the effects TQM, LPS, IT, and SCM will have on the DFP, PFT, and MC performance objectives and ultimately on ROI, another layer of detail is required. The objectives must first be defined in terms of the functional requirements to meet the objectives. This will be demonstrated by focusing on TQM and LPS.

The Massachusetts Institute of Technology Production System Design Laboratory (Cochran 2000) has developed a manufacturing system design decomposition that hierarchically decomposes functional requirements and design parameters. A subset of the elements of this decomposition is used in the decision hierarchy. These elements include:

Defect free production

1. Reduce defects from machines (FR1)
2. Reduce defects from methods (FR2)

3. Reduce defects from people (FR3)
4. Reduce defects from materials (FR4)

#### Predictable flow times

1. Produce to customer demand (FR5)
2. Minimize production disruption (FR6)
3. Factory arrangement facilitates flow (FR7)
4. Ensure availability of relevant production information (FR8)
5. Ensure predictability of worker and equipment output (FR9)
6. Ensure material availability (FR10)

#### Minimize Cost

1. Reduce facility expense (FR11)
2. Reduce inventory costs (FR12)
3. Reduce waste in direct labor (FR13)
4. Reduce waste in indirect labor (FR14)

Adding these elements to the AHP decision model while maintaining the focus on TQM and LPS results in the hierarchy shown in Figure 12: 6-Level Hierarchy. This hierarchy is almost complete enough to be used to calculate a priority vector. The priority vector indicates which alternative strategy is the focus for strategic direction. Once this direction is taken, the next set of activities involves planning and implementing the physical part of the system that delivers the functional requirements. These physical parts of the system are described in terms of system design parameters.

Functional requirements are the means to achieve the business objectives and system design parameters are the means to achieve the functional requirements (Cochran, Eversheim, Kubin, and Sesterhenn, 2000). What you see when you enter a facility are the design parameters or the physical implementation of the functional requirements of the production system. Once again, referring to the Massachusetts Institute of Technology Production System Design Laboratory manufacturing system design decomposition, a set of design parameters are identified for the two alternative strategies in the current AHP hierarchy. These are listed in Table 6: Design Parameters for Strategic Alternatives. This

information is useful in determining weights for lower level elements during the AHP process. Table 7: AHP Hierarchy displays the full AHP hierarchy in tabular format.

Figure 12: 6-Level Hierarchy

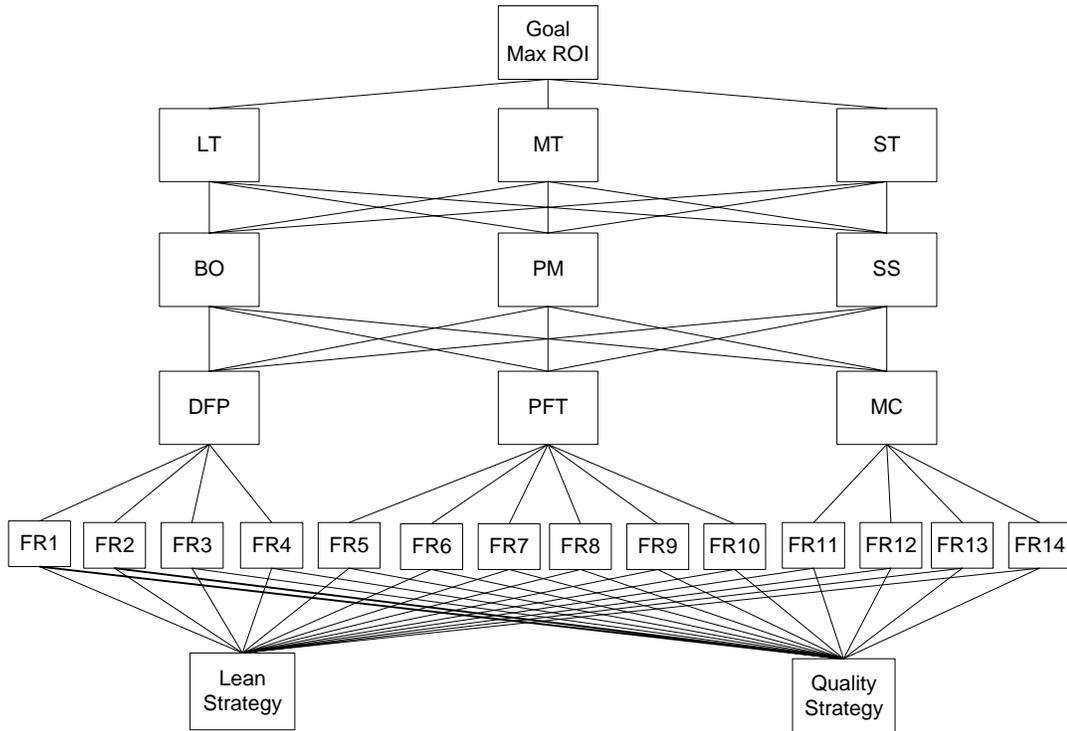


Table 6: Design Parameters for Strategic Alternatives

Strategy	Design parameters
Quality	<ol style="list-style-type: none"> <li>1. Implement Statistical Process control at all work centers</li> <li>2. Mistake proof operations (poke-yoke)</li> <li>3. Implement Total Preventive Maintenance</li> <li>4. Implement supplier excellence program</li> <li>5. Standardize work methods</li> </ol>
Lean	<ol style="list-style-type: none"> <li>1. Arrange factory in flow lines</li> <li>2. Standardize material replenishment system (Kanban, supermarkets)</li> <li>3. Implement visual controls</li> <li>4. Implement self managed work teams (horizontal organization structure)</li> <li>5. Throughput based on takt time</li> </ol>

Table 7: AHP Hierarchy

Level 1 Goal: Design manufacturing system to maximize long term return on investment				
Level 2: Planning horizon	Level 3: Key decision makers	Level 4 Objectives	Level 5 Functional requirements	Level 6 Alternatives
Long term (LT)	Business owner (BO)	Defect Free production (DFP)	<ol style="list-style-type: none"> <li>1. Reduce defects from machines (FR1)</li> <li>2. Reduce defects from methods (FR2)</li> <li>3. Reduce defects from people (FR3)</li> <li>4. Reduce defects from materials (FR4)</li> </ol>	<u>Implement Quality strategy</u> <ol style="list-style-type: none"> <li>1. Implement Statistical Process control at all work centers</li> <li>2. Mistake proof operations (poke-yoke)</li> <li>3. Implement Total Preventive Maintenance</li> <li>4. Implement supplier excellence program</li> <li>5. Standardize work methods</li> </ol> <u>Implement Lean Strategy</u> <ol style="list-style-type: none"> <li>1. Arrange Factory in flow lines</li> <li>2. Standardize material replenishment system (Kanban, supermarkets)</li> <li>3. Implement visual controls</li> <li>4. Implement self managed work teams (horizontal organization structure)</li> <li>5. Throughput based on takt time</li> </ol>
Medium term (MT)	Plant Manager (PM)	Predictable, reliable and minimized flow times (PFT)	<ol style="list-style-type: none"> <li>1. Produce to customer demand (FR5)</li> <li>2. Minimize production disruption (FR6)</li> <li>3. Factory arrangement facilitates flow (FR7)</li> <li>4. Ensure availability for relevant production information (FR8)</li> <li>5. Ensure predictability of worker and equipment output (FR9)</li> <li>6. Ensure material availability (FR10)</li> </ol>	
Short term (ST)	Shop supervision (SS)	Minimize operating costs (MC)	<ol style="list-style-type: none"> <li>1. Reduce facility expense (FR11)</li> <li>2. Reduce inventory costs (FR12)</li> <li>3. Reduce waste in direct labor (FR13)</li> <li>4. Reduce waste in indirect labor (FR14)</li> </ol>	

### Illustrative Example of AHP Implementation

AHP is a decision process that prioritizes improvement alternatives differently under different business circumstances. This is due to the assumptions and rationale planners bring forth when making judgments on the relative importance of the factor in the decision hierarchy, based on their business circumstance. This is demonstrated through descriptions of a possible set of assumptions and rationale for each hierarchical level under different business circumstances. The assumptions and rationale for each business circumstance are referred to as business scenarios. Each business scenario is followed by the results of applying the AHP procedure. Four business scenarios are used to test and demonstrate the AHP procedure:

- 1) Poor quality and poor on time delivery performance
- 2) Good quality and poor on time delivery performance
- 3) Poor quality and good on time delivery performance
- 4) Good quality and good on time delivery performance

These scenarios provide the context for judgments when weighting elements in the comparison matrices at each level of the hierarchy. Excel spreadsheets were used to implement the mathematics of the AHP hierarchy shown in Figure 12: 6-Level Hierarchy.

#### Scenario 1 Assumptions: Poor Quality and Poor on Time Delivery Performance

Importance of planning horizon with respect to the goal: The focus on the planning horizon is short term. Immediate correction is required or the business enterprise may not have enough customers or cash flow to continue operating.

Importance of actors with respect to planning horizon: The comparison matrix at this level of the hierarchy is somewhat independent of the business scenario. The role actors' play, within the enterprise organization structure, to a great extent determines their planning horizon orientation (Senge 1990). Authority and accountability issues along with knowledge, skill and abilities orient the business owner to long term planning,

the plant manager to medium term planning and the shop supervisor to short term planning. However, under the current business situation the intervals of the planning are compressed to the short term. Short term planning is measured in hours and days, medium term planning is measured in weeks and months, and long term planning is less than a year.

Importance of objectives with respect to actors: Under the current business circumstances each actor would recognize the importance of meeting customer’s needs for defect free production and predictable flow times over minimized cost. Under these circumstances the business enterprise is concerned with correcting problems in the short term. The matrix for prioritizing planning horizon preferences when considering maximizing return on investment is shown in Table 8: Importance of Planning Horizon with Respect to Maximizing Return on Investment.

The eigenvector calculated from the comparison matrix shows that Long Term (LT) planning has a priority of 0.110; Medium Term (MT) planning has a priority of 0.309; and Short Term (ST) planning has a priority of 0.581. The Consistency Ratio (CR) is well below the 0.100 value required by the AHP procedure indicating acceptable consistency of judgment in the matrix. The eigenvector indicates that under the current business context short term planning is of highest priority.

The next step is to integrate these priorities into a comparison matrix at the next level of the hierarchy. Table 9 shows the importance of actors with respect to planning horizon.

Table 8: Importance of Planning Horizon with Respect to Maximizing Return on Investment

Long Term (LT)					
Medium Term (MT)					
Short Term (ST)					
	LT	MT	ST	EgVec	CR
LT	1	1/3	1/5	0.110	0.003
MT	3	1	1/2	0.309	
ST	5	2	1	0.581	

Table 9: Importance of Actors with Respect to Planning Horizon

Business Owner (BO)							
Plant Manger (PM)							
Shop Supervisor (SS)							
LT	0.110						
	BO	PM	SS	EgVec	CR	LT*EV	
BO	1	5	7	0.738	0.012	0.081	
PM	0.200	1	2	0.168		0.018	
SS	0.143	0.500	1	0.094		0.010	
							<b>Global importance of actors</b>
MT	0.309						BO <b>0.333</b>
	BO	PM	SS	EgVec	CR	MT*EV	PM <b>0.319</b>
BO	1	1	3	0.443	0.016	0.137	SS <b>0.348</b>
PM	1	1	2	0.387		0.12	
SS	0.333	0.500	1	0.170		0.053	
ST	0.581						
	BO	PM	SS	EgVec	CR	ST*EV	
BO	1	0.500	0.5	0.198	0.046	0.115	
PM	2	1	0.5	0.312		0.181	
SS	2	2	1	0.490		0.285	

There are three comparison matrices shown in Table 9: Importance of Actors with Respect to Planning Horizon. The first shows the importance of actors when considering Long Term (LT) Planning; the second the importance of actors when considering Medium Term (MT) Planning; and the third shows the importance of actors when considering Short Term (ST) Planning.

The resulting eigenvector when considering Long Term planning indicates that the Business Owner (BO) has a priority of 0.738, the Plant Manager (PM) has a priority of 0.168 and the Shop Supervisor (SS) has a priority of .094. The Consistency Ratio (CR) is below the 0.100 value required by the AHP procedure indicating acceptable level of consistency of judgment in the matrix. These values are multiplied by the 0.11 (the LT priority derived from the higher level comparison matrix) to produce a new vector. The resulting vector values, listed in the column heading LT\*EV, are 0.081 for BO, 0.018 for PM and 0.01 for SS.

The above procedure is repeated for Medium Term (MT) and Short Term (ST) planning and the resulting vectors are shown in Table 9: Importance of Actors with Respect to Planning Horizon. To calculate the priority vector for this level of the hierarchy the vector rows are summed between the three comparison matrices. That is, the value of the BO row for the LT matrix (0.081) is added to the value of the BO for the MT matrix (0.137) that is added to the value BO for the ST matrix (0.115) that result in a final priority of BO of 0.333. This summing procedure is repeated to the PM and SS rows and produces the vector values under the column heading - "Global importance of actors." The result of the comparison matrix at this level of the hierarchy indicates that the actors are approximately of equal importance in solving the problems under the current scenario. These values are carried to the next level of the hierarchy. Table 10: Importance of Objectives with Respect to Actors shows the matrix calculations for importance of objectives with respect to actors.

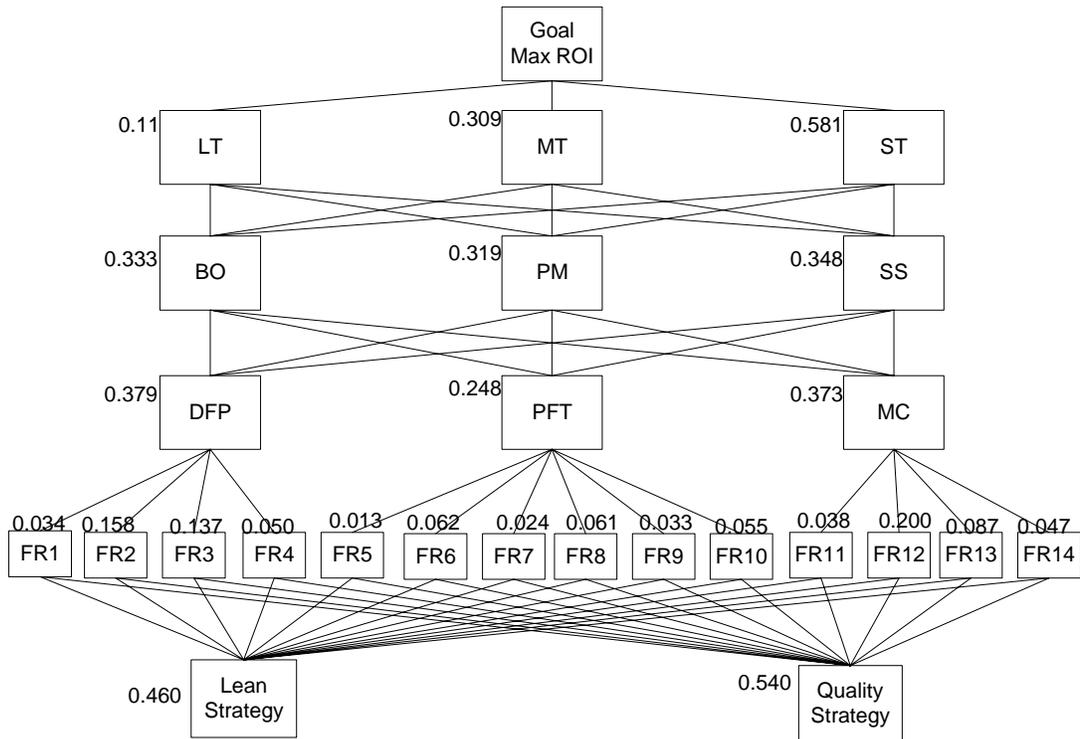
The calculation procedure is the same as that used to calculate the values in: Importance of Actors with Respect to Planning Horizon. The result of the calculation at this level of the AHP hierarchy indicates that the relative global importance of Defect Free Production (DFP) is 0.380, the relative global importance of Predictable Flow Time (PFT) is 0.248 and the relative global importance of Minimized Cost (MC) is 0.373.

The calculation procedure progresses down the hierarchy until the bottom level is reached. For this scenario the relative priority values are displayed in Figure 13: Priority Values for AHP Hierarchy for Scenario 1. A complete set of calculation tables for the various scenarios can be found in Appendix A. The result of the AHP procedure of this scenario is that the two alternatives are approximately equal in priority with the Quality Strategy being only slightly preferred.

Table 10: Importance of Objectives with Respect to Actors

BO	0.333								
	DFP	PFT	MC	EgVec	CR	BO*EV			
DFP	1	3	0.333	0.272	0.064	0.0905			
PFT	0.333	1	0.25	0.12		0.0399			
MC	3	4	1	0.608		0.2022			
									Global importance of objectives
PM	0.319						DFP	0.380	
	DFP	PFT	MC	EgVec	CR	PM*EV	PFT	0.248	
DFP	1	0.5	0.5	0.2	4E-16	0.0639	MC	0.373	
PFT	2	1	1	0.4		0.1278			
MC	2	1	1	0.4		0.1278			
	5	2.5	2.5						
SS	0.348								
	DFP	PFT	MC	EgVec	CR	SS*EV			
DFP	1	3	5	0.648	0.003	0.2255			
PFT	0.333	1	2	0.23		0.0800			
MC	0.2	0.5	1	0.122		0.0425			

Figure 13: Priority Values for AHP Hierarchy for Scenario 1



### Scenario 2 Assumptions: Good Quality and Poor on Time Delivery Performance

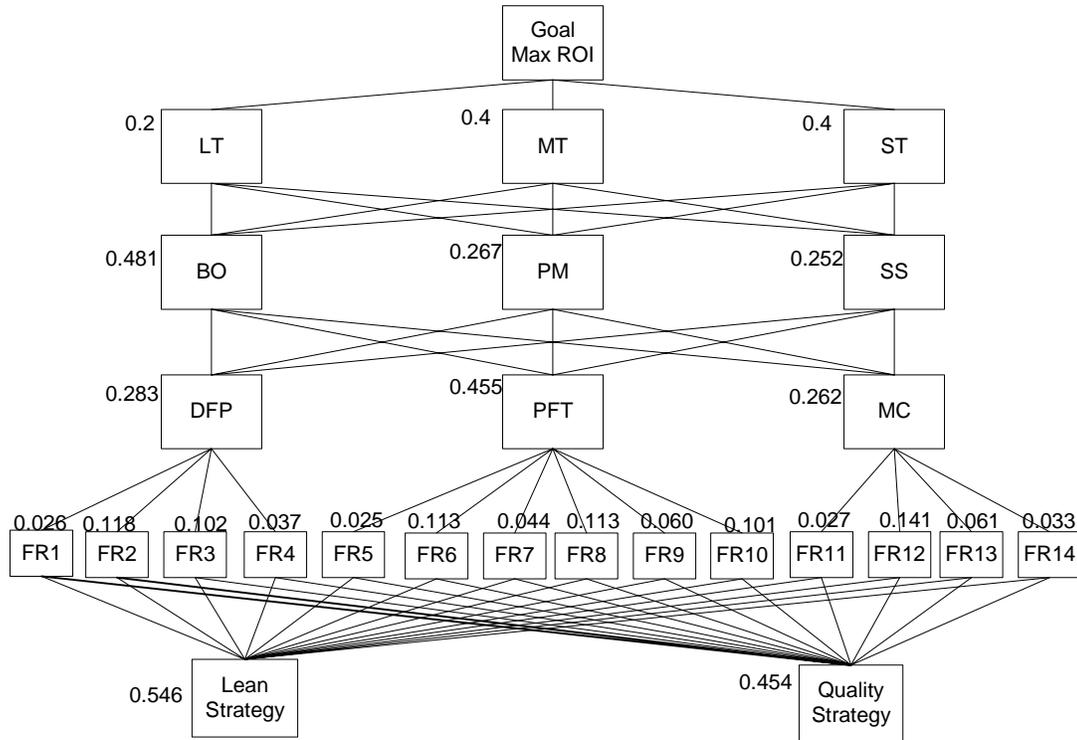
Importance of Planning Horizon with respect to the goal: The focus on the planning horizon is medium with short term being slightly more important than long term. Immediate correction is required to correct late delivery problems.

Importance of actors with respect to planning horizon: The role actors' play is causing the Business Owner (BO) to take on more importance as the focus of the planning horizon shifts. With product quality under control the BO is under less pressure to react to out of control conditions requiring their immediate attention and spend more time on strategic issues that require longer term planning. Under the current business situation the intervals of the planning are somewhat longer in interval. Short term planning is measured in days and weeks, medium term planning is measured in months to a year, and long term planning is more than a year.

Importance of objectives with respect to actors: Under the current business circumstance the Plant Manager (PM) is focused on correcting delivery problems and each actor would recognize the importance of improving the predictability of flow times over minimize cost and quality.

The results of the AHP procedure applied to this scenario are shown in Figure 14: Priority Values for AHP Hierarchy for Scenario 2. There is a shift in the outcome for each level of the hierarchy consistent with the assumptions for this scenario. Medium Term (MT) and Short Term (ST) planning are of equal importance and are more important than Long Term (LT) Planning. The importance of actors is shifted to the Business Owner (BO). The importance of objectives has shifted toward Predictable Flow Time (PFT). The result with respect to a choice of the alternatives has shifted toward the Lean Strategy.

Figure 14: Priority Values for AHP Hierarchy for Scenario 2



Scenario 3 Assumptions: Poor Quality and Good on Time Delivery Performance

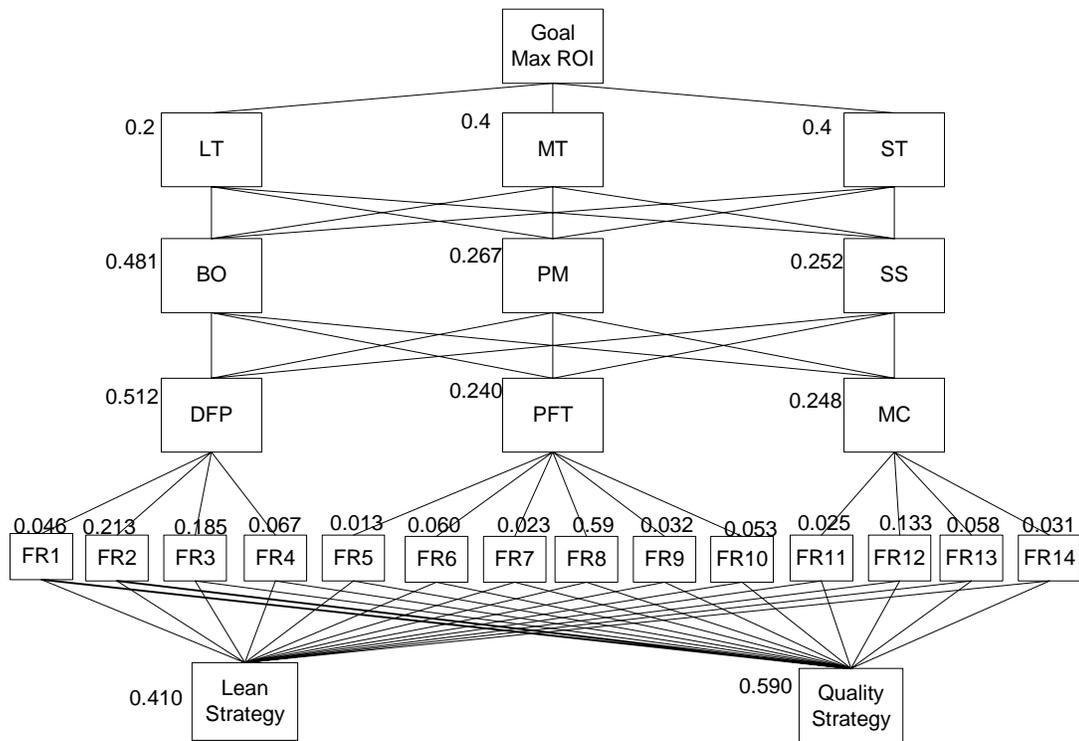
Importance of planning Horizon with respect to the goal: As with scenario 2, the focus on the planning horizon is medium and short term is slightly more important than long term. Immediate correction is required to correct poor quality problems.

Importance of actors with respect to planning horizon: The role actors' play is causing the Business Owner (BO) to take on more importance as the focus of the planning horizon shifts. However, under the current business situation the intervals of the planning are somewhat longer in interval. With product delivery performance under control the BO is under less pressure to react to out of control conditions requiring their immediate attention and spend more time on strategic issues that require longer term planning. Short term planning is measured in days and weeks, medium term planning is measured in months to a year, and long term planning is more than a year.

Importance of objectives with respect to actors: Under the current business circumstance the Plant Manager (PM) and Shop Supervisor (SS) would be focused on quality issues and each actor would recognize the importance of improving the quality over predictability of flow times and minimize cost.

The results of the AHP procedure applied to this scenario are shown in Figure 15: Priority Values for AHP Hierarchy for Scenario 3. As with scenario 2 there is a shift in the outcome for each level of the hierarchy consistent with the assumptions for this scenario. Medium Term (MT) and Short Term (ST) planning are of equal importance and are more important than Long Term (LT) Planning. The importance of actors is shifted to the Business Owner (BO). However, in this scenario the importance of objectives has shifted toward Defect Free Production (DFP). The result with respect to a choice of the alternatives has shifted toward the Quality Strategy.

Figure 15: Priority Values for AHP Hierarchy for Scenario 3



#### Assumptions Scenario 4: Good Quality and Good on Time Delivery Performance

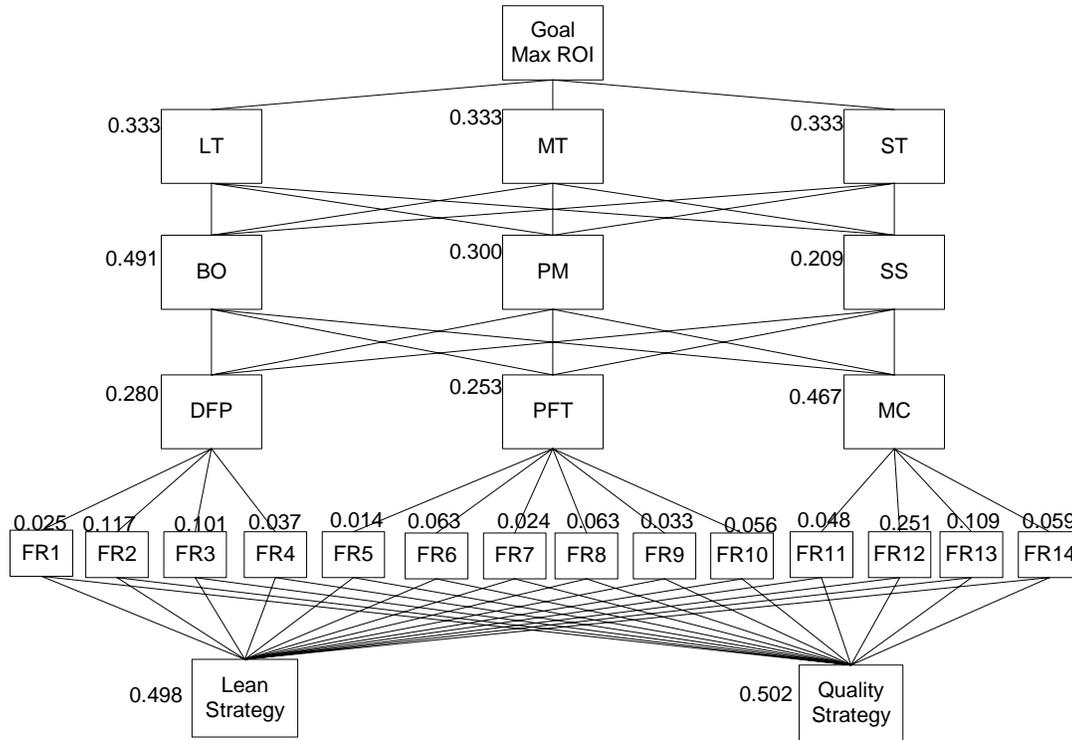
Importance of planning Horizon with respect to the goal: The focus on the planning horizon is on all three planning horizons. Short, medium and long term planning become equally important.

Importance of actors with respect to planning horizon: The role actors' play is following closer to the theoretical perspective shown in Figure 10: Actors Mental Models. However, under the current business situation the intervals of the planning are once again expanding. With overall performance under control the focus is on continuous improvements and innovation. Short term planning is measured in weeks and months, medium term planning is one to two years, and long term planning is more than two years.

Importance of objectives with respect to actors: Under the current business circumstance each actor would recognize the importance of minimizing cost.

The results of the AHP procedure applied to this scenario are shown in Figure 16: Priority Values for AHP Hierarchy for Scenario 4. As with the other scenarios there is a shift in the outcome for each level of the hierarchy consistent with the assumptions for this scenario. Long Term (LT), Medium Term (MT), and Short Term (ST) planning are of equal importance. The importance of actors is shifted ranking the Business Owner (BO) as having the greatest importance the Plant Manager (PM) as next important and the Shop Supervisor (SS) as least important. However, in this scenario the importance of objectives has shifted toward Minimize Cost (MC). The result with respect to a choice of the alternatives indicates that both alternatives are of equal importance with respect to the priority objective.

Figure 16: Priority Values for AHP Hierarchy for Scenario 4



Summary of the AHP Illustrative Application

With thoughtful and thorough research rational hierarchies appropriate for strategic alternative analysis using the analytic hierarchy process can be constructed. The four scenarios of this illustrative example demonstrate that the AHP method prioritizes alternative strategies differently under different business circumstances. In addition, a great deal of important and relevant data about the nature of the current business situation is generated during the consensus building process to weight the elements in the pair wise comparison process at each level of the hierarchy.

Planners can input the outcome of the AHP procedures into a project planning process to plan implementation of the selected strategic alternatives. The data is organized into a project statement of work and a communication plan, which is the rationale behind improvement projects. The communication plan is important in order to build commitment to implement project plans and achieve business benefit.

### Statement of Work (SOW) for Improvement Strategy

The statement of work (SOW) format developed here is to provide a logical integration between objectives, purpose, and activities. The SOW is developed in parallel with the collaboration to conduct the pair wise comparison in the AHP procedure. Notes are taken during the discussions of the pair wise comparison to document the assumptions, intent, and rationale for the element weightings. The data from the documentation process are organized into the following structure.

1. Objective: (What is the higher level effect?)
2. Action: (What to do?)
3. Purpose: (Why do it?)
4. Work to be performed: (How do I do it?)
5. Constraints: (What are the resource limitations or other factors that will put limits of the work being done?)
6. Measurements: (How do I know I am doing a good job and that it is achieving the objectives?)

The following is the SOW for implementing the Quality and Lean Strategies based on previous research on quality and lean production system implementation.

#### SOW for Quality System Implementation Strategy

Objective: Defect free production and reduce operating expense

Action QS1:

Implement Statistical Process Control (SPC)

Purpose:

Reduce defects from methods and maintain predictable process output. Product conformance is currently assured by sample inspection. In the future product conformance will be assured through statistical process control.

Work to be performed:

1. Target improvement areas
2. Analyze procedure as a process
3. Identify part data collection requirements
4. Develop data management procedure
5. Update standard work documents
6. Train employees
7. Collect and analyze data
8. Maintain process control

Constraints:

Initial implementation cost not to exceed \$10,000. Additional expenditures must be justified through cost saving of SPC implementation. Employee training is to be less than 8 hours per employee.

Measurements:

Number of defects per “n” parts with an assignable cause  
Difference between process mean and target  
Variance of process output

Action QS2:

Mistake proof operations (implement poke-yoke)

Purpose:

Ensure operator errors are not translated into defects. Reduce defects from people and maintain predictable worker output. Quality assurance records indicate that many defects are being produced due to operator error. Poke-yoke practices will be incorporated into standard methods for all workstations.

Work to be performed:

1. Collect defect data
2. Identify errors
3. Develop error-proofed procedure
4. Update standard work documents

5. Train employees
6. Iterate through factory and implement for each work center
7. Conduct continuous mistake proofing

Constraints:

Initial implementation cost not to exceed \$10,000. Additional expenditures must be justified through cost saving of pole-yoke implementation. Employee training is to be less than 8 hours per employee.

Measurements:

Number of defects caused by human errors

Action QS3:

Implement Total Preventive Maintenance (TPM) procedures

Purpose:

Reduce defect from machines and maintain equipment reliability and ensure predictable equipment output. Equipment and tool failure have been a major contributor to production disruption and non-conforming product

Work to be performed:

1. Target improvement areas
2. Develop maintenance procedure
3. Develop data management procedure
4. Update standard work documents
5. Train employees
6. Conduct TPM process
7. Iterate through factory until all work areas are implemented

Constraints:

Initial implementation cost not to exceed \$10,000. Additional expenditures must be justified through cost saving of TMP

implementation. Employee training is to be less than 8 hours per employee.

Measurements:

Frequency and duration of unplanned equipment service

Action QS4:

Implement supplier relationship program

Purpose:

Reduce defects for incoming materials and eliminate disruption due to supplier. Purchasing orders are released base on master schedule, managed through conventional purchasing contracts, and are lacking requirements to support quality standards and lean production. Suppliers will be treated as production partners and purchasing contract will incorporate total quality management and lean production requirements

Work to be performed:

1. Use production data to target problem areas
2. Select supplier for participation in new program
3. Develop new procedures and contract requirements with supplier
4. Iterate until all major suppliers are incorporated into program

Constraints:

Initial implementation cost not to exceed \$20,000. Additional expenditures must be justified through cost saving of supplier relationship program implementation.

Measurements:

Number of defects assigned to incoming material quality  
Delay due to late supplier delivery

Action QS5:

Standardize work methods

Purpose:

Assure operator consistently performs task correctly. In the past work practices have evolved and have been maintained by the experience of leads and supervisors. No standard work methods have been documented. As a consequence, different production personnel to accomplish the same task have used different work methods. In the future all workstations will have standard work methods. These are work methods that, by design, achieve reliable repeatable performance and that everyone is expected to use.

Work to be performed:

1. Analyze procedure as a process which includes documenting inputs, processing, outputs, controls, mechanisms and calls
2. Develop work center layouts
3. Determine standard/cycle times
4. Document work instructions and personnel assignment
5. Incorporate health and safety procedures
6. Train employees in standard methods

Constraints:

Initial implementation cost not to exceed \$15,000. Additional expenditures must be justified through cost saving of standardized implementation. Employee training is to be less than 8 hours per employee.

Measurements:

Defect due to non-standard methods  
Variance in task completion time

### SOW for Lean Production Implementation Strategy

Objective: Predictable, reliable and minimized flow-times and reduced operating expense

Action LS1:

Arrange factory into flow lines to facilitate material flow

Purpose:

Reduce transportation delay. The factory is currently in a functional layout. All similar processing equipment (lathes, mills, welding, etc.) is grouped in departments. In the future layout the processing equipment will be arranged into a chain of processing centers that will build up products as the materials are passed down the flow line.

Work to be performed:

1. Construct current state value stream map
2. Construct future state value stream map
3. Plan and conduct kaizan events
4. Assign and locate equipment into work centers
5. Update standard work documentation
6. Train employees

Constraints:

Implementation cost not to exceed \$35,000. Initial work is to be completed over holiday break.

Measurements:

Flow time variability associated with transportation delay

Inventory cost

Indirect labor cost

Action LS2:

Standardize material replenishment system (Kanban, supermarkets)

Purpose:

Assure material availability with minimum inventory level. Currently there is a central inventory center managing and controlling inventory distribution throughout the factory. This requires production personnel to go to the inventory center to get the materials to fill an order. In the future

material will be delivered to the point of use based on demand tracked by Kanban signals.

Work to be performed:

1. Construct current state value stream map
2. Construct future state value stream map
3. Plan and conduct kaizan events
4. Construct point of use store area
5. Update standard work documents
6. Train employees

Constraints:

Implementation cost not to exceed \$15,000

Measurements:

Delay due to material shortage

Inventory holding costs

Action LS3:

Implement visual controls

Purpose:

Reduce labor required to schedule system and ensure coordination of production activities and availability of relevant production information to support a procedure to detect and rapidly respond to production disruption. Currently production control schedules work and controls inventory flow through the release of production orders. In the future, a customer order will trigger a production order and Kanban signal will control inventory flow. Currently if a production disruption occurs (e.g. defects, non-conforming materials, planning errors, drawing errors, equipment or tool failure etc.) the problem is documented and the document is used to call appropriate production support personnel. In the future, workstation personnel will turn on different colored lights when a problem occurs that

will act as a call signal for appropriate production support personnel. Turning on the light will also start a timer. Production support personnel will turn off the light when they arrive at the workstation and the response time will be recorded.

Work to be performed:

1. Construct current state value stream map
2. Construct future state value stream map
3. Plan and conduct kaizan events
4. Implement Kanban material control
5. Implement andon light for shop floor support
6. Update standard work documents
7. Train employees

Constraints:

Implementation cost not to exceed \$5,000

Measurements:

Indirect labor cost to schedule and coordinate production activity

Action LS4:

Implement self-managed work teams (horizontal organization structure)

Purpose:

Reduce indirect labor cost and improve effectiveness of production managers. The current management structure is organized into functional departments. The new management structure will be based on shared performance and customer supplier relationship along the line of site production.

Work to be performed:

1. Align shop supervision to line of site process
2. Develop team management training
  - i. Performance management measurements
  - ii. Scheduling / personnel assignment procedures

iii. 5S practices

3. Train work team in management procedures

Constraints:

Implementation cost not to exceed \$15,000

Measurements:

Amount of indirect labor to manage system

Action LS5:

Implement procedures to establish takt time based on customer demand

Purpose:

Establish pace of factory production. Production control constructs a master schedule and plans order release. Production rate is adjusted according to capacity constraints. Production rate will be adjusted to a takt time base on customer demand.

Work to be performed:

1. Develop procedure to establish takt times based on customer demand
2. Adjust production resources to synchronize work center cycle time to takt time balancing work processing time for each work station (arrival time = processing time)
3. Establish implementation schedule
4. Update standard work documentation
5. Train employees

Constraints:

Implementation cost not to exceed \$15,000

Measurements:

Difference between mean throughput time and expected customer lead-time

Cost and frequency of takt time adjustments

Time to adjust pitch across factory

The SOW for the quality and lean production system strategies show the level of detailed data required for proper project planning. These written statements provide the scope of various action, resource guidelines, and criteria to determine if the SOW action has been successfully completed. The next step is to logically group and sequenced the actions so that a workable project plan can be scheduled and resource loaded. This information is necessary to monitor project execution and determine corrective action in order to meet project plan requirements. This is accomplished through DSM.

### Illustrative Example of DSM Implementation

The implementation of activity-based DSM involves two steps: first, the decomposition of strategic direction into activities; and second, the integration of the activities into an implementation plan. The first step was accomplished when the data collected during the AHP process was organized into the SOW for different strategic alternatives. The following is the procedure for integration of the activities into an implementation plan.

#### The DSM Procedure

The first step of the DSM procedure is to enter the SOW actions into the rows of the matrix. Next, the action outputs/inputs are identified and the appropriate cells are marked with an “X”. The actions from the SOW are organized into a matrix as shown in Table 11: DSM matrix of SOW Actions for Quality and Lean strategies. The rationale behind the entries in the matrix is listed in Table 12: Rationale for Matrix Entries.

The next step is to partition the matrix. The partitioning algorithm begins by looking for empty rows and columns. Observe that in Table 11: DSM matrixes of SOW Actions for Quality and Lean Strategies, there are no empty columns. However, row three is an empty row. Because this action does not receive any inputs from any other action it can be moved to the top row and removed from further consideration. The new matrix is shown in Table 13: DMS Partitioning Algorithm Step 1.

Table 11: DSM matrix of SOW Actions for Quality and Lean Strategies

SOW Actions		1	2	3	4	5	6	7	8	9	10
Implement Statistical Process Control (SPC) at all work centers	1		X								
Mistake proof operations (poke-yoke)	2	X									
Implement Total Preventive Maintenance (TPM)	3										
Implement supplier excellence program	4							X			
Standardize work methods	5	X	X	X			X	X			
Arrange factory in flow lines	6					X					
Standardize material replenishment system	7				X	X	X		X		
Implement visual controls	8	X		X				X			
Implement self managed work teams	9	X	X			X	X				X
Implement throughput based on takt time	10				X		X			X	

Table 12: Rationale for Matrix Entries

Row, Column	Comment
2,1	Data from SPC provides input to Poke-Yoke
5,1	SPC is part of Standard work methods
8,1	SPC charts are a visual control
9,1	SPC provides data for self management
1,2	Poke-Yoke addresses assignable causes
5,2	Poke-Yoke updates of Standard work methods
9,2	Poke-Yoke is a Team management practice
5,3	TPM is part of standard methods
8,3	TPM requires visual control trigger
7,4	Supplier provide point of use delivery
10,4	Supplier adjust delivery to takt time
6,5	Standard times for standard work methods are balanced for factory flow
7,5	Standard methods define replenishment procedure
9,5	Standard methods define policies and procedures for self management
5,6	Factory flow define boundaries of work centers and standard work content
7,6	Factory flow define boundaries of work centers and points of material storage
9,6	Flow line define work cell boundaries and work team customer/supplier relationships
10,6	Flow line define work centers and point of flow time balance
4,7	Replenishment procedure define supplier requirements
5,7	Replenishment procedure provide content for standard work
8,7	Standard material replenishment system defines visual control
7,8	Material replenishment uses visual control
10,9	Takt time is a performance measure to work teams
9,10	Self managed work teams adjust resources to achieve takt time

Table 13: DMS Partitioning Algorithm Step 1

SOW Actions		3	1	2	4	5	6	7	8	9	10
Implement Total Preventive Maintenance (TPM)	3										
Implement Statistical Process Control (SPC) at all work centers	1			X							
Mistake proof operations (poke-yoke)	2		X								
Implement supplier excellence program	4							X			
Standardize work methods	5	X	X	X			X	X			
Factory arrange in flow lines	6					X					
Standardize material replenishment system	7				X	X	X		X		
Implement visual controls	8	X	X					X			
Implement self managed work teams	9		X	X		X	X				X
Implement throughput based on takt time	10				X		X			X	

Since no additional empty rows or columns remain, the next step is to examine loops, starting at the next task. The relationship between the action “Implement Statistical Process Control (SPC) at all work centers” and the action “Mistake proof operations (poke-yoke)” is a loop. Therefore, these tasks are combined and placed in row 2 as shown in Table 14: DMS Partitioning Algorithm Step 2.

Table 14: DMS Partitioning Algorithm Step 2

SOW Actions		3	2-1	4	5	6	7	8	9	10
Implement Total Preventive Maintenance (TPM)	3									
(SPC)/poke-yoke	2-1									
Implement supplier excellence program	4						X			
Standardize work methods	5	X	X			X	X			
Factory arrange in flow lines	6				X					
Standardize material replenishment system	7			X	X	X		X		
Implement visual controls	8	X	X				X			
Implement self managed work teams	9		X		X	X				X
Implement throughput based on takt time	10			X		X			X	

Next, by examination, it appears that Table 14: DMS Partitioning Algorithm Step 2 contains following looping relationships:

1. Implement supplier excellence program and Standardize material replenishment system loop
2. Standardize work methods and Factory arrange in flow lines loop

3. Standardize work methods and Standardize material replenishment system loop
4. Standardize material replenishment system depends on Implement visual controls

These tasks are combined, placed in the third, row and removed from further consideration. The result is shown in Table 15: DMS Partitioning Algorithm Step 3.

Table 15: DMS Partitioning Algorithm Step 3

SOW Actions		3	2-1	8-7-6-5-4	9	10
Implement Total Preventive Maintenance (TPM)	3					
(SPC)/poke-yoke	2-1					
Combined actions	8-7-6-5-4					
Implement self managed work teams	9	X				X
Implement throughput based on takt time	10			X	X	

The final partition shown in Table 16: Final Partitioned Matrix, is made by observing that Implement self managed work teams and Implement throughput based on takt time loop and can be combined. The clustering algorithm has organized the actions from the SOW into three blocks and one independent task. These blocks provide the basis for partitioning the SOW for assignment to different action teams. The work breakdown structure is shown in Table 17: Work Breakdown Structure for Strategy Implementation.

Table 16: Final Partitioned Matrix

SOW Actions		3	1	2	4	5	6	7	8	9	10
Implement Total Preventive Maintenance (TPM)	3										
Implement Statistical Process Control (SPC)at all work centers	1		X								
Mistake proof operations (poke-yoke)	2		X								
Implement supplier excellence program	4							X			
Standardize work methods	5	X	X	X			X	X			
Factory arrange in flow lines	6					X					
Standardize material replenishment system	7				X	X	X		X		
Implement visual controls	8	X	X					X			
Implement self managed work teams	9		X	X		X	X				X
Implement throughput based on takt time	10				X		X			X	

Table 17: Work Breakdown Structure for Strategy Implementation

Task ID	Task Name
1	Implement Total Preventive Maintenance (TPM)
2	Block1:
2.1	Implement Statistical Process Control (SPC) at all work centers
2.2	Mistake proof operations (poke-yoke)
3	Block2:
3.1	Implement supplier excellence program
3.2	Standardize work methods
3.2	Factory arrange in flow lines
3.4	Standardize material replenishment system
3.5	Implement visual controls
4	Block3:
4.1	Implement self managed work teams
4.2	Implement throughput based on takt time

These blocks of activities can be input into a project management software tool along with resource constraints defined in the SOW to begin the process of defining an integrated project for implementing strategic direction. A schedule can be developed, personnel assigned to task teams, and management review scheduled in order to control project implementation.

#### Summary of the DSM Illustrative Application

The data generated during the AHP process can be aggregated into various statements of work in order to capture the objectives, purpose, and activities associated with the requirements of the priority strategic alternatives. The statements of work can be integrated into an implementation project using DSM.

The results of this DSM illustrative application show that the project consists of three blocks of actions and one independent task. The blocks and the task can be logically organized into a chronological sequence and scheduled for implementation. The business objective of Defect Free Production is affected by the design parameters associated with

the functional requirements of the quality strategy and are implemented with Block 1 and the independent task of implementing Total Productive Maintenance. The business objective of Predictable Flow Time is affected by the design parameters associated with the functional requirements of the lean strategy and are implemented in Block 2. The business objective of Minimize Cost is achieved through the direct and indirect labor savings associated with implementing Block 3 along with the expected cost savings resulting from the other activities in the project.

## CHAPTER 5

## SUMMARY AND RECOMMENDATIONS

Many organizations fail to achieve expected performance results when implementing business system improvements. A possible reason for the failure to achieve performance results despite management's desire and best efforts is that such organizations lack the knowledge, skill and appropriate planning practices for engaging and aligning the organization. The lack of appropriate knowledge, skills, and planning practices results in improvement plans that are not systemic and congruent. Such improvement plans do not comprehensively address performance issues and fail to build commitment for implementation.

Many management system engineering ideas and theories have evolved to help businesses grow and achieve their goals. Applying these ideas and theories to a business system is a strategic planning issue and results in a bewildering array of strategic alternatives for business system improvement. Choosing the appropriate alternatives is a very complex and difficult decision. Some of the challenges facing today's business planners include determining strategy and course of action, understanding and obtaining the skills and knowledge needed to lead the organization, developing results oriented action plans and soliciting organization member's cooperation and participation in plan execution.

The literature review explored some of the vast body of knowledge that can be used to support today's business planning. An insight from the literature review is that organizational learning practices are a cornerstone of a modern business planning system. Planning practices that apply organizational learning principles help develop plans that are not only technically feasible, but also overcome social and cultural obstructions. This body of knowledge provides insights about how to transform the organizational learning cycle into a formal planning system for designing and implementing improved business systems based on strategic intent.

This literature review also attempted to capture the more prominent theories and practices comprising the function, structure and processes of strategic management. The strategic management process was characterized as having three steps: building a shared vision, defining the system architecture, and planning system implementation. This information provides the foundation for structuring planning practices that characterize an organizational learning cycle. These planning practices articulate an organization's core ideology and beliefs, analyze the external and internal business environment, specify the design of the business architecture and infrastructure, and build commitment by embedding modern social engineering in appropriate organizational capability maturity and project management practices.

The objectives of this thesis were achieved through the proposed planning approach. Embedding organizational learning into a planning approach encourages reflection on shared attitudes, beliefs, and values that shape policies and assists business planners in building agreements about strategic direction. It also helps assure congruency by accounting for the formal and informal structures within the organization. Formal structures are implemented by integrating AHP, PMT, and DSM into a planning approach that provides a disciplined process to translate high-level goals and values into priorities for tactical business initiatives and to translate tactical priorities into a workable implementation plan. Informal arrangements and structure are taken into account through all the conversations taking place to negotiate the pair wise comparison during the AHP procedure.

Illustrative examples were used to demonstrate that with thoughtful and thorough research, rational hierarchies appropriate for strategic alternative analysis using AHP can be constructed and that the AHP method prioritizes alternative strategies differently under different business circumstances. In addition, it has been demonstrated that data generated by AHP can be aggregated into statements of work and input into a Design Structure Matrix to generate a project plan to implement organizational design changes and achieve strategic intent.

To achieve results when making organizational design change requires both a good plan supported by appropriate infrastructure and motivated people committed to

implementing the change and achieving the results. The planning approach developed in this research requires key actors at all levels to actively participate in a structured planning process. This is intended to invoke organizational learning practices (Senge 1990) and create a participative and collaborative planning environment that will build commitment to implementing the selected alternative. The outcome of applying this methodology is that it will simultaneously address technical and social/cultural issues that may be obstructions to successful implementation of organizational change associated with the strategic direction.

Although this planning approach has been developed using theories and business practices that have demonstrated business benefit and been documented in existing literature, there are some potential difficulties with the proposed planning approach. First, this planning approach is knowledge dense. That is, it requires someone who knows a great deal about organizational learning and modern business theory, principles and planning practices. If this knowledge is not present in the organization, the planning approach would have to be facilitated by someone with appropriate knowledge and skills. Second, the planning approach is detailed and time consuming. People may not have the patience to use it. This is particularly true if the organization is stressed because of poor current and/or past performance. Both of these issues also make it difficult to generate sponsorship to use the planning approach. The third issue is organizational readiness. This planning approach requires an appropriate cultural fit. This is a participative and collaborative method that probably would likely not work well in a punitive and autocratic cultural environment.

Further research is needed to test this planning approach. Several pilot studies should be conducted in a variety of different business environments to validate its utility. After gaining more experience with the planning approach, enhancements could be made to overcome some of the identified issues. Automating the data management associated with the planning approach would also be a focus of future work. In addition, the planning approach could be formalized using Capability Maturity Model methods. This would provide documentation to communicate the function, structure, and process of the planning approach and facilitate generating sponsorship.

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APPENDIX A: AHP MATRIX CALCULATIONS

Planning Scenario 1 - Importance of Planning Horizon with Respect to Maximizing Return on Investment

Importance of Planning Horizon with respect to maximizing return on Investment												
Long Term (LT)												
Medium Term (MT)												
Short Term (ST)												
	LT	MT	ST					EgVec				
LT	1	1/3	1/5	0.111	0.100	0.118	0.329	0.110	0.329	3.001	3.004	$\lambda_{\max}$
MT	3	1	1/2	0.333	0.300	0.294	0.927	0.309	0.929	3.004	0.002	CI
ST	5	2	1	0.556	0.600	0.588	1.744	0.581	1.747	3.006	0.003	CR
	9	3.3	1.7				3.000	1.000				



Planning Scenario 1 - Importance of Objectives with respect to Actors

Defect Free Productinos (DFP)															
Predictable Flow Time (PFT)															
Minimized Operating Cost (MC)															
<b>BO</b>	<b>0.333</b>														
	DFP	PFT	MC					EgVec							
DFP	1	3	1/3	0.231	0.375	0.211	0.816	0.272	0.835	3.067	3.074	$\lambda_{max}$	0.091		
PFT	0.333	1	1/4	0.077	0.125	0.158	0.360	0.120	0.363	3.023	0.037	CI	0.040		
MC	3	4	1	0.692	0.500	0.632	1.824	0.608	1.904	3.132	0.064	CR	0.202		
	4.333	8	1.583				3.000	1.000							
<b>PM</b>	<b>0.319</b>														
	DFP	PFT	MC					EgVec							
DFP	1	1/2	1/2	0.200	0.200	0.200	0.600	0.200	0.600	3.000	3.000	$\lambda_{max}$	0.064	DFP	0.380
PFT	2	1	1	0.400	0.400	0.400	1.200	0.400	1.200	3.000	0.000	CI	0.128	PFT	0.248
MC	2	1	1	0.400	0.400	0.400	1.200	0.400	1.200	3.000	0.000	CR	0.128	MC	0.373
	5	2.5	2.5				3.000	1.000							
<b>SS</b>	<b>0.348</b>														
	DFP	PFT	MC					EgVec							
DFP	1	3	5	0.652	0.667	0.625	1.944	0.648	1.948	3.007	3.004	$\lambda_{max}$	0.225		
PFT	0.333	1	2	0.217	0.222	0.250	0.690	0.230	0.690	3.003	0.002	CI	0.080		
MC	0.2	0.5	1	0.130	0.111	0.125	0.367	0.122	0.367	3.001	0.003	CR	0.043		
	1.533	4.5	8				3.000	1.000							

Global importance of objectives

Planning Scenario 1 - Importance of Functional Requirements with Defect Free Production

Reduce defects from machines (FR1)														
Reduce defects from methods (FR2)														
Reduce defects from people (FR3)														
Reduce defects from materials (FR4)														
DFP	0.380													
	FR1	FR2	FR3	FR4					EgVec					DFP*EgVec
FR1	1	1/3	1/5	1/2	0.091	0.154	0.058	0.059	0.090	4.064	4.199	$\lambda_{\max}$	0.034	
FR2	3	1	2	3	0.273	0.462	0.580	0.353	0.417	4.332			0.158	
FR3	5	1/2	1	4	0.455	0.231	0.290	0.471	0.361	4.282			0.137	
FR4	2	1/3	1/4	1	0.182	0.154	0.072	0.118	0.131	4.120	0.066	CI	0.050	
	11	2.17	3.45	8.5					1.000	CI	0.074	CR		

Planning Scenario 1 - Importance of Functional Requirements with respect to Predictable Flow Time

Produce to customer demand (FR5)																	
Minimize production disruption (FR6)																	
Factory arrangement facilitates flow (FR7)																	
Ensure availability of relevant production information (FR8)																	
Ensure predictability of worker and equipment output (FR9)																	
Ensure material availability (FR10)																	
PFT	0.248																
	FR5	FR6	FR7	FR8	FR9	FR10							EgVec				PFT*EgVec
FR5	1	1/4	1/3	1/4	1/2	1/3	0.059	0.061	0.029	0.055	0.056	0.067	0.054	6.440	6.432	$\lambda_{\max}$	0.013
FR6	4	1	3	2	1	1	0.235	0.245	0.265	0.436	0.111	0.200	0.249	6.446			0.062
FR7	3	1/3	1	1/2	1/2	1/3	0.176	0.082	0.088	0.109	0.056	0.067	0.096	6.291			0.024
FR8	4	1/2	2	1	3	2	0.235	0.122	0.176	0.218	0.333	0.400	0.248	6.541			0.061
FR9	2	1	2	1/3	1	1/3	0.118	0.245	0.176	0.073	0.111	0.067	0.132	6.368			0.033
FR10	3	1	3	1/2	3	1	0.176	0.245	0.265	0.109	0.333	0.200	0.221	6.507	0.086	CI	0.055
	17	4.083	11.33	4.583	9	5							1.000		0.070	CR	

Planning Scenario 1 - Importance of Functional Requirements with respect to Minimizing Operating Costs

Reduce facility expense (FR11)														
Reduce inventory costs (FR12)														
Reduce waste in direct labor (FR13)														
Reduce waste in indirect labor (FR14)														
MC	0.373													
	FR11	FR12	FR13	FR14					EgVec					DFP*EgVec
FR11	1	1/4	1/2	1/2	0.111	0.140	0.103	0.053	0.102	4.089	4.167	$\lambda_{\max}$		0.038
FR12	4	1	3	5	0.444	0.561	0.621	0.526	0.538	4.238				0.200
FR13	2	1/3	1	3	0.222	0.187	0.207	0.316	0.233	4.282				0.087
FR14	2	1/5	1/3	1	0.222	0.112	0.069	0.105	0.127	4.059	0.056	CI		0.047
	9	1.783	4.833	9.5					1.000		0.062	CR		





Planning Scenario 2 - Importance of Planning Horizon with Respect to Maximizing Return on Investment

Long Term (LT)												
Medium Term (MT)												
Short Term (ST)												
	LT	MT	ST					EgVec				
LT	1	1/2	1/2	0.200	0.200	0.200	0.600	0.200	0.600	3.000	3.000	$\lambda_{\max}$
MT	2	1	1	0.400	0.400	0.400	1.200	0.400	1.200	3.000	0.000	CI
ST	2	1	1	0.400	0.400	0.400	1.200	0.400	1.200	3.000	0.000	CR
	5	2.5	2.5				3.000	1.000				

Planning Scenario 2 - Importance of Actors with respect to Planning Horizon

Business Owner (BO)																				
Plant Manger (PM)																				
Shop Supervisor (SS)																				
LT	0.200																			
	BO	PM	SS					EgVec											LT*EgVec	
BO	1	5	7	0.745	0.769	0.700	2.214	0.738	2.237	3.031	3.014	$\lambda_{max}$	€	0.148						
PM	0.2	1	2	0.149	0.154	0.200	0.503	0.168	0.504	3.008	0.007	CI		0.034						
SS	0.143	0.5	1	0.106	0.077	0.100	0.283	0.094	0.284	3.004	0.012	CR		0.019						
	1.343	6.5	10				3.000	1.000												
MT	0.400																			
	BO	PM	SS					EgVec											MT*EgVec	Global importance of actors
BO	1	2	2	0.500	0.500	0.500	1.500	0.500	1.500	3.000	3.000	$\lambda_{max}$	€	0.200	BO				0.481	
PM	0.5	1	1	0.250	0.250	0.250	0.750	0.250	0.750	3.000	0.000	CI		0.100	PM				0.267	
SS	0.5	1	1	0.250	0.250	0.250	0.750	0.250	0.750	3.000	0.000	CR		0.100	SS				0.252	
	2	4	4				3.000	1.000												
ST	0.400																			
	BO	PM	SS					EgVec											ST*EgVec	
BO	1	1	1	0.333	0.333	0.333	1.000	0.333	1.000	3.000	3.000	$\lambda_{max}$	€	0.133						
PM	1	1	1	0.333	0.333	0.333	1.000	0.333	1.000	3.000	0.000	CI		0.133						
SS	1	1	1	0.333	0.333	0.333	1.000	0.333	1.000	3.000	0.000	CR		0.133						
	3	3	3				3.000	1.000												

Planning Scenario 2 - Importance of Objectives with respect to Actors

Defect Free Productinos (DFP)															
Predictable Flow Time (PFT)															
Minimized Operating Cost (MC)															
	DFP	PFT	MC					EgVec							
<b>BO</b>	<b>0.481</b>														
DFP	1	1/3	1/3	0.143	0.211	0.063	0.416	0.139	0.426	3.071	3.222	$\lambda_{max}$	0.067		
PFT	3	1	4	0.429	0.632	0.750	1.810	0.603	2.051	3.400	0.111	CI	0.290		
MC	3	0.25	1	0.429	0.158	0.188	0.774	0.258	0.825	3.197	0.192	CR	0.124		
	7	1.583	5.333				3.000	1.000							
<b>PM</b>	<b>0.267</b>														
	DFP	PFT	MC					EgVec							
DFP	1	1/2	1/2	0.200	0.200	0.200	0.600	0.200	0.600	3.000	3.000	$\lambda_{max}$	0.053	DFP	0.283
PFT	2	1	1	0.400	0.400	0.400	1.200	0.400	1.200	3.000	0.000	CI	0.107	PFT	0.455
MC	2	1	1	0.400	0.400	0.400	1.200	0.400	1.200	3.000	0.000	CR	0.107	MC	0.262
	5	2.5	2.5				3.000	1.000							
<b>SS</b>	<b>0.252</b>														
	DFP	PFT	MC					EgVec							
DFP	1	3	5	0.652	0.667	0.625	1.944	0.648	1.948	3.007	3.004	$\lambda_{max}$	0.163		
PFT	0.333	1	2	0.217	0.222	0.250	0.690	0.230	0.690	3.003	0.002	CI	0.058		
MC	0.2	0.5	1	0.130	0.111	0.125	0.367	0.122	0.367	3.001	0.003	CR	0.031		
	1.533	4.5	8				3.000	1.000							

Global importance of objectives

Planning Scenario 2 - Importance of Functional Requirements with Defect Free Production

Reduce defects from machines (FR1)														
Reduce defects from methods (FR2)														
Reduce defects from people (FR3)														
Reduce defects from materials (FR4)														
DFP	0.283													
	FR1	FR2	FR3	FR4					EgVec					DFP*EgVec
FR1	1	1/3	1/5	1/2	0.091	0.154	0.058	0.059	0.090	4.064	4.199	$\lambda_{\max}$	0.026	
FR2	3	1	2	3	0.273	0.462	0.580	0.353	0.417	4.332			0.118	
FR3	5	1/2	1	4	0.455	0.231	0.290	0.471	0.361	4.282			0.102	
FR4	2	1/3	1/4	1	0.182	0.154	0.072	0.118	0.131	4.120	0.066	CI	0.037	
	11	2.17	3.45	8.5					1.000	CI		0.074	CR	

Planning Scenario 2 - Importance of Functional Requirements with respect to Predictable Flow Time

Produce to customer demand (FR5)																	
Minimize production disruption (FR6)																	
Factory arrangement facilitates flow (FR7)																	
Ensure availability of relevant production information (FR8)																	
Ensure predictability of worker and equipment output (FR9)																	
Ensure material availability (FR10)																	
PFT	0.455																
	FR5	FR6	FR7	FR8	FR9	FR10							EgVec				PFT*EgVec
FR5	1	1/4	1/3	1/4	1/2	1/3	0.059	0.061	0.029	0.055	0.056	0.067	0.054	6.440	6.432	$\lambda_{\max}$	0.025
FR6	4	1	3	2	1	1	0.235	0.245	0.265	0.436	0.111	0.200	0.249	6.446			0.113
FR7	3	1/3	1	1/2	1/2	1/3	0.176	0.082	0.088	0.109	0.056	0.067	0.096	6.291			0.044
FR8	4	1/2	2	1	3	2	0.235	0.122	0.176	0.218	0.333	0.400	0.248	6.541			0.113
FR9	2	1	2	1/3	1	1/3	0.118	0.245	0.176	0.073	0.111	0.067	0.132	6.368			0.060
FR10	3	1	3	1/2	3	1	0.176	0.245	0.265	0.109	0.333	0.200	0.221	6.507	0.086	CI	0.101
	17	4.083	11.33	4.583	9	5							1.000		0.070	CR	

Planning Scenario 2 - Importance of Functional Requirements with respect to Minimizing Operating Costs

Reduce facility expense (FR11)													
Reduce inventory costs (FR12)													
Reduce waste in direct labor (FR13)													
Reduce waste in indirect labor (FR14)													
MC	0.262												
	FR11	FR12	FR13	FR14					EgVec				DFP*EgVec
FR11	1	1/4	1/2	1/2	0.111	0.140	0.103	0.053	0.102	4.089	4.167	$\lambda_{\max}$	0.027
FR12	4	1	3	5	0.444	0.561	0.621	0.526	0.538	4.238			0.141
FR13	2	1/3	1	3	0.222	0.187	0.207	0.316	0.233	4.282			0.061
FR14	2	1/5	1/3	1	0.222	0.112	0.069	0.105	0.127	4.059	0.056	CI	0.033
	9	1.783	4.833	9.5					1.000		0.062	CR	





Planning Scenario 3 - Importance of Planning Horizon with Respect to Maximizing Return on Investment

Long Term (LT)													
Medium Term (MT)													
Short Term (ST)													
	LT	MT	ST					EgVec					
LT	1	1/2	1/2	0.200	0.200	0.200	0.600	0.200	0.600	3.000	3.000	$\lambda_{\max}$	
MT	2	1	1	0.400	0.400	0.400	1.200	0.400	1.200	3.000	0.000	CI	
ST	2	1	1	0.400	0.400	0.400	1.200	0.400	1.200	3.000	0.000	CR	
	5	2.5	2.5				3.000	1.000					

Planning Scenario 3 - Importance of Actors with respect to Planning Horizon

Business Owner (BO)																				
Plant Manger (PM)																				
Shop Supervisor (SS)																				
LT	0.200																			
	BO	PM	SS					EgVec						LT*EgVec						
BO	1	5	7	0.745	0.769	0.700	2.214	0.738	2.237	3.031	3.014	$\lambda_{max}$	€	0.148						
PM	0.2	1	2	0.149	0.154	0.200	0.503	0.168	0.504	3.008	0.007	CI		0.034						
SS	0.143	0.5	1	0.106	0.077	0.100	0.283	0.094	0.284	3.004	0.012	CR		0.019						
	1.343	6.5	10				3.000	1.000												
MT	0.4																			
	BO	PM	SS					EgVec						MT*EgVec						
BO	1	2	2	0.500	0.500	0.500	1.500	0.500	1.500	3.000	3.000	$\lambda_{max}$	€	0.200	BO	0.481				
PM	0.5	1	1	0.250	0.250	0.250	0.750	0.250	0.750	3.000	0.000	CI		0.100	PM	0.267				
SS	0.5	1	1	0.250	0.250	0.250	0.750	0.250	0.750	3.000	0.000	CR		0.100	SS	0.252				
	2	4	4				3.000	1.000												
ST	0.4																			
	BO	PM	SS					EgVec						ST*EgVec						
BO	1	1	1	0.333	0.333	0.333	1.000	0.333	1.000	3.000	3.000	$\lambda_{max}$	€	0.133						
PM	1	1	1	0.333	0.333	0.333	1.000	0.333	1.000	3.000	0.000	CI		0.133						
SS	1	1	1	0.333	0.333	0.333	1.000	0.333	1.000	3.000	0.000	CR		0.133						
	3	3	3				3.000	1.000												

Planning Scenario 3 - Importance of Objectives with respect to Actors

Defect Free Productinos (DFP)															
Predictable Flow Time (PFT)															
Minimized Operating Cost (MC)															
<b>BO</b>	<b>0.481</b>														
	DFP	PFT	MC					EgVec							
DFP	1	2	2	0.500	0.500	0.500	1.500	0.500	1.500	3.000	3.000	$\lambda_{max}$	0.240		
PFT	0.5	1	1	0.250	0.250	0.250	0.750	0.250	0.750	3.000	0.000	CI	0.120		
MC	0.5	1	1	0.250	0.250	0.250	0.750	0.250	0.750	3.000	0.000	CR	0.120		
	2	4	4				3.000	1.000							
<b>PM</b>	<b>0.267</b>														
	DFP	PFT	MC					EgVec							
DFP	1	2	2	0.500	0.500	0.500	1.500	0.500	1.500	3.000	3.000	$\lambda_{max}$	0.133	DFP	0.512
PFT	0.5	1	1	0.250	0.250	0.250	0.750	0.250	0.750	3.000	0.000	CI	0.067	PFT	0.240
MC	0.5	1	1	0.250	0.250	0.250	0.750	0.250	0.750	3.000	0.000	CR	0.067	MC	0.248
	2	4	4				3.000	1.000							
<b>SS</b>	<b>0.252</b>														
	DFP	PFT	MC					EgVec							
DFP	1	3	2	0.545	0.600	0.500	1.645	0.548	1.662	3.030	3.018	$\lambda_{max}$	0.138		
PFT	0.333	1	1	0.182	0.200	0.250	0.632	0.211	0.634	3.012	0.009	CI	0.053		
MC	0.5	1	1	0.273	0.200	0.250	0.723	0.241	0.726	3.013	0.016	CR	0.061		
	1.833	5	4				3.000	1.000							

Global importance of objectives

Planning Scenario 3- Importance of Functional Requirements with Defect Free Production

Reduce defects from machines (FR1)														
Reduce defects from methods (FR2)														
Reduce defects from people (FR3)														
Reduce defects from materials (FR4)														
DFP	0.512													
	FR1	FR2	FR3	FR4					EgVec					DFP*EgVec
FR1	1	1/3	1/5	1/2	0.091	0.154	0.058	0.059	0.090	4.064	4.199	$\lambda_{max}$	0.046	
FR2	3	1	2	3	0.273	0.462	0.580	0.353	0.417	4.332			0.213	
FR3	5	1/2	1	4	0.455	0.231	0.290	0.471	0.361	4.282			0.185	
FR4	2	1/3	1/4	1	0.182	0.154	0.072	0.118	0.131	4.120	0.066	CI	0.067	
	11	2.17	3.45	8.5					1.000	CI	0.074	CR		

Planning Scenario 3 - Importance of Functional Requirements with respect to Predictable Flow Time

Produce to customer demand (FR5)																	
Minimize production disruption (FR6)																	
Factory arrangement facilitates flow (FR7)																	
Ensure availability of relevant production information (FR8)																	
Ensure predictability of worker and equipment output (FR9)																	
Ensure material availability (FR10)																	
PFT	0.240																
	FR5	FR6	FR7	FR8	FR9	FR10							EgVec				PFT*EgVec
FR5	1	1/4	1/3	1/4	1/2	1/3	0.059	0.061	0.029	0.055	0.056	0.067	0.054	6.440	6.432	$\lambda_{\max}$	0.013
FR6	4	1	3	2	1	1	0.235	0.245	0.265	0.436	0.111	0.200	0.249	6.446			0.060
FR7	3	1/3	1	1/2	1/2	1/3	0.176	0.082	0.088	0.109	0.056	0.067	0.096	6.291			0.023
FR8	4	1/2	2	1	3	2	0.235	0.122	0.176	0.218	0.333	0.400	0.248	6.541			0.059
FR9	2	1	2	1/3	1	1/3	0.118	0.245	0.176	0.073	0.111	0.067	0.132	6.368			0.032
FR10	3	1	3	1/2	3	1	0.176	0.245	0.265	0.109	0.333	0.200	0.221	6.507	0.086	CI	0.053
	17	4.083	11.33	4.583	9	5							1.000		0.070	CR	

Planning Scenario 3 - Importance of Functional Requirements with respect to Minimizing Operating Costs

Reduce facility expense (FR11)														
Reduce inventory costs (FR12)														
Reduce waste in direct labor (FR13)														
Reduce waste in indirect labor (FR14)														
MC	0.248													
	FR11	FR12	FR13	FR14					EgVec					DFP*EgVec
FR11	1	1/4	1/2	1/2	0.111	0.140	0.103	0.053	0.102	4.089	4.167	$\lambda_{\max}$		0.025
FR12	4	1	3	5	0.444	0.561	0.621	0.526	0.538	4.238				0.133
FR13	2	1/3	1	3	0.222	0.187	0.207	0.316	0.233	4.282				0.058
FR14	2	1/5	1/3	1	0.222	0.112	0.069	0.105	0.127	4.059	0.056	CI		0.031
	9	1.783	4.833	9.5					1.000		0.062	CR		





Planning Scenario 4 - Importance of Planning Horizon with Respect to Maximizing Return on Investment

Long Term (LT)													
Medium Term (MT)													
Short Term (ST)													
	LT	MT	ST					EgVec					
LT	1	1	1	0.333	0.333	0.333	1.000	0.333	1.000	3.000	3.000	$\lambda_{\max}$	
MT	1	1	1	0.333	0.333	0.333	1.000	0.333	1.000	3.000	0.000	CI	
ST	1	1	1	0.333	0.333	0.333	1.000	0.333	1.000	3.000	0.000	CR	
	3	3	3				3.000	1.000					

Planning Scenario 4 - Importance of Actors with respect to Planning Horizon

Business Owner (BO)																		
Plant Manger (PM)																		
Shop Supervisor (SS)																		
LT	0.333																	
	BO	PM	SS					EgVec						LT*EgVec				
BO	1	5	7	0.745	0.769	0.700	2.214	0.738	2.237	3.031	3.014	$\lambda_{max}$	€	0.246				
PM	0.2	1	2	0.149	0.154	0.200	0.503	0.168	0.504	3.008	0.007	CI		0.056				
SS	0.143	0.5	1	0.106	0.077	0.100	0.283	0.094	0.284	3.004	0.012	CR		0.031				
	1.343	6.5	10				3.000	1.000										
MT	0.333																	
	BO	PM	SS					EgVec						MT*EgVec	Global importance of actors			
BO	1	1	2	0.400	0.400	0.400	1.200	0.400	1.200	3.000	3.000	$\lambda_{max}$	€	0.133	BO	0.490		
PM	1	1	2	0.400	0.400	0.400	1.200	0.400	1.200	3.000	0.000	CI		0.133	PM	0.300		
SS	0.5	0.5	1	0.200	0.200	0.200	0.600	0.200	0.600	3.000	0.000	CR		0.067	SS	0.209		
	2.5	2.5	5				3.000	1.000										
ST	0.333																	
	BO	PM	SS					EgVec						ST*EgVec				
BO	1	1	1	0.333	0.333	0.333	1.000	0.333	1.000	3.000	3.000	$\lambda_{max}$	€	0.111				
PM	1	1	1	0.333	0.333	0.333	1.000	0.333	1.000	3.000	0.000	CI		0.111				
SS	1	1	1	0.333	0.333	0.333	1.000	0.333	1.000	3.000	0.000	CR		0.111				
	3	3	3				3.000	1.000										

Planning Scenario 4 - Importance of Objectives with respect to Actors

Defect Free Productinos (DFP)															
Predictable Flow Time (PFT)															
Minimized Operating Cost (MC)															
<b>BO</b>	0.490														
	DFP	PFT	MC					EgVec							
DFP	1	2	1/3	0.222	0.286	0.211	0.718	0.239	0.722	3.014	3.018	$\lambda_{max}$	0.117		
PFT	0.5	1	1/4	0.111	0.143	0.158	0.412	0.137	0.413	3.007	0.009	CI	0.067		
MC	3	4	1	0.667	0.571	0.632	1.870	0.623	1.891	3.034	0.016	CR	0.306		
	4.5	7	1.583				3.000	1.000							
<b>PM</b>	0.300														
	DFP	PFT	MC					EgVec							
DFP	1	1/2	1/2	0.200	0.200	0.200	0.600	0.200	0.600	3.000	3.000	$\lambda_{max}$	0.060	DFP	0.280
PFT	2	1	1	0.400	0.400	0.400	1.200	0.400	1.200	3.000	0.000	CI	0.120	PFT	0.253
MC	2	1	1	0.400	0.400	0.400	1.200	0.400	1.200	3.000	0.000	CR	0.120	MC	0.467
	5	2.5	2.5				3.000	1.000							
<b>SS</b>	0.209														
	DFP	PFT	MC					EgVec							
DFP	1	2	2	0.500	0.571	0.400	1.471	0.490	1.510	3.078	3.054	$\lambda_{max}$	0.103		
PFT	0.5	1	2	0.250	0.286	0.400	0.936	0.312	0.952	3.053	0.027	CI	0.065		
MC	0.5	0.5	1	0.250	0.143	0.200	0.593	0.198	0.599	3.030	0.046	CR	0.041		
	2	3.5	5				3.000	1.000							

Global importance of objectives

Planning Scenario 4 - Importance of Functional Requirements with Defect Free Production

Reduce defects from machines (FR1)														
Reduce defects from methods (FR2)														
Reduce defects from people (FR3)														
Reduce defects from materials (FR4)														
DFP	0.280													
	FR1	FR2	FR3	FR4					EgVec					DFP*EgVec
FR1	1	1/3	1/5	1/2	0.091	0.154	0.058	0.059	0.090	4.064	4.199	$\lambda_{\max}$	0.025	
FR2	3	1	2	3	0.273	0.462	0.580	0.353	0.417	4.332			0.117	
FR3	5	1/2	1	4	0.455	0.231	0.290	0.471	0.361	4.282			0.101	
FR4	2	1/3	1/4	1	0.182	0.154	0.072	0.118	0.131	4.120	0.066	CI	0.037	
	11	2.17	3.45	8.5					1.000	CI	0.074	CR		

Planning Scenario 4 - Importance of Functional Requirements with respect to Predictable Flow Time

Produce to customer demand (FR5)																	
Minimize production disruption (FR6)																	
Factory arrangement facilitates flow (FR7)																	
Ensure availability of relevant production information (FR8)																	
Ensure predictability of worker and equipment output (FR9)																	
Ensure material availability (FR10)																	
PFT	0.253																
	FR5	FR6	FR7	FR8	FR9	FR10							EgVec				PFT*EgVec
FR5	1	1/4	1/3	1/4	1/2	1/3	0.059	0.061	0.029	0.055	0.056	0.067	0.054	6.440	6.432	$\lambda_{\max}$	0.014
FR6	4	1	3	2	1	1	0.235	0.245	0.265	0.436	0.111	0.200	0.249	6.446			0.063
FR7	3	1/3	1	1/2	1/2	1/3	0.176	0.082	0.088	0.109	0.056	0.067	0.096	6.291			0.024
FR8	4	1/2	2	1	3	2	0.235	0.122	0.176	0.218	0.333	0.400	0.248	6.541			0.063
FR9	2	1	2	1/3	1	1/3	0.118	0.245	0.176	0.073	0.111	0.067	0.132	6.368			0.033
FR10	3	1	3	1/2	3	1	0.176	0.245	0.265	0.109	0.333	0.200	0.221	6.507	0.086	CI	0.056
	17	4.083	11.33	4.583	9	5							1.000		0.070	CR	

Planning Scenario 4 - Importance of Functional Requirements with respect to Minimizing Operating Costs

Reduce facility expense (FR11)														
Reduce inventory costs (FR12)														
Reduce waste in direct labor (FR13)														
Reduce waste in indirect labor (FR14)														
MC	0.467													
	FR11	FR12	FR13	FR14					EgVec					DFP*EgVec
FR11	1	1/4	1/2	1/2	0.111	0.140	0.103	0.053	0.102	4.089	4.167	$\lambda_{\max}$	0.048	
FR12	4	1	3	5	0.444	0.561	0.621	0.526	0.538	4.238			0.251	
FR13	2	1/3	1	3	0.222	0.187	0.207	0.316	0.233	4.282			0.109	
FR14	2	1/5	1/3	1	0.222	0.112	0.069	0.105	0.127	4.059	0.056	CI	0.059	
	9	1.783	4.833	9.5					1.000		0.062	CR		



