AN INTRODUCTION TO OPERATIONS MANAGEMENT

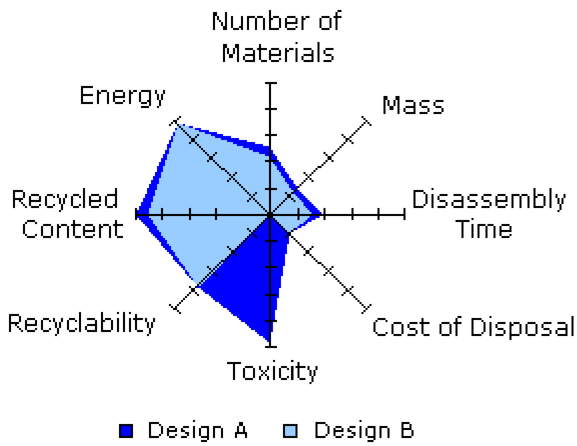
Welcome to my beach. I chose a beach as a framework for this learning endeavor because much can be learned in this setting. Beach shells remind us of the finiteness of life, something that all firms must deal with. It reminds us that Nature has an ongoing recycling program—an issue that is increasingly becoming an important issue in the business world. And the beach's mix of wave-riding surfers, child-guarding parents talking on their cellular phones reminds us that our business environment is a diverse mix of generations, genders, and lifestyles.

Many of you are or soon will be actively engaged in this so-called real world. As a business student, you no doubt have to take a course that is often called production operations management (POM) or just operations management. This is the course that I teach—often to students majoring in other functional areas. This is my personal challenge because many students are all too ready to focus on their major. I fondly recall Julie, a student who informed me that "I really liked your course but there was just too much readings for me since I am an accounting major." I vividly recall my unspoken response—"damn those tunnel thinkers!"

Shortly thereafter, Steven Melnyk and I wrote an introductory operations management textbook. It was comprehensive and about 81 pages shorter than the Bible. Once again, I heard my students say, "Good book but it is just too damn long!" Our fellow professors who had adopted the text also informed us that by the time students had read the chapters, there wasn't sufficient time left to do anything else. We got the message.

What follows is my attempt to correct this problem. What used to be called a chapter is now called a learning shell. They are called shells because each is, *by design*, incomplete. Each shell is approximately 20 pages in length and can be downloaded free from the homepage. Each of the fourteen shells allows the instructor sufficient educational slack to extend the learning plan with other "stuff" that he or she thinks is needed to create a fuller learning experience. This "other stuff" might include: problem solving exercises, case analyses, field trips, POM-related article discussions, or even some additional POM topics that may be deemed important.

This course format uses the *mass customization* concept -- an approach that permits a firm to produce goods and services that are more responsive to customer needs by using a mix of standardize components and custom features. *My*POM, the standardized component, has fourteen shells. We leave it up to your instructor to customize your course to create a truly great learning endeavor. So Julie, wherever you are—this course is dedicated to you and the belief that learning POM can and should be fun.



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BUCKET ONE

A VALUE DRIVEN APPROACH

Since we are using the beach as a metaphor, we placed our learning shells into three buckets. Bucket One introduces the value driven approach to operations management. Bucket Two describes how value can be used to design systems capable of delivering products that customers will value. Bucket Three describes how the operations function can be managed to ensure that a well-designed system delivers value.

We use value as the key theme because we find it a useful way to ensure that operations managers and the designers of operations system always stay focused on the customer. Knowing who these customers are and what they value enables systems designers to understand what blend of goods and services the firm must deliver if it is going to win the battle for the customer's wallet

The first shell introduces the reader to operations management and how it contributes to the success of a firm competing in an ever-changing world. The operations management function is defined broadly because this view is needed if the operations manager is to effectively serve in organizations stressing cross-function thinking. The second shell introduces the concept of value and the value model. The third shell explains how the concept of value can be used to define capability specifications, i.e., the things a firm must do well in order to be competitive. This shell also introduces the concept of performance metrics—the means through which a firm determines if it is delivering value. The fourth shell introduces the roles processes and process thinking play in building systems capable of delivering value. The last shell in this bucket introduces the concept of the learning organization—the foundation through which firms transform experience and observation into enhanced capabilities. Shell Five concludes with an introduction to the Operations Managers' Toolkit—a brief overview of the tools practitioners use to support their organization's learning processes.

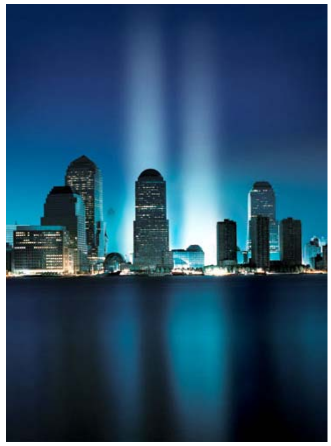
myPOM's Guide to Learning

Learning occurs best when you are motivated and awake. How you learn best is student specific --- but it is my personal experience that is occurs best when:

- The individual *carefully* reads the materials and then tries to relate what was just read to one's personal experiences. Since we live in an economy both as a consumer of goods and services, it makes sense to relate what is taught to one's everyday experiences.
- *My*POM does this by giving you an opportunity to quickly find out whether or not you "gets it," i.e. what the instructor wants you to learn. We try to accomplish this in the following ways:
    - Within the body of the text, we have placed ***dialogue*** *drivers*. Throughout each shell, *my*POM asks you specific questions that are designed to force you to think about what you have just read and then relate it to some aspect of your everyday life. *Some instructors are known to use these questions to stimulate your contributions to in-class discussion*.
    - Each shell includes an ***introductory story*** and a number of ***"boxed" stories***—each of which is designed to help you relate the concepts introduced to some of your life's experiences.
    - At the end of shell, *my*POM provides ***a set of learning competencies*** that you should have attained after reading the shell's materials and then thinking about them.. In general, they mirror the learning objectives listed at the start of each shell.
    - At the end of each shell, we provide ***a set of frequently asked questions*** (AKA FAQs). The purpose of these is to give you a better sense of the types of quiz and/or exam questions that a reasonable instructor might ask. We will leave it up to you and your professor to get a better reading as to how reasonable he or she is.
    - Some students' learning processes are enhanced if they see relevance to what is happening in the so-called real world. Thus, for students who have the time to read additional materials, we have included an Operations Management Digest on ClubPOM's home page. You should be able to access these through your college library e-reference resource. Most can be downloaded directly from the publication's web site.

As we indicated in Shell Zero, *my*POM is the standard component of a mass customizing approach to learning. No doubt, your instructor will add "stuff" that is not included in *my*POM.

SHELL ONE
OPERATIONS MANAGEMENT CIRCA 2003



The Lexus and the Olive Tree

"I was in Japan on a reporting assignment and had arranged to visit the Lexus car factory outside of Toyota City, south of Tokyo. It was one of the most memorable tours I've ever taken. At that time, the factory was producing 300 Lexus sedans each day, made by 66 human beings and 310 robots. From what I could tell, the humans were there mostly for quality control. Only a few of them were actually screwing in bolts or soldering parts together. The robots were doing all of the work. There were even robot trucks that hauled materials around the floor and could sense when a human was in their path and would "beep, beep, beep" at them to move. I was most fascinated watching the robot that applied the rubber seal that held in place the front windshield of each Lexus. The robot arm would neatly paint the hot molten rubber in a perfect rectangle around the window. But a tiny drop of rubber was left hanging from the tip of the robot's finger—like the drop of toothpaste that might be left at the top of the tube after you squeezed it onto your toothbrush. At the Lexus factory, though, this robot arm would swing around in a wide loop until the tip met a tiny, almost invisible metal wire that would perfectly slice off that last drop of hot rubber—leaving nothing left over. I kept staring at this process, thinking to myself, how much planning, design, and technology it must have taken to get that robot arm to do its job and then swing around each time at the precise angle so that this little thumbnail-sized wire could snip off the last drop of hot rubber and start clean on the next window. I was impressed.

After touring the factory, I went back to Toyota City and boarded the bullet train for the ride back to Tokyo. The train is aptly named for it has both the look and feel of a speeding bullet. As I nibbled away on one of those sushi dinner boxes you can buy in any Japanese train station, I was reading that day's *International Herald Tribune*. A story caught my eye on the top right corner of page three. At the daily State Department briefing, a spokeswoman had given a controversial interpretations of a 1948 United Nations resolution relating to the right of return for Palestinian refugees to Israel. I don't remember all of the details, but whatever her interpretation, it had clearly agitated both the Arabs and the Israelis, and sparked a furor in the Middle East.

So there I was speeding along at 180 miles an hour on the most modern train in the world, reading this story about the oldest corner of the world. And the thought occurred to me that these Japanese, whose Lexus factory I had just visited and on whose train I was riding were building the greatest luxury car in the world with robots. And over here, on the top of page 3 of the *Herald Tribune*, these people with who I had lived for so many years in Beirut and Jerusalem, whom I knew so well, were still fighting over who owned which olive tree. It struck me then that the Lexus and the olive tree were actually pretty good symbols of this Post-Cold War era; half the world seemed to be emerging from the Cold War with the intent to modernizing, streamlining, and privatizing their economies in order to thrive in the system of globalization. And the other half of the world—sometimes in the same country, sometimes within the same person—was still caught up in the fight over who owns which olive tree."

Source: Thomas L. Friedman, *The Lexus and the Olive Tree*, Farrar, Straus Giroux, New York, 1999

Shell One: Operations Management Circa 2003

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Shell One Learning Objectives

After reading this shell and thinking about its contents, you should be able to:

1. Understand the influence pace has on the way firms setup and operate their businesses.
2. Understand the roles of operations and operations managers within the firm. You should be able to define the roles of operations managers both from a narrow traditional perspective and as the text has broadly define it.
3. Understand the framework used in this text that argues that there are two major facets of operations management—the product innovation process and the supply chain management process.
4. Be prepared to describe the intra-firm interactions OM has with engineering, marketing, finance, accounting, and human resource management.
5. Understand the roles of strategy and how the operations management function uses strategy to serve as guidance in the operation and the design of operations systems.
6. Understand the OPJ framework that can be used to implement strategy.
7. Understand the major future challenges that operations managers are likely to face.

INTRODUCTION

Tom Friedman, the author of *The Lexus and the Olive Tree,* provides an excellent framework for explaining how operations management functions within different types of business environments. Friedman uses the Lexus and the olive tree to set up his interpretation of the Post-Cold War world. While this metaphor is not perfect, it is useful in explaining how businesses and their functional areas must adapt to new global realities. Friedman argues that three forces are propelling countries and businesses toward this globally competitive environment. These forces are:

- *The Democratization of Technology* that is the result of major technological innovations that came together in the 1980s—mostly in the information technology arena.
- *The Democratization of Finance* that results in risk capital flowing freely between continents, countries, and within industries. In this post-Cold War era, massive amounts of risk capital can be raised and moved—often at the whim of individuals, such as the financier George Soros. Ample venture capital enables startups to raise massive amounts to support promising startups.
- *The Democratization of Information* that has resulted from satellite technology, the Internet, and the ability to store massive amounts of information in digital form.

Few countries can hide from these global forces. Post-Colonial India tried to survive as an isolated economy only to have most of its industrial sectors become noncompetitive in the global marketplace. In the late 1990s, Malaysia tried to protect its economy from these forces only to have its national economy shunned by the movers and shakers in the financial world. In the Post-Cold War world, there are over 180 economies to invest in, most of which are eagerly seeking the technologies and investment capital from advanced economies.

Failure to deal effectively with these forces of change can result in what Friedman calls, a *Microchip Immune Deficiency Syndrome,* which he defined as a disease that can afflict "any bloated, overweight, sclerotic system in the Post-Cold War era." Friedman argues that the only known cure for this disease is a fourth democratization—*the democratization of decision-making and information flows*. This fourth democratization enables the organization to compete effectively by empowering more people in a country and/or company to "share knowledge, experiment, and innovate faster."

The metaphor that Friedman uses to explain the Post-Cold War world can also be used to describe the competitive environment in what some used to call the New Economy. Some firms seemingly move at a glacial pace while others respond quickly to change. Even so-called old economy companies face change and the need to rethink and adjust the firm's business strategy and resource mix, but these need not be done at a fast pace.

Since no one management system will work well for firms competing at the different extremes of this pace spectrum, we need some means to classify firms and industries. Charles Fine of MIT coined the term, *clockspeed*, to describe the pace of change existing within an industry. [1] The *pace of an industry* is defined by the rate customers demand or are able to get *new* goods or services. Fine argued that in fast-pace environments, most competitive advantages are quite temporary. The challenge for firms in the Lexus- lane is to be able to anticipate and adapt to change -- lest they face decline and possibly extinction.

Better yet, a firm could take a more proactive role to create situations in which *its competitors* must respond to the change that it introduces to the competitive environment. It is generally better to play in a game in which your team has the "first mover advantage." While it is difficult to define one attribute to measure a firm's clockspeed, Fine cites a list of industries to illustrate the concept.

Exhibit 1
Industry Classification by Clockspeed

Fast Clockspeed	Moderate Clockspeed	Slow Clockspeed
Personal Computers	Bicycles	Commercial aircraft
CAE Software	Automobiles	Tobacco
Toys and games	Computer operating systems	Steel
Athletic footwear	Agriculture	Military aircraft
Semiconductors	Fast food	Shipbuilding

Source: Charles Fine, *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*, Perseus Books, Reading Massachusetts, 1998, page 239.

Citing a list of fast pace industries in a slow clockspeed medium (i.e., books) is risky. Fine's 1998 list does not include industries such as: e-commerce, personal digital assistants, or web-capable cellular phones.

Dialogue Driver: What changes do you think should be made to this list?

Clockspeed is an important attribute in that it defines how fast a firm, or parts of a firm, must respond to change, to competitive threats, and other organizational challenges. In 1999, Amazon.com learned that another online bookseller had cut its discount on books on the New York Times best-selling books list. Within an hour, Amazon had matched the discount.

Note that being able to respond has two components. First is the ability to *detect* quickly that something has happened. No doubt, Amazon's market intelligence unit monitors all of its competitors continuously. The second component is the organization's ability to quickly assess the nature of a new competitive threat and then to quickly select appropriate responses.

One of the learning goals of this course is to provide a framework for helping an operations manager design, develop, and manage business processes capable of performing effectively given the pace of the competitive environment. When a firm is operating in the Lexus lane, its product design and development processes should focus on being agile rather than relying on efficiency-oriented best practices.

Going With the Flow

In Bakersfield California, the Kern Sand Company exists in a slow pace world. Many years earlier, it purchased the right to dredge sand at one point along the Kern River. Its operations involve one dragline, which consists of a huge scoop that traverses the river on a steel cable. At the far side of the channel, the scoop is dropped and dragged across the riverbed to the near side. The scooped sand is then lifted by cable to a storage area and dropped on top of a pile. No further processing is necessary because sand's excellent drainage characteristic and Bakersfield's arid climate quickly removes excess moisture from the sand. After a while, the sand is ready to be loaded in its customers' trucks. Such a deal! Natural forces deliver your product. You pick it up without paying for it. In a short time, the Kern River's swift current has filled in the scooped out river bed and the process can begin anew.

We use this story to illustrate that not all businesses environments demand that business processes have agility. It also illustrates that being an effective commodity producer can be both satisfying and profitable, provided that the firm can achieve by some means a low cost producer advantage.

Olive tree like firms need not be a producer of commodities. An example of a highly profitable olive tree like firm is the McInnery Company which makes Tabasco® pepper sauce. This firm has: excellent brand-recognition, superior product presence in its market channels, and the ability to command a premium price for its products. To remain successful, it needs to develop and refine its business processes that enable it to effectively manage the making and marketing of Tabasco® products. Firms in McInnery's competitive position often base their business strategy on the "best practices" associated with branded-oriented businesses. To succeed, it must protect its brand, maintain and develop reliable sources of appropriate quality raw materials, provide good service to its marketing channels, and manage its human resources. Each is an important task, but the pace at which they are done is just slower. It should also be noted that olive-tree like industries often offer limited opportunities for growth. But for the olive tree stakeholders, that may be okay.

WHAT IS OPERATIONS MANAGEMENT?

Before we go much further, it is useful to first define the operations management function. There are two ways to define operations management (OM).* The first is to define OM by what it does. Put simply, *operations management is the business function that manages that part of a business that transforms raw materials and human inputs into goods and services of higher value.* Traditionally, many have viewed OM using this narrow view, i.e., thinking of it as being involved with the making of goods.

A second way to define operations management is to do so in context of the overall activities of the firm. The second approach starts by recognizing that a business is really *a set of processes*, each of which has *inputs*, *outputs*, and *structure*. Each process has a job to do and each should be measured on how effective it is in achieving the desired outcomes. We think the second approach makes more sense, especially since we want to emphasize cross-functional thinking.

In its simplest form, the second approach notes that most companies are engaged in *four core business processes*. One set attracts customers, the second designs and develops products, the third secures the factors of production and then transforms them into products of value, and the fourth provides business support services needed to effectively operate as a business. Each of these core process sets is listed on the left of Exhibit 2 while *some* of the supporting business processes are shown on the right.

The first core process determines customer needs. For an olive tree company, such as Kern Sand that serves local construction firms, determining customer needs involves "doing lunch" with its key customers to learn what their building plans are for the next year. At the other extreme are firms that sell products in rapidly changing markets that constantly demand new and innovative goods and services. Knowing what existing and potential customers need is critical here—both to support the firm's demand forecasting needs

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* In academia, the OM course evolved from what was once called Production Management. The term POM—which stands for Production Operations Management is sometimes used. Please do not ask your instructor what the P stands for –- lest your instructor will believe that you do not read footnotes or the text diligently.

and its product design and development activities. For fast pace firms, a new business acronym has been created. It is CRM, which stands for Customer Relations Management. Software firms are developing applications that are designed to keep a firm on top of understanding what customers want and in some cases, how it can enhance the marketing capabilities of its sales force. Is this an operations management activity? Not really, but if it is not done right, it cripples the ability of the OM function to know what, when, and how much it needs to make. In the Lexus lane, there is no getting around the need to develop cross-functional business processes in this area.

Exhibit 2
A Business Process Model

Core Process	**Business Process**			
Determine Customer Needs	Monitor Competitive Environment	Market Products & Provide Post-sale Services	Measure Customer Satisfaction	Understanding Customers, Market Segments, and the Competitive Environment
Develop Product Strategy	Evaluate Product Concept	Design New Product or Product Refinements	Develop, Build, and Test Prototype Products	Design and Develop New Products and/or Product Refinements
Estimate Demand & Secure Needed Materials	Operations Planning & Control Processes	Manage Product Transformation Processes	Manage Business Logistics	Manage the Supply Chain Process
Manage Strategic Planning Processes	Manage Human Resources	Manage Information Systems	Manage Financial Resources	Enterprise Management and Business Support Activities

The second core process also involves a set of cross-functional activities. Marketing, operations, and engineering need to create products that customers want and value. The slower the pace, the more we focus on our customers in a never-ending pursuit of better ways to refine existing products. But as the pace of a business increases, the greater the need to be aware of the competitive challenges that new technologies and competitors introduce into the marketplace. If your firm does not understand the potential customer-pleasing/displeasing consequences associated with these changes, you can be assured that an invading competitor will. The risk is that if your firm does not replace its existing products, some other firm will.

The third core process involves managing all of the activities involved from the selection of raw materials vendors to the ultimate delivering and servicing of the product to the customer. These activities are part of the firm's *supply chain*. Not all supply chain players will lie within your firm's legal boundaries, but this does not diminish the need to manage the flow of materials effectively.

The fourth core process includes the set of supporting business processes that are essential in all organizations. The strategic planning process defines what the firm and its OM function wants to be and specifies what it must do to achieve its corporate goals. The human resource management function creates an *organization design* that is hopefully well suited to the competitive environment and provides and/or enhances the human capital needed by the other functions to effectively carry out their tasks. The MIS groups provide timely information that is needed to assess the competitive environment and the performance of its business functions. The accounting and finance groups must monitor the use of financial assets and take steps to assure that the financial base of the organization is both adequate and efficiently utilized.

Operations management activities mostly are involved in the second and third core processes. In the shells that follow, the activities that are most associated with the second core process are called the *product innovation process*. The role of this key business process varies with the clockspeed of a firm. Maintaining product quality is always important but quality starts with product design. The importance of this business function may be less in olive tree like firms, such as Kern Sand and McInnerry. But even olive trees risk being surprised by unforeseen developments. The folks selling yellow pages thought that they had a stable business environment—until the development of the Internet.

The product innovation process is the most important core business process in fast pace firms, such as Cisco, Nokia, and eBay. With fast pace firms, OM's role in this core business process is mostly as a team player given the cross-functional nature of this task.

World class firms understand how the product innovation process benefits when OM is participating at each stage of the product design and development The first benefit occurs because OM, along with R&D, often bring to the product innovation process insights as to what emerging technologies might do to create new products and/or product delivery processes. This is particularly true when you consider what information technology has or will soon be able to do to create customer-oriented services. The second benefit is that OM's early involvement in the product innovation process helps operations managers stay focused on serving the customer and not just on getting the product out. Operations personnel all too often develop mindsets that stress efficiency, sometimes at the expense of the firm's effectiveness in meeting the unique needs of the customer. Focusing on what the customer values helps to minimize this tendency.

Defining the third core process as *supply chain management* also broadens the view of operations management. The broader perspective defines OM as including: demand forecasting, procurement and purchasing, managing inbound transportation, operations planning, the actual product transformation processes, and managing the flow of materials to the plant and through the distribution channels.

Deciding how, what, where, and who should perform the activities within the supply chain is a critical part of this third core process. A critical part of this decision making set involves the extent to which the firm will *outsource* some or all of its supply chain activities. In an earlier time, most firms sought to maximize manufacturing efficiency by performing as many of the supply chain's activities as possible. Today, many leading edge firms seek to outsource all but those activities that are critical to the firm's effectiveness. Boston Brewing outsources the brewing and bottling of its Samuel Adams beer but its operations managers must continue to monitor its suppliers' brewing processes to assure that demand and its quality standards are met.

Dialogue Driver: To what extent do you think that this business process model of a business provides you a better description of what operations managers do within a business? What might you change?

The Operations Manager's Many Hats

A modern operations manager is expected to wear many hats. The most obvious hat is hung in your department where you are expected to perform your department's mission as well as possible. Cost minimization is important, but so too are the other dimensions of performance, such as delivery reliability and product quality. The most important role this hat requires is the ability to manage humans in a way that is mutually satisfying to your subordinates, peers, and superiors. It involves getting the necessary things done. One common definition of management is the art of getting work done through people. The first definition of OM typifies this view of the operations manager's role.

A second hat that effective operations managers wear is the supply chain manager/coordinator hat. When wearing this hat, the manager must view the entire flow of goods and information within the supply chain. This may involve managing parts of the business that fall within the corporation's legal boundaries. But in other situations, you will be dealing with suppliers and customers outside your firm. In either case, firms are adopting B2B (business-to-business) supply chain management tools that use information technology to enhance the flow of materials within the supply chain. What traditionally has been called purchasing will continue to exist, but the roles of humans within *e-purchasing* systems will be dramatically different.

The third hat operations managers wear involves cross-functional participation with the business processes in the other three core processes. The most important non-supply chain business process is the product innovation process. But activities involving human resource management, accounting, marketing, and R&D processes also are critical contributors to the operations manager's effectiveness.

A fourth hat is the scout hat that is often worn in fast pace business settings. Since operations managers are amongst those closest to the customer, they can provide quick feedback to the strategic planning process of changes in the market place. Lexus-lane operations managers are expected to manage existing business processes while helping get the firm ready for the future.

In addition to wearing many hats, effective operations managers must show commitment—commitment both to their employees and to the organization's objectives. Workers expect good managers to be fair and impartial. They would like to feel that their manager is an effective advocate when it comes to advancing or protecting their jobs. In an era of downsizing and disintermediation, many workers have good reason to be concerned.

This advocacy role is often in conflict with another real corporate need—the need to have team players that understand and are committed to the corporate mission. If there is a better way to serve customers, then this perspective should prevail. Consider the following comments by one management consultant.

The One Sixth Perspective

At a recent professional meeting, Professor Wick Skinner of Harvard reported that a longitudinal study of the advancement rate of manufacturing management executives found that their advancement to positions higher in their firm seemed to be slower than that observed with the other functional areas. Over the years he had interviewed individuals who were viewed as being fast-track individuals. It was his observation that those persons that "made it" had more of a "consultant's perspective" than those who had not advanced.

A consultant rose to explain why. He argued that the typical operations manager was "looking at only one sixth of the equation." What equation, we asked? He then went to the whiteboard and wrote:

$$MS_1 \text{ x } MS_2 \text{ x } MS_3 = \text{Profits}$$

Where

MS_1 is the size of the market
MS_2 is your firm's market share
MS_3 is margin on sales which is Price – Cost of Goods Sold

He argued that the typical operations manager, including most executives, focused too much on the cost of goods sold part of MS_3.

Source: The Last Annual Operations Management Association Meeting, Santa Cruz, California, 1997

The cost of having the one-sixth perspective is evident to any student of business history. Tabasco dominated the hot pepper sauce market but missed the salsa revolution. At the other extreme, Sony's product innovation process continues to expand both the size of its markets and its market share. And Toyota has shown that manufacturing and service expertise enabled it to emerge as a maker of high quality cars capable of winning market share from the other makers of world-class automobiles. Soon we will see Toyota take the lead in making some of their cars electronic workstations on wheels.

WHAT IS MANAGEMENT?

Before we proceed, it might make sense to spend a moment to define what we mean by the second term in operations management. Management is an on-going process consisting of the following five major activities, each contributing to the successes of the strategic objectives:

- *Planning*—the process of deciding what to do. Effective planning seeks to answer questions such as:
  - *What* should the firm do? The output of this process are goals and objectives.
  - *When* must the firm achieve these goals? The output is a schedule defining milestones and due dates.
  - *Who* is responsible for doing it? The outputs are assigned responsibilities.
  - *How* should this be done? The outputs may be directions or plans of action.
  - *How should performance be measured*? The output includes standards of performance.

  Planning is *forward looking*. When planning is operational, the planning horizon is shorter and the level of detail within is greater. When strategic, the planning horizon is long and done in less detail.
- *Analyzing*—the process of making sense of data that is often: poorly structured, incomplete, inconsistent, inaccurate, and/or available in overwhelming quantities. Analysis supports the planning process by providing the "facts" in useful formats that can then be used to evaluate business alternatives. Analyzing also supports management's control activity by providing the basis for corrective actions.
- *Organizing*—the process of building organization structures and interrelated task coordination teams. In the past, organizing dealt mostly with humans, but increasingly it involves data--getting the right person the right information in the right form at the right time is a key success factor in organization design.
- *Directing/Implementing*—an action-oriented process that carries out the outputs of the first three management activities. This is where money is made and lost. In this process, management expends resources to perform the tasks defined by the planning process.

- *Controlling*—the process of measuring the results of the other four management activities. Were the plans any good? Did the analysis provide meaningful information to the other processes? How well did we organize our resources to get the job done? How well did we do it? We might even add, how well did we measure the performance of our control function?

The five-activity view of management was first developed by Henri Fayol, (1841-1925), who served as the head of a French mining firm. We cite Fayol to recognize the robustness of his contributions even though many in this country consider Peter Drucker the father of modern management.

Many individuals who are elevated to positions of management have the impression that their major role is that of being a decision maker. The word "boss" is both a noun that describes a position and a verb that describes an activity. Most of us would like to be boss but not bossed. If you are content with being a one-hat manager, bossing will get you there—or out the door. In the Lexus lane, effective operations managers will need to spend far more time performing the first three activities of management. Management activities require managers to gain consensus with individuals over which they have little or no direct control. Indeed, the people involved may not even work for your company. They may work for suppliers or *even customers*. Empowering customers often provide key inputs to a business' management process.

The New Manager

When I was younger, I managed a division that manufactured and marketed SuperSoil®--a houseplant growing medium, AKA dirt! During a plant startup, we encountered many problems. There were problems associated with our new workers, new vendors, new equipment, and the like. At the end of the day, I often was quite proud that I had: quickly figured out how to solve many problems, i.e., the problem on the packaging line, material shortages, and people problems. I often mused, "How would this firm have survived without me?"

During the evening, as I was reading about the Japanese style of management, I was struck by the way a Japanese manufacturing manager might have viewed similar snafus. What would he say at the end of a day? I realized that he might say: "Today, I was a failure. I had not trained my workers sufficiently to operate the new equipment safely and effectively. My planning was insufficient because I had to order that rush shipment of raw materials. And I had not adequately screened my job candidates to get reliable, caring workers. I must work harder to gain control." *

STRATEGY AND THE OPERATIONS FUNCTION

In the previous section, we referred a to firm's business strategy without defining this term. Although this is not a strategic planning course, it makes sense to offer a brief introduction and to indicate how strategy relates to the operations management function. The root of the word, strategy, comes from the Greek verb, *stratego*, which means to plan the destruction of one's enemies through effective use of resources. Many strategy theorists utilize game theory to define a strategic process as a means of winning a contest, much like a game of chess. Combat-oriented approaches might have been useful ways to strategize in an earlier time when both armies and businesses viewed competition in terms of territorial expansion or market dominance.

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* Being the SuperSoil® Division Manager was the best education I ever had. At the start, I was long on experience doing the first three activities of management, but I had never supervised anyone other than knowledge workers. Ten years later, I had learned the value of the broader view of operations management. I had learned the art of listening--listening to: your customers, your market channel, your truck drivers, and your workers.

Over the years, strategic planning has evolved as follows:

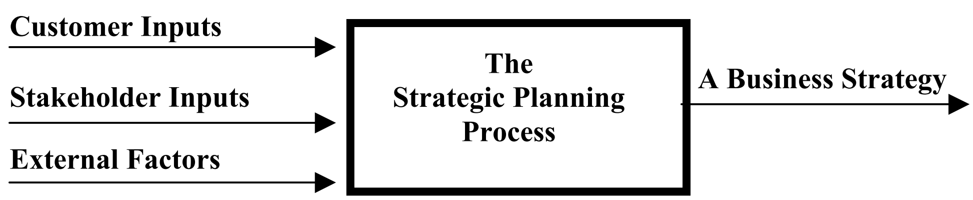
- Know thy enemy (Sun Tsu -- the great Chinese strategist)
- Only the paranoid survive (Andy Grove -- Intel's former CEO)
- Pay attention to your workers, who will take care of your customers, and good things will happen to your profits. (Herb. Kelleher – Southwest Airlines' former CEO)

Winning and survival are important, but *the goal of strategic planning should be to win customers by offering them better value.* Market share will follow, but only as long as no other competitor comes along to out-value you with your customers. In the fast pace world, a good dose of paranoia is healthy in that it helps guard against corporate smugness. But listening to customers is a wonderful antidote to corporate smugness.

The process of developing a business strategy has two stages: *strategic planning* and *strategy implementation*. Put simply, the first seeks to assess the competitive environment, the values of the firm's stakeholders, and the needs of its targeted customers. The output of the strategic planning process is a clear statement of what the firm intends to be (AKA a mission statement) and a plan specifying how it plans to implement the business strategy. This is called the business strategy formulation.

The strategy implementation process involves the last three management activities, i.e., the organizing, directing/implementing, and controlling facets of management. The nature of this planning process is characterized by the old adage: "*Plan your work, and then work your plan*." For many business environments, this still is an effective approach to strategy formulation.

Exhibit 3
The Strategic Planning Process



Strategic planning in the post-Cold War era is more challenging. Tom Friedman notes that this era is marked by a world-without-walls--a world in which your success may be determined by how well you can: harness the capabilities of those within your firm *and your supply chain*, understand the potential impact of emerging technologies, and understand what your current and future customers *really want*. In the Lexus lane, your success will be determined by how well you maintain friendships and customer relationships. The olive-tree lane is not much different but it provides you time to study the consequences of change.

Harvard's Rosebeth Kantor described life in the fast pace world as being akin to a golf game in which the capabilities of your golf club kept changing form while you were swinging at a ball that has a mind of its own and moves about as you swing, as you try to reach a golf green that often relocates without prior notice. While this example may seem extreme, in a fast paced world, the strategic processes can no longer be done in a sequential fashion. Your firm may not have the luxury of having the folks at the corporate headquarters formulate a business strategy and then have the business functions implement it. Life in the Lexus lane moves too fast for the traditional annual strategic planning process.

In *Competing on the Edge*, Brown and Eisenhardt suggest that effective strategic planning involves simultaneous, adaptive processes. They argue that in fast pace industries, strategic processes must involve collaborative endeavors where the strategy generating activities emanate not only at the corporate level, but within those areas of the firm that are more capable of monitoring and understanding change. [2] They note that when this happens, business managers control both parts of strategy, i.e., "where do you want to go' and "how are you going get there." Managers in high-velocity industries understand that strategy cannot be driven top down because change may occur too fast to have plans that trickles down through a hierarchy.

While we cannot capture the entirety of Eisenhardt and Brown's book, it is sufficient to say that operations managers, as well as the other managers, must don their scouting hat in firms with rapid clock speeds. The activities associated with this hat require operations managers to be intimately involved with the firm's strategic planning processes. Not just as an implementer, but as one of the firm's chief scouts.

Perhaps the best example of an industry fraught with change is today's telecommunications industry. Who could have imagined a world in which:

- A Federal judge breaks up the world's largest regulated monopoly. (AT&T and the Baby Bells)
- A small Alabama upstart called WorldCom gains access to sufficient financial resources to challenge AT&T for supremacy of this country's long distance telephone market.
- The economic viability of the country's wired telephone network is challenged by Internet technology.
- A former rubber band manufacturer from Finland (Nokia) becomes the largest cellular phone maker.
- The hamburger chain, McDonald's, sells disposable cellular phones with limited minute capabilities.
- Starbuck's installs Wi-Fi at its local coffee bars.
- A thirsty cash-less individual uses his cellular phone to order a Mountain Dew from a vending machine and charges it to his telephone bill.
- WorldCom files for bankruptcy and is charged with massive fraudulent business practices.

It is unlikely that an individual sitting at corporate headquarters will be able to anticipate future events. Managers at the business level of the firm, including operations managers, will need to be wearing their scout hats to help in a collaborative business strategy process.

Rapid change is having a major impact on operations managers. There are three forces driving this change. The first major force is information technology, which provides operations managers vast new ways to communicate—both within their operations, such as having machines talking to machines, and between the players within the firm's supply chain, such as is the case with B2B vendor management software.

The second force is the market's demand for product customization. While it may have started with Burger Kings' "have it your way" program, customers can and do participate in leading edge firms' product innovation process. Surefoot®, a small ski-boot marketer, uses foot-scanning software to customize ski boots to fit the precise shape of a skier's feet. In Japan, Panasonic built customized bicycles to match the size, use, and preferences of the customer. College textbooks can be designed to suit the needs of the professor and/or the idiosyncrasies of the student. Would you like your copy underlined to match prior exam questions?

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* While all of this was going on, WorldCom was telling the industry that its Internet traffic was growing by 85% a month, which in turn contributed to the massive amount of overcapacity experienced in 2002.

The third major force impacting operations managers is increased globalism -- especially within the firms' supply chain. Visit the loading dock at Apple's final assembly plant in Sacramento, California. There, you will see that crates from China and Taiwan represent the majority of incoming part shipments. Within the plant, computers are assembled with the keyboard in the language of the customer --as is the supporting documentation. Indeed, in many Silicon Valley plants, English is the second language since management must communicate with its workers, suppliers, *and customers* in their own languages.

Globalism also impacts the services. Banking and other financial services have long led the change toward offering their products in offshore markets. Wal-Mart is expanding the number of retail outlets in China. Not surprisingly, Chinese entrepreneurs have responded by opening Wu-Mart stores.

Globalism also has impacted the product innovation process. During the early part of the American Industrial Revolution, economies of scale induced manufacturers to make standard products using standard parts. The American market was large enough to support this approach. American firms were not as effective in foreign markets, partly due to costs, but also due to the fact that our plants did not or could not customize product to serve offshore markets. Standardized products, such as Ford's black Model T to McDonalds' pre-2000 Big Mac, were the norm.

Firms selling most of their products to offshore markets, such as Sony, Toyota, and Nokia, have a distinct advantage. Within their product innovation processes, they long had developed the capability of determining the needs of customers in foreign lands. This capability enabled these firms to gain a small market share in many market. Selling their goods in many offshore markets enabled them to achieve the scale needed to be profitable provided their plants were designed to produce a wide variety of products in small batches. This, in turn, gave them an advantage when it came to customizing product to satisfy unique needs for increasingly demanding market players.

To increase sales, a firm can expand its market either by geographical means or product line extensions. The ability to make and/or deliver product quickly in small volumes is often a key capability in today's markets. Nokia gained its number one position in the cellular telephone market by both means. But even this market leader must continue to find ways to better serve its existing customers while looking over its shoulder to guard against invaders capitalizing one or more of the democratizing forces.

Friedman likens competing in the Lexus lane as a sequence of 100-meter dashes. Yesterday's winners are back at the starting line with today's competitors. First and foremost, a business must adopt a strategy that enables it to secure the resources needed to effectively remain at the cutting edge of technological advances in the pursuit of creating and retaining the customers the firm wants.

The quality guru, W. Edwards Deming once commented, "He who worries about the competition is lost." He argued that focusing on what its competitors are doing can have the following adverse consequences:

- the product improvements will be late to the marketplace,
- the product innovation process risks being blindsided by new competitors,
- the rate of product innovation in your markets risks being marginal as each competitor incrementally parries each competitor's moves. Few "wows" are likely to be heard.

In a world without walls, strategic analysis requires viewing the marketplace with wide-angle lens. Others have noted that focusing on competitors may redirect corporate resources away from their product innovation processes. History is rife with firms that failed to see new technologies coming. As Deming noted, "no customer ever asked for the light bulb or the telephone."

When Competitive Advantage is Neither

Recently, Professor W. Chan Kim and Renee Mauborgne of Insead suggested that competitive analysis in which companies assess what their competitors do and then "strive to do it better" may not be in either the customers or the company's best interests. Their study of 30 high-growth companies and their competition found that this form of competitive analysis is counterproductive in that it all-too-often results in incremental improvement, imitation, and not much product innovation.

They suggest three ways to get beyond what they called the fallacy of competitive advantage.

A. Challenge managers to dominate the market. Instead of trying to beat the competition, challenge them to create blockbuster ideas to dominate the market and make the competition irrelevant. They suggest that the following question be asked: "What would it take to win the mass of buyers even without marketing?" If you can do this, benchmarking the competition becomes less meaningful.

B. Pursue radically superior value for the mass of buyers. Not only must a product be radically superior, but it must be sold at a price that the mass of buyers can afford.

C. Raise frame-breaking questions. Confront the conventional ways competitors think by asking four fundamental questions about the characteristics of the products that you sell:
   - -What are the characteristics that our industry takes for granted that should be eliminated?
   - -Which ones should be reduced well below the industry standard?
   - -Which ones should be raised well above the industry standard?
   - -What characteristics should be created that the industry never has offered?

They contend one result of me-too product innovation is over-designed or over –featured products.

Source: W.C. Kim and R. Maubougne, "When Competitive Advantage is Neither, WSJ April 18, 1997, p.18

Dialogue Driver: Can you identify a firm that comes close to doing what these authors propose?

STRATEGY IMPLETMENTATION

Strategy implementation, the second phase, is more difficult since it requires top management to secure and manage the resources needed to actually achieve the business' strategic goals objectives. In a slower pace world, the means used to deploy and implement a corporate strategy throughout a firm can be policy driven. As one moves down through an organization, each level down can define what its function needs to do to support the firm's efforts to achieve its strategic goals. First you define the sub-goal, then install *business processes* capable of achieving these goals, and lastly you measure how well each business process contributes to achieving the business unit's objectives. This approach has been called *management by objectives* and it has served many businesses well.

But in a fast pace industry, a top down approach to strategy implementation often fails because it can't respond quickly to unforeseen opportunities and threats. In such cases, the organization design must provide the firm's units *broad strategic guidelines* and then *empower* the units to do that which is necessary to contribute to achieving its goals. In the faster lane, *people become more important than policy*. This reality is true for each of the firm's functional areas, but it is especially true for its operations management function.

Translating Strategic Plans into Operational Effectiveness

Strategy gives the functional areas their marching orders. From strategy, the operations function learns:

- Who the targeted customers are and what they want.
- An estimate of the size of the market and the anticipated distribution of customers
- A profile of how the firm intends to compete to win these customers

The firm's expectations provide the basis for evaluating the effectiveness of management.

Once given these marching orders, operations managers must fill in the details. Within operations, this is often done using a systems perspective that views management as a three-stage process. The three stages are:

- *The Organization Level*: This is the macro-level description of the organization. It uses the corporate strategy as an input to a process that transforms it into a broad description of how senior management wants the firm and its sub-units to be run. Outputs of this level include:
  - Organization Goals: Goals define how the firm intends to achieve and maintain its desired competitive advantage as well as how the firm intends to benefit from said advantage, i.e., how much sales, market share, and earnings are expected. Organizational goals may also be qualitative, involving things such as awards, prestige, etc.
  - Organization Design: This defines how top management wants a sub-unit structured. This involves both physical entities such as plant and equipment, the organization structure, and how it expects to treat/rewards its people
  - Organizational Management: This translates the above into specific goals for each group, creates measures to evaluate their performance, formulates a resource management plan, and develops an understanding of how the groups will interact with each other.
- *The Process Level:* This is the level at which sub-units actually do the work. Processes include such activities as order entry, product innovation, and the actual making of the good or service. Within the process level, the following sub-systems exist:
  - Process Goals: These are measurable goals for each of the processes. For example, order entry might be expected to translate customer orders into production orders within three working days. Process goals can be multi-dimensional, i.e., a production process might be evaluated on the basis of cost, product quality, and on-time delivery reliability.
  - Process Design: This involves designing or redesigning processes to make sure that each is capable of achieving its process goals. The objective is to provide each person with a work situation that can be done effectively when given proper guidance and adequate resources,.
  - Process Management: Here we want to make sure that the way in which the process is managed is able to achieve process goals. This involves translating process goals into specific sub-goals for its subgroups, metrics to evaluate their performance.
- *The Job/Performer Level:* Now that we have stated what we want done and have designed and developed an organizational structure and a set of processes to do a job, we now have to worry about whether or not the people have performed these jobs effectively. Activities are akin to the organizing/directing and control activities of the management process. It is similarly broken down to include the following tasks:
  - Job Goals: Here we establish goals for the people staffing the process. On a basketball team, we might assign our point guard to hold the opponents star shooter to less than ten points and to cause her to make three turnovers. In a similar vein, a food server might be expected to serve five tables an hour during the peak shift—with minimum customer complaints.
  - Job Design: The Scientific Management Movement taught us that there is a right way to do each job. This school would argue that it is managements' task to figure out what that way is and then to train employees to do each task in the right manner. Employees today often resist short leashes so the appropriateness of job design has to be done within the context of the organization's culture.
  - Job Management: Here we manage human performance. The job holder has been told what is expected of him and provided the training to do the job in a correct way. Now we must manage that person in a way that enhances the likelihood of the task being performed effectively.

If the above seems overly systematic and perhaps a tad boring, you are right -- it is. But the road to an implemented business strategy is rife with potholes. In businesses with slow pace environments, this three level approach to strategy implementation works well. The trick is to know when and where to ease up in faster paced business environments. In the following shells, we will often start with some of the *best practices* others have found to work well. These serve as a starting point within the operations management arena. If they do not achieve the desired effect, then the operations manager needs to put on the analyzing hat to see how the failing sub-system can be modified or better managed to function better.

A caveat

Fast pace businesses are not fast pace in all areas. Since management is likely to be a scarce resource, it pays to do as much of the work using the best practices approach. Best practices work well on repetitive problems. This allows the organization to focus its scarce talent on future opportunities and non-recurring problems.

OM's FUTURE CHALLENGES

We only know that change will come, but not when and how. September 11, 2001 drove this lesson home in a most tragic way. The following represents one individual's projections on what operations managers should consider possible as possible future challenges with OM.

Marketplace Challenges

- Market fragmentation: America's industrial greatness was achieved using mass marketing and mass manufacturing processes. Domestic customers increasingly want their goods and services "their way." Even McDonalds was forced to switch to a Burger King like system in 1999. Marketing goods and services on a global scale increases the need to have an ability to customize product for local markets.
- Vocal customers: Some customers will become increasingly vocal—especially those with single-issue agendas. Customers will vote with their dollars and let you know why. Environmental concerns will be voiced loudly. Recently a single memo from Green Peace to Gerber's Swiss parent led this baby food firm to switch to organic inputs to its product. Guitar makers now worry about whether or not their veneer has come from endangered rain forests. Home Depot has responded to environmentalists by announcing that it no longer will sell lumber from "old growth" forests. Privacy concerns will become commonplace as society more fully understands the extent to which *they* know "all about you."
- The customer is your partner—often unwillingly so. We all have experienced "some assembly required," on Christmas Eve. Now this trend will extend to the service industry. Telephone triaging will expand. Restaurants will give you a beeper to tell you when *you* should come up to serve yourself. Casinos currently provide you beepers to eliminate the need to wait in line *when you could be losing money*. This trend is partly due to labor shortages but it is also driven by low-cost technologies.
- It's a Wired World: Customers, employees, and supply chain players will become increasingly wired—often via wireless technology. Cellular phones and beepers will expand the scope of their capabilities. Global positioning technology will spread quickly, which in turn will create some interesting employee control/privacy issues. Three dimensional bar coding will greatly enhance the amount of information that can be stored on a product or workstation. Wireless access to databases will become common.

Factors of Production Challenges

- Employee diversity: The job of managing an increasingly diverse workforce will become an even greater challenge. I am not talking about just gender and race issues. The OM function will have to figure how to manage an increasingly older work force. Human skills are too scarce to allow older workers to migrate to the service sector. The time has come to start viewing employees as a renewable resource, or keep them at least as long as we want to keep our trees.

- <u>Human resource scarcity:</u> American businesses will find it increasingly difficult to hire and keep quality workers. While the nation is likely to increase the number of skilled immigrants, in an expanding economy, the increase will be insufficient. A shortage of hirable unskilled workers will continue to plague the service industry.
- <u>The global workforce</u>: The location of work and workers will be dramatically impacted by the Internet. The outputs of many service activities can and will be done by competent persons residing in lower cost areas of the world. General Electric moved many of its back office jobs to India while Boeing is hiring Russian engineers to design product at its Moscow Engineering Center.
- <u>Declining raw material prices</u>: In the late 1990s, the prices of certain electronic parts were declining at a rate of 1.5% a month. Much of the rest of American industry has experienced little or no inflation. Indeed, deflation may be a real possibility. There will be little incentive to hold inventory above what is needed to meet immediate needs.

Technological Challenges

- <u>Technological change</u>: The challenge of investing in and mastering the right technologies is a major one. No firm has either the financial or the managerial resources needed to engage every new technology. Short product/process life spans mean that investing firms must recover investments even faster.
- <u>Bio-genetic</u>: Synthetic and/or animal substitutes will become commonplace as replacement body parts, foodstuffs, and drugs. On the plus side, advances in medical health may alleviate some of the more troublesome behavioral problems in the workplace.
- <u>Miniaturization:</u> The size of products and processes will continue to be made smaller. Manufacturing technologies will permit products being made in undreamed of sizes. Tiny mechanical roto-rooters will soon be cleaning out your bodies. More functions will be added to what you now call your cell phone.

Societal Challenges

- <u>The environment</u>: There are two challenges here. The first is to understand how to use technology to make products more earth friendly. Certainly in the product packaging area, this can be done. But before much more progress is made, a better method for understanding the full life cycle product-costing model is needed. The second challenge involves dealing effectively with certain environmental "enthusiasts." Firms need to realize that there is no way that most businesses will ever satisfy certain sectors of the environmental movement. Nor do most of their customers want to forego electrical power and /or their SUVs. Too often, we have been unwilling or unable to take a public stand that is capable of winning the understanding of those in the middle ground.
- <u>Intellectual property</u>: It seems unlikely that advanced nations will be able to restrain the piracy that is commonplace both in domestic and international markets. Protection will lie more with the delivery process rather than the product. Firms will rely more on industry alliances than governments to protect intellectual property.
- <u>Financial Reporting</u>: Fiscal chicanery has forced the SEC to demand fuller disclosure rules. This will require that a firm's financial control system have better more timely inputs from operations possibly to stabilize short-term earnings. If that is not possible, operations managers will need to be able to alert top management whenever there will be significant deviations from the announced financial projections.

Geopolitical Challenges

- <u>China</u>: Ever since Marco Polo, Western entrepreneurs have dreamt of selling millions of products to the world's most populous nation. With a few minor exceptions, these dreams have been unmet. Initial sales often are quickly replaced with Chinese goods since they have proven particularly adept in adopting new technologies. China's respect for Western intellectual capital is at best suspect. Since cultures change slowly, China's rising industrial base will result in economic friction through most of your lives. China will not be willing to remain solely as the source of low-cost, labor-intensive products.
- <u>Japan</u>: Even though Japan's economic problems seem intractable, it remains a formidable manufacturing threat. Toyota continues to extend its manufacturing advantage as it hones its ability to make vehicles desired by Americans -- at the expense of Detroit's Big Two's market share.
- <u>Mexico</u>: This neighbor will continue to be a mixed blessing. As a source of unskilled labor, Mexico will provide the US a competitive advantage in the global marketplace. It matters little if the workers reside on this or their side of the border. We will have access to scarce unskilled labor. Unfortunately, the

mode in which we do business with Mexico has not advanced its economic infrastructure. In order for Mexico to take full advantage of its proximity to our economy, it needs to greatly expand its investment in its human resources. Now that China has been admitted to the WTO, Mexico is losing low-cost jobs.

- Post-WTC Trauma: The destruction of the World Trade Center and the ensuing military actions has caused many firms to reconsider where they make or procure products. The threat of terrorism will hinder the flow of goods and personal throughout the world.

America's advantage will be that it is the most information-technology-driven economy. More important, we have an economic system that *allows* humans to be relocated within the firm when information technology, such as B2B software, renders jobs redundant. This is not true in many Asian economies—such as Korea. America will be able to realize the benefits of IT innovations sooner.

Jack Welch's Parting Thought

At his exit interview, the retiring CEO of GE was asked: "Over the next ten years what will be the big story for CEOs?" He responded: "I think that China and its impact on developed economies--and how developed economies and their politicians react to it--is going to be a huge story. We'll be wrestling with many of the same issues that we had in the late '70s and early '80s with the Japanese, and imported cars and televisions. Now it'll be computer peripheral equipment and all that stuff. Just think of the impact Taiwan has had on the U.S. Now multiply that by 1,000."

Source: " Jack: The Exit Interview." *Fortune*. September 17, 2001

SUMMARY

To recap, the broader view of the operations management function stresses:

- That all activities going on within a firm are viewed as business processes. Each business process has a set of inputs that may be physical, informational, and even subjective messages. Each business process accepts these inputs, evaluates them in the context of the organization's objectives, resource base, and culture. A well-designed process then emits outputs in a form designed by the organization's architects. An output can be a well-made product, a timely correct decision, or an action contrary to goals.
- That the role of the OM function within the firm involves cross-functional thinking. OM can't assume that it has an exclusive role in the product innovation process-nor should others. This is too important a process to be completely developed within the realm of one functional area.
- That the most important attribute of a operations management system is that it is customer driven. Being customer driven means that all business functions must focus their activities toward achieving a common goal, i.e., that of winning, satisfying, and keeping cash carrying customers.
- That the OM function not only deals with the other functional areas, it increasingly must involve parts of organizations that lie outside the legal jurisdiction of the firm as well. Within the supply chain, many of the participants are independent. These can include: suppliers, distributors, retailers, and the firms that provide the informational and transport services needed to carry on efficient business logistics activities.

If you want a challenge, a career in operations management may be right for you. But whatever your goal, it will be necessary to understand that operations managers are key players within the value chain.

End Notes

1. Charles Fine, *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*, Perseus Books, Reading Massachusetts, 1998.
2. Shona Brown & Kathleen Eisenhardt*, Competing on the Edge: Strategy as Structured Chaos*, HBR Press, 1998

References

1. T. Friedman, *The Lexus and the Olive Tree: Understanding Globalization*, Farrar, Straus & Giroux, Boston, 1999.
2. S. Melnyk and D. Denzler, *Operations Management: A Value Driven Approach*, McGraw-Hill, 1996.
3. Geary A. Rummler and Alan P. Brache, "*Improving Performance: How to Manage the White Spaces of the Organizational Chart*," Second Edition, Jossy-Bass, San Francisco, 1995.

Expected Learning Competencies

Before putting Shell One down, you should ask yourself the following questions. Am I able to explain?

1. The differences between the narrow and broad definition of the operations manager's job.
2. Where the operations function "fits in" with the other business functions, i.e., marketing. finance, accounting/MIS, engineering, and human resource management.
3. How the discussion about the operations managers' many hats and the One-Sixth Perspective story relate.
4. What a business strategy is and how it might influence how an operations manager goes about designing the operations function and its management control systems.
5. How current political and economic forces are likely to impact the operations manager's job.
6. What your instructor added to this shell and why he or she thought that it was important enough to warrant its inclusion.

Frequently Asked Questions

In the academic world, instructors have been known to give quizzes or examinations. The following reflect the level of learning a reasonable instructor might expect.

1. How would you define the operations management function in each of the following businesses?
   a. Ben & Jerry Ice Cream
   b. A Holiday Inn
   c. Your local supermarket
   d. Dell Computer
2. Why is the operations function necessary? Or is it?
3. If you were an operations manager of the following businesses, which of OM's future challenges do you think would be most relevant for your business?
   a. A toy company
   b. A company that writes accounting software for small businesses
   c. A firm supplying small and lightweight automotive parts to General Motors
   d. A firm supplying dairy goods to your local supermarket's grocery distributor.
4. If you were a senior operations manager of a Chinese firm, how might you rewrite the section of the shell titled OM's Future Challenges?
5. Thomas Friedman thought that the cure for what he called the Microchip Immune Deficiency Syndrome was to Democratize Technology. (T/F)
6. The One Sixth Perspective story, the consultant was pointing out that many operations managers fail because they focus too much on being efficient, i.e., focusing too much on cost reduction activities.
7. Kim and Maubougne argued that too many firms erred in that by focusing too heavily on what their competition was doing, their product design and development activities tended to be limited to making incremental improvements to their firm's product offerings.
8. The OPJ procedure was cited to illustrate one way a firm can use to formulate a business strategy.

SHELL TWO
Value

The Decline of the Schwinn Bicycle Company

For almost a hundred years, the name "Schwinn" was synonymous with value. A good bike enters the life of a child like a good friend, and generations of kids learned how to ride on Schwinn's sturdy, brightly colored bikes. Many of these kids grew up to be parents-parents who wanted their kids to ride Schwinn bikes.

In the early 1970s, the market was changing but Schwinn seemingly did not quite understand what was happening. Out in California, a loose fraternity of gear heads and hippies were converting Schwinn's single speed, coaster-braked “clunkers," into a new vehicle capable of "screaming" down Mount Tamalpais. Its dirt trail with a 1,300-foot drop and breath-snatching switchbacks was not for the timid, but the five-minute ride yielded what these hippies called a "lifetime buzz."

An early gearhead was Gary Fisher--the inventor of what we now call a mountain bike. Fisher selected a Schwinn frame for its sturdiness and new engineered parts from around the world to make a revolutionary bike that was capable of pedaling up a hill and with sufficient braking to survive the test of the Mount Tamalpais downhill run. Gary had become a local cult hero.

Soon, the executives of Schwinn had dispatched a team of engineers to visit Fisher's new company, Mountain Bikes Company. Fisher recalls, "This guy in his fifties was looking down at me like I was some jerk kid who didn't know anything." One snickered, "this wasn't a bicycle, it was a mongrel." As you might have expected, the Schwinn team returned to Chicago with the firm conviction that this "amateur's knowledge” was inferior to their firm's collective knowledge of the bicycle market.

Schwinn survived for almost another twenty years. But by the summer of 1992, the family dominated board of directors was forced to declare bankruptcy. It was losing about $1 million a month, it was $75 million in debt, and its unpaid suppliers were refusing to ship more components. The great grandchildren of founder, Ignaz Schwinn, tearfully watched as their dividends, corporate perks and their children's birthrights all were being lost. When they asked CEO, Edward R. Schwinn, the person some consider responsible for this mess, he responded, "We are where we are." Thus ended a 100 year chapter in one of America's great companies.

Sources: Gary Strauss, "Schwinn Files for Chapter 11," *USA Today*, October 9, 1992, p. 1B, and "Judith Crown and Glenn Coleman, *No Hands*, Henry Holt, New York, 1996.

Dialogue Driver: Assume for the moment that you are in the market for a bicycle. To what extent does the Schwinn brand name have any influence in your bicycle buying decision-making process?

Shell Two: Value

Table of Contents

Shell Two Learning Objectives

After reading this shell and thinking about its concepts, you should be able to:

1. Understand how the concept of value can be used to orient the thinking of operations managers and the designers of operations management systems by using what customers value as the primary driver.
2. Understand the value equation and how the text defines performance and costs.
3. Understand both the elements of the value equation by the following supporting concepts
    a. The various lead time categories
    b. Market orientation and how it impacts lead times
    c. The fast to market and fast to product categories and their subcategories
    d. The various types of flexibilities and how each supports delivering customer value
4. Understand the various issues and concepts that relate to costs, including”
    a. The various costs that go into the denominator of the value equation
    b. The concept of lifetime value of a customer
    c. The role activity based costing can play in operations management
5. Understand the concept of postponement and the impact its various forms have on the elements of the value equation.
6. Understand the role of technology and emerging technologies can have on firms living in the Lexus lane. Understand the following concepts”
    a. The Innovator’s Dilemma
    b. A disruptive technology
    c. A sustaining technology
7. Lastly, this shell should have started you thinking about the possible impact of global forces and information technology on what a modern operations management system can do. It is never to early to start thinking.

INTRODUCTION

Schwinn’s failure illustrates both facets of the material covered in this shell. The first is the phenomenon called *customer disconnect*. This company had fallen so deeply in love with what it had been that it no longer listened to what its customers and the bicycle market wanted. What did "gearheads" know? Schwinn’s greatest failure was that it no longer understood its customers' values.

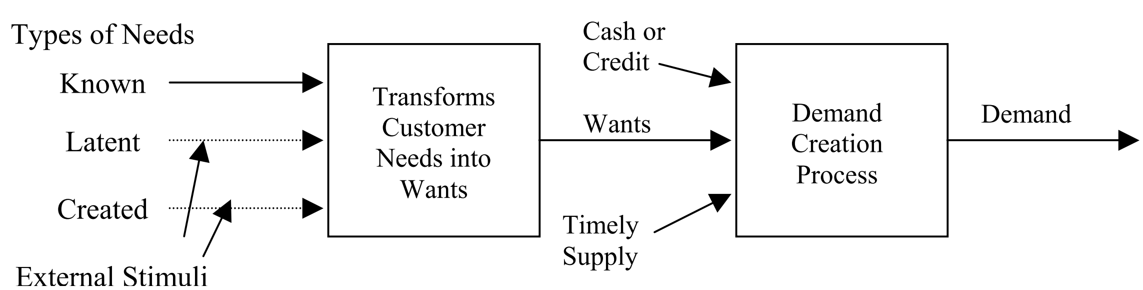
Value is a core concept in a business because it forces managers to strive to understand the customer buying process. People part with their money to buy a product when it delivers more "value" than it costs. Customers buy your product when your firm’s product offers more value than your competitors’ product. This must be the primary way in which a firm views the marketplace.

Secondly, Schwinn failed to see the disruptive forces that were changing its industry. The values of its customers were changing. Weird Californians were doing things to and with bicycles that Schwinn could not fathom. At the same time, the values of its customers in its marketing channel were changing. New bicycle firms were assembling a wide range of products, often using highly engineered components made by others. Schwinn took pride that it made *all of its components*. It could not see the merits of buying components from outside suppliers, such as Shimano. But the new breed of cyclists started to buy upscale bikes through the same marketing channel that heretofore had sold Schwinn. At the other end of the market, mass merchandisers, such as Wal-Mart, were selling a large number of low-end bicycles. Schwinn looked askance at these foreign made bikes and their discount marketers. Schwinn was simultaneously losing market share at both ends of the bicycle market

Needs, Wants, and Demand

To better understand value, let us go back into the realm of marketing to define some terms.

Exhibit 1
The Relationship Between Needs, Wants, and Demand



Known needs do not require any external stimulus to be recognized as needs. They can be physical, such as being thirsty. These needs are individual-specific. *Latent needs* exist within the individual but for some reason, they have not yet been transformed into wants. Many older individuals do not see the need to have a cell phone but many of their grown children want them to have them—just in case. Some needs may even be fabricated or induced. Clearly the need to have a certain toy at Christmas time may be induced by advertising or peer pressure. Whether or not there really is a need is immaterial if you are in the business of satisfying customers.

Wants get transformed into demand when the customer has the financial wherewithal to buy the product and the belief that an acceptable product will be available in a timely manner. Demand gets transformed into a sale when the financially capable customer believes that the product being acquired will satisfy a need at a reasonable price. A company will normally get the sale if the deal it offers is a better value than the customer's alternative.

Dialogue Drivers:
Assume for the moment that you are a cash-starved student. What might be some of your wants that are awaiting a better cash flow environment?
Can you think of any latent needs your parents might have had earlier in their lives but now believe they cannot now live without? What transformed this latent need into a want?

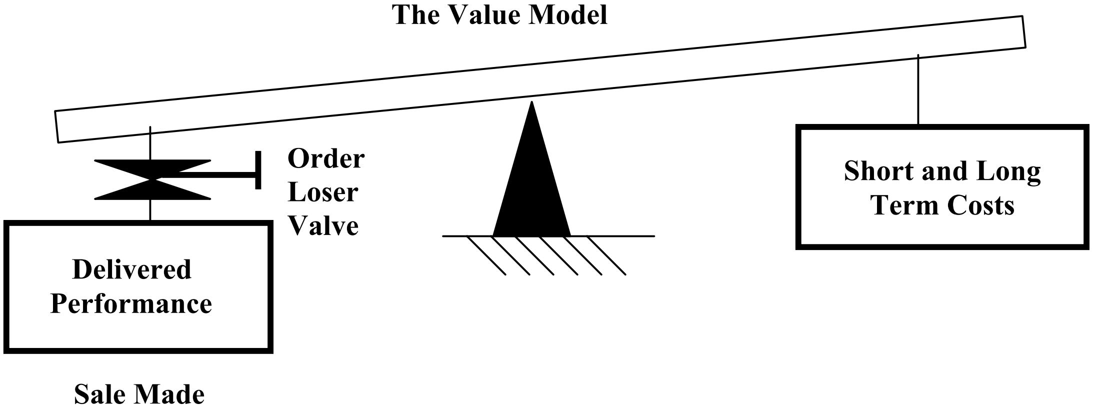
Operations management contributes to this customer satisfaction process in two ways. First, it assists in the firm's product innovation process to design and develop products that possess the capability to satisfy the customer's functional need with the desired level of design quality and cost. Second, OM must design and manage the supply chain needed to create, deliver, and service the products sold. Performance metrics should include: delivering a product that measures up to design specifications, being flexible enough to offer customers products how, when, and where they want it, and do the above at an acceptable cost.

Before proceeding, we should note that the customer and the consumer are not always the same person. The customer is the person or organization that makes the purchasing decision. In many instances, a customer does not actually use or consume the good or service. This often is the case in industrial markets. The consumer is the party that actually uses the product. Consumers can be the individuals, processes within the firm, other parties within supply chain. When the customer and the consumer are the same, we refer to it as the customer. But whenever the customer and the consumer are different, it is necessary to ascertain how each value the product involved. Didn't your mother ever buy something for you that you didn't value?

THE VALUE MODEL

We use the value model because it is a powerful reminder to *all* within the firm that the ultimate driver for all activities done within the organization is to satisfy the targeted customer. The value model assumes that a customer elects to purchase a product when a need exists and when the core and augmented benefits derived from making a purchase exceed the product's cost. Consider the following diagram.

Exhibit 2
The Value Model



On the right is a box that represents the product-life cost associated with acquiring, operating, and disposing of the product. For a simple product, such as a Snickers™ candy bar, this is the price of the candy bar and perhaps some tooth decay. Note that the customer, perhaps your mother worries about tooth decay but you as a consumer are less concerned with this long-term consequence. For other products, such as a nuclear power plant, calculating the life cycle costs of the product is more difficult since its economic life and end-of-life disposal costs are hard to estimate.

The left-most box represents the sum of the benefits that will occur if the product is purchased and consumed. No matter how cheap a candy is, consumers won't want it if it doesn't satisfy the need for a sweet treat that melts in your mouth and not your hand. What we need is some means to measure these benefits.

The approach used here assumes that the value of a product is the ratio of performance divided by cost.

$$\text{Value} = \text{Performance} / \text{Cost} \qquad [1]$$

This is the *value equation*. If a company's product is being compared with the competitions' product, presumably, that product with the highest ratio is most valued by the customer.

The performance of a product has two components. The first is *delivered performance* which is defined the cumulative benefits that will result if the product is purchased and used as intended. One might express performance as:

$$\text{Delivered Performance} = f\,(\text{functionality, quality, speed, timeliness, flexibility}) \qquad [2]$$

While performance is expressed as a mathematical equation, it is appropriate to think of it as a conceptual model. Later we will develop specific metrics for each of these terms.

Cost, the second component of the value equation, introduces reality. Have you ever purchased something that did not offer the best performance, but your need arose at an inopportune time, such as when you didn't have the cash or enough time to search for a better performing product?

Some operations managers use the term, *order winners*, to denote an element of the value equation that is more important to a customer or a market segment. They are attributes that reflect a customer's preference that *dominate the other elements of value*. A dress that makes you look *fabulous* is an order winner.

Over time order winners may evolve into *order qualifiers*, i.e., a trait that must be present before the purchase is made but one that is not sufficiently important to cause you to buy the item. For years, Sony's Trinitron picture tube was an order winner because it was superior to those offered by the competition. As the quality of the competitors' picture tube increased, the quality associated with Sony's television sets became an order qualifier. Having a high quality picture tube no longer was enough for Sony to win the customer.

Sometimes a value equation component has a trait that can veto the product's purchase. Such traits are called *order losers*. Few customers will purchase a garment that makes them appear heavier. Likewise, human rights advocates might not buy a product made in China and an ardent trade unionist only buys garments made using nonunion labor.

Dialogue Driver: What situations doesn't the value equation model address?

Let us now define each term in the value equation.

Functionality

Any time a good or service is purchased, the buyer has an intended use for it. *Functionality is a measure of the extent the product, when properly used, is able to accomplish the intended feat*. In some instances, there are specific measures for functionality. A light bulb's performance can be measured both in terms of the number of lumens it gives off and the number of hours it works before burning out. In other situations, the user subjectively defines the functionality of a product. A parent might find the functionality of a Huffy bicycle quite adequate whereas a child might rate the functionality of this bike woefully inadequate.

Quality

Quality is broadly defined *as the extent to which a good or service is delivered consistent with what the customer has been lead to expect*. The customer's quality appraisal process occurs in two stages. The first occurs in the purchase decision-making process. Here quality is one of the inputs to the value equation used to decide which products, if any, are worthy of the customer expending cash. In the second stage, the user of the product evaluates quality as it is used, or in some cases after it has been used up. If the product is a service, such as a meal, the determinants of quality might include: the meal itself, its presentation, the manner in which it was delivered, and quite possibly the behavior of the people at the next table.

One approach customers use to evaluate quality is to cite attributes of the product or its product delivery process. For example, if someone were to ask you to judge the quality of a personal computer, you might reply by citing such things as: the way it looks, how long it took to set up, how long it takes to boot up, and whether or not it has *Intel Inside*.

In effect, you are citing attributes of quality, i.e., the traits associated with quality that can be identified and, more importantly, measured. Attributes, however, are not the same as quality. Identifying every attribute of quality for a product would not describe that product's quality level. Some attributes used to help define quality are:

- Freshness: The quality of some products decline over time. Flowers and French bread fall into this category. Fashion items also are subject to obsolescence. At the other extreme, the value associated with some products increases with age, as is the case with antiques and red wine.
- Reliability: The quality associated with a product often increases with the dependability of the product-customer experience. Customers expect telephones to work and be answered quickly. Web-site viewers expect a page to come up in less than eight seconds. Electric utility customers expect reliable service.
- Durability: The quality attribute that implies product performance under adverse conditions. Levis' 501 blue jeans earned this reputation with its early gold-mining customers. EverReady's bunny commercials are designed to convey the durability of its batteries.
- Safety: An attribute of quality that measures the likelihood of harm from a good or service. It can relate to the product itself or its packaging as is the case with safety-cap aspirin bottles. What is safe can be a controversial issue. Is a gun with a safety clip safe? Is it safe to eat the meat of animals that have eaten antibiotic-laced feeds or been genetically modified?
- Environmental Friendly: As is the case with safety, this quality attribute is both a moving target and individual specific. The trend is toward raising the bar as to what is considered an environmentally friendly. Increasingly, firms must focus on how a product is disposed of after its useful life.

- Serviceability: This attribute relates to the ease and cost associated with servicing a product after the sale has been made. Some product precludes service, such as a D-cell battery. But many others do require service and this capability must be both designed into the product and the post-sale service system.
- Aesthetics: This attribute may relate to a product's appearance, feel, sound, taste, or smell. Aesthetics are hard to define, but most people know what they like when they experience it. In that sense, it is customer specific and sometimes situation specific. What is aesthetically pleasing to one individual may be considered ugly to another. The design of a log cabin may be appreciated in a sylvan setting but be deemed ugly in a fashionable suburb.
- Attribute Consistency: The attributes associated with a product should be internally consistent. It would make little sense to build a VW Beatle with airfoils, a turbo-charged Neon, or a biodegradable cigarette filter. Products with inconsistent combinations of features aren't likely to match the needs of their buyers.

To a certain degree, there is overlap between the functionality and the quality input to the value equation. Products with excellent designs will excel in the aforementioned attributes that matter to the targeted customers. These in turn should increase the functionality of the product.

Organization-wide efforts to build and maintain the quality of a firm's product and product delivery system are often called *total quality management (TQM)* programs. Effective TQM programs have been considered the reasons why American businesses have been able to narrow the quality gap with most Japanese made products. These efforts require managers to work to improve quality by identifying areas that offer the greatest opportunity for developing exciting, and unexpected quality. The ways in which firms go about managing for enhanced quality and process improvement will be covered in Shell 12.

Speed

Speed can be an important contributor to an organization's ability to enhance the value of its products. An organization's speed is often measured in two dimensions: how long a customer must wait for the product once it is requested, and how long its takes to design, develop, and introduce new products. When a firm can quickly get you the product, it is said to be *fast to product*. Fast food chains, such as McDonald's, succeed because they have fast to product capabilities. Firms can achieve a competitive advantage if they are faster to product than their competition. Domino's Pizza advertises its 30-minute delivery as its order winner.

When a firm can design, develop, and introduce new products quickly, it is said to be *fast to market.* General Motor's inability to market a product comparable to Chrysler's PT Cruiser may indicate that it does not have fast to market capabilities. Firms operating in industries with fast clockspeeds must possess the ability to be fast along one of these two dimensions—and often along both dimensions.

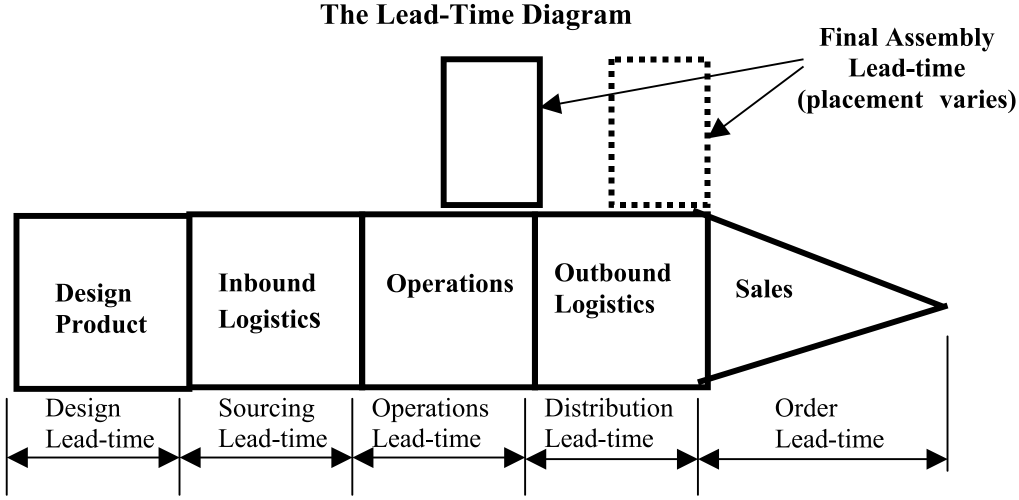
Rather than using rate as a speed metric, many within operations management prefer to use elapsed time. The term most used to measure the "fastness" of an organization is called *lead-time.* Lead-time is used to measure a firm's responsiveness, quickness, and reliability. This preference exists because it is easier to quantify, i.e., it can be defined as the interval between the start and end of an activity or series of activities. Within that interval, the rate at which tasks get done may vary. What most concerns operations managers is "How long will these tasks take?" To illustrate, when a parent asks you how fast you will earn your degree, most of you will respond in terms of years rather than your rate of education.

Operations managers can study *fast to product* lead times in two dimensions. They can look at them as individual events, perhaps evaluating how long the system takes to fill a specific order or design a specific product. Alternatively, they can look at the *distributions of lead times*. For example, an airline manager might measure how long a commercial jet takes to complete a particular flight. Over time, the manager can develop a history of such flights and summarize the information as a distribution. This distribution provides data to evaluate the airline's system in terms of reliability, i.e., what percent of the time will a flight be on time?.

Generally, lead-time reductions enhance value, especially when that performance can be counted on to occur as promised. Hence managers strive to reduce both the duration and the variability of lead-times.

Lead Time Categories: To illustrate the different types of lead-times a product or a customer experiences, consider the following supply chain diagram.

Exhibit 3
The Lead-Time Diagram



To understand lead-time, we need to measure the interval between the start and the end of an activity. Consider the following breakdowns in system lead times.

- Design Lead-Time measures the time needed to design a product. This covers all activities from the moment a firm first recognize a need in the marketplace until it delivers a design for production that is feasible to produce. It may define how long it takes to revise and enhance an existing product.
- Sourcing Lead-Time is the elapsed time associated with procuring the inputs that go into operations process. This includes the following:
  - Time from identifying a component requirement to placing an order: This component of sourcing lead-time describes the time that elapses from the moment managers identify a need until the supplier receives a purchase order or authorization to buy.
  - Time from supplier receipt of the order to delivery: This is the total amount of lead-time the supplier takes from receipt of an order to delivering it.
- Operations Lead-Time. Once the firm has designed the product, selected and scheduled suppliers, and initiated the flow of orders, it must make the product within its operations management system. In manufacturing operations, this is of course called, manufacturing lead-time. This category of lead-time, operations lead-time, can be broken into two major components:
  - Time from receipt of an order to the start of operations: When a customer places an order, a series of events occurs. It starts with recording the order, entering it into the firm's database, verifying it, planning to identify component requirements and their timing and to place orders with suppliers, and scheduling to assign capacity to fill the order and set start and ending times or due dates. The OM system must accomplish all of these activities before it can start filling the order.
  - Time from start of operations to entry into the distribution system: This component measures the lead-time from the moment the OM system begins working on an order until it transfers the finished product to the distribution system for delivery.

Note that Exhibit 3 has a box for final assembly operations lead-time. This denotes that the making of a product often consists of two or more stages -- often a fabrication stage and an assembly stage. As we will see shortly, final assembly can occur during the operations stage or after some of the distribution stages. Some firm's postpone final assembly to enable to customize a product to meet specific customer's needs.

- Distribution Lead-Time: Distribution lead-time measures the time from when the plant finishes the product until that product reaches the customer. This includes time for packing the item, preparing it for shipping, shipping transit time, and receiving at the customer's site. The distribution system is responsible for such activities as warehousing and selecting a mode of transportation.
- Order Lead-Time: This measures the time between when the customer recognizes a need and the time the customer receives the goods. It can be broken down into two components.
  - Time from customer recognition of a need to the placement of an order.
  - Time from shipment of the product to the customer to its receipt of the product.

How long a customer actually waits for a product to be delivered is a function of the *market orientation* that exists between the customer and the vendor.

Dialogue Driver:
Exhibit 3 indicates that the placement of the final assembly of a good may vary. Can you think of three additional examples that you have experienced where final assembly occurs at a stage other than the final stage that is contiguous to the manufacturing operations?

Market Orientation and Fast to Product Capabilities: Whether the customer, the seller, or the maker of the good bears the burden of lead-time depends on the market orientation a firm uses to supply a product. In general, any product has one of four market orientations:

- Make to stock (MTS)
- Assemble to order (ATO)
- Make to order (MTO)
- Engineer to order (ETO)

These four categories describe how, when and where a product provider makes the good and what types of lead time the customer experiences. Market orientation influences the components of the value equation.

- Make to Stock: As the name implies, a seller must stock inventories of previously made products for purchase *whenever the customer arrives*. To meet this availability requirement, firms often produce MTS items based on forecasts rather than known orders. Firms in the distribution channels incur the costs associated with carrying inventory but are able offer end products quicker—provide it is in stock. The goods usually are standard, mature products with few product customization options. As a general rule of thumb, make to stock products compete primarily on the basis of cost and availability. Examples of such products include most retail goods such as breakfast cereals, milk, shirts, jeans, and office desks. With the MTS orientation, the total product lead-time is:

  Total Product Lead-time = Order lead-time
- Assemble to Order: Assemble to order products are standard items that are assembled from in-stock sub-assemblies. This orientation usually allows customers to specify a wide range of options. For example, a Home Depot can "assemble" any color of paint from a base stock, pigments, and a color recipe. By waiting until the customer specifies the exact color desired, the paint store avoids investing in premixed paints. In marketing, this approach is referred to as *postponement*. Successful sellers of assemble to order products must keep their assembly lead-times as short as possible. The total product lead-time experienced by customers buying ATO products is:

  Total Product Lead-time = Order lead-time + Assembly lead-time

If the assembly occurs at the factory, then the total product lead-time would include: distribution lead-time. With the ATO orientation, the firm absorbs the cost of time to design the product, select suppliers, order raw materials and components, and assemble components from inventory.

- Make to Order: Make to order products are made from previously engineered designs, but only are made after an order has been received. MTO is used when a standard product is: too costly to stock, has too uncertain demand, or will deteriorate if stocked on a shelf. Examples of goods made using the MTO market orientation are: commercial airplanes, a copy of an obscure document, and an exquisite French meal. The lead time a customer experiences with MTO products is

  Total product lead-time = Order lead-time + Distribution lead-time + Operations lead-time

  Whether or not supplier lead-times must be added to the above depends on whether or not the firm can and will stock raw materials in anticipation of orders. The company saves by not having to commit resources in production until a firm order is received. But MTO places factory workload at the mercy of the rate at which customers place orders. This may mean that the factory will experience alternating periods of being busy and idle.
- Engineer to Order: This market orientation is used to make unique products that have not been previously engineered. Extensive customization to suit the customer's need is possible, but only if the customer is willing to wait for this addition stage in the value creation process. Examples of ETO products include: a customized product maker, an oil tanker, specialized industrial equipment, and a hand-built bicycle.

  A producer of ETO products must wait for customers to place orders before beginning any activity. As a result, the customer bears the entire cost of the total product delivery lead-time. In other words, the external lead-time often exactly equals the total product delivery lead-time.

Many service systems operate on a MTO or ATO basis, in part because it is not possible to inventory the product being requested. Many restaurants stock ingredients in anticipation of a customer's arrival but must await a request. Whether the meal is engineered to order or made to order will depend on the degree of meal customization the chef practices. When the chef uses a recipe, then you have experienced a MTO meal. Burger King's "have it your way" slogan reflects the assemble-to-order approach. Prior to 2001, when you ordered a Big Mac, you experienced McDonald's make-to-stock service. *

Some competitive situations allow *do-to-order* systems, i.e., MTO, ATO, or ETO, to add another delay which is called a *backlog*. When orders are placed, these orders may be placed in a queue in which it waits until the firm has the productive resources to start making the product. When business is good, backlogs may be extended—when things start to slow down, the backlog shrinks. Firms are able to do this, in part, because customers want a particular product and are willing to wait. Early in its product life cycle customers wanting a PT Cruiser were willing to wait. Yearlong backlogs were common. Companies backlogging orders do so at the risk of losing a customer as the uniqueness of the product fades.

The ability to be *faster to product* than your competitors can give a firm a competitive advantage. In August of 1999, Toyota announced that it would be able to make its Canadian assembled Camry customized to a customer's order in five days. This is about 15 days less than most American car companies can achieve. Does this mean that Toyota's use the ATO market orientation will give it a competitive edge? It depends. How many customers really want customization? Would you be willing to wait a week when Honda dealers have ample cars in stock? It may give Toyota the capability to sell customized cars over the Internet much like Dell currently does with computers. Might we live to the see the day when UPS delivers cars?

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* Product freshness issues forced McDonald's in 2000 to change to an assemble-to-order market *Business Week* suggest that this market orientation change might be reducing profits because it was experiencing a lower sales/labor ratio.

On the other hand, the car sales force may not use this option since salesmen are loath to let a customer leave the premise without the car. They may have second thoughts. To the salesman, *a car not delivered is a car not truly sold*. GM's Cadillac Division tried positioning cars at regional depots, but the program was not successful because its dealers' sales force claimed "their customers wanted to drive their newly purchased cars home."

Dialogue Driver: Can you think of another instance where the "values" of the distribution channel might thwart a firm's plans to market a new product and/or to market it in a different fashion?

Product Development Lead Times: Being able to design, develop, and introduce a new product quickly was defined earlier as giving a firm *fast to market* capabilities. There are two types of fast to market activities. The first relates to being able to developed products to meet the specific needs of a customer. This is called *fast to customization*. Being able to quickly design a customized product, perhaps with the participation of the customer, may give your firm a competitive advantage.

The second type relates to developing products to meet the needs of a cluster of customers. *Fast to design* product innovation can be used in MTS, ATO, and MTO market orientations. As GM develops its response to market hits, such as the PT Cruiser, it will design a car for a cluster of perceived potential customers. In other situations, being fast to market may not be less important. It depends on how quickly a product's design becomes stale. Mercedes-Benz traditionally had customers that valued good design more than a model year.

For some products, being fast to market may not be in your firm's best interest. A creative advertising executive always makes his clients wait a week or two, even though he thought of the copy for the ad in a day. Likewise, if a gourmet restaurant that serves your meal five minutes after you order, you *know* that they must be using a microwave oven. They may be, but if they make you wait 30 minutes, you will never know.

Another way to bring customized products quickly is to use *modular designs*. In the fashion world, this is called mix and match clothing. In manufacturing, assemble to order systems allow the customer to specify a need and then either the customer or the vendor selects pre-engineered sub-assemblies to meet a customer's need. The product then is either assembled or shipped as a kit to the customer. This is the system that Dell uses. A wider variety of end product options is possible but within certain limits. Even Burger King limits the number of ways you can have it *your way*.

Another important type of product innovation involves refining or rejuvenating products within the existing product line. For some companies, this is an annual event, such as is the case with the automotive industry. Major redesigns in the automobile industry can take years and costs billions. This becomes a catch-22 situation. Because it costs so much to develop new models, auto companies often try to sell as many copies of the new product as possible, even if it takes four or five years. But the older a car's design gets, the greater the chance that it will lose market share to competitors with fresher models. And worse yet, if it takes five years to develop a new model and you want to sell that model for another five years, your firm must project what your customers' preferences are likely to be ten years from now. This is a challenge.

In Shell 9, we discuss ways in which leading edge firms have become fast to market. At this point, we just want to stress that along with supply chain management, a firm's product innovation process is one of the most important activities of the firm--too important to be solely left to engineers.

Timeliness

In the previous section we discussed organizational speed. Any football quarterback will tell you, speed is nice, but it is more important that your receiver get free at the right spot and the right moment. Timeliness, while related to speed, is different. *Timeliness is the ability of a firm to get the right product to targeted customers at the most desirable time.* It is a factor individuals use to evaluate the performance of those offering products. They might not care how long it took to deliver or how long it took to get it suitably positioned in the market channel. They just care that it is ready when they want it.

As a student, your willingness to purchase a course textbook quickly declines if it is not available during the first week of class. The value of a hot-house-grown tomato is much higher in January than in August when many consumers are able to harvest their own homegrown tomatoes. In other instances, timeliness may relate to the ability of a vendor to design and develop a new and better product to serve customers. For a seller, the importance of timeliness increases whenever the consumer has alternatives for a desired product.

The importance of timeliness in the value model varies because it is both individual specific and situation specific. We all know individuals who just can't wait. They clearly will forgo any transaction in which they must wait for a product.

> **Dialogue Driver**: Can you think of three situations when you wanted something right away but since the good or service was not immediately available, your want disappeared?
> How can a business measure these lost sales?

Delivery reliability should be considered an integral part of timeliness. When customers are told something will be in stock, they place value in that promise. When customers are told a product will be delivered on a specific date, they value the product higher when that promise is kept. Anything less diminishes the value of the firm's product.

Delivery reliability also enables the supply chain to operate effectively with lower levels of inventory. This is because some stock is held to protect against uncertainty. In many cases we need inventory to cover demand uncertainty. This is not waste. But what is wasteful is to carry additional inventory to buffer against supply uncertainty. More reliable deliveries lessen the need for *just-in-case inventory*.

Flexibility

Flexibility is the input to the value equation relating to the ability of the OM system to give the customer the product desired. With make-to-stock market orientation, flexibility is the ability to provide the customer sufficient finished good choices. Most customers like that. With the three do-to-order market orientations, flexibility relates to the ability of the system to create products capable of meeting a customer's need. This becomes a necessary condition for customer satisfaction, but speed, timeliness, and/or cost factors might negate the possibility of a sale. Being able to make the right product too late can kill the deal. Having the right product at a cost that you cannot afford also will be an order loser.

It is easy to say that a system needs to be flexible enough to satisfy the needs of customers. However, designers of OM systems need to understand *which type of product variety the customer needs*. Clearly what the customer wants can impact both the firm's product innovation system and its supply chain management system. In Exhibit 5, we suggest a framework for addressing the design issues in each area.

Exhibit 5
A Framework for Designing for Flexibility

Product Innovation Issues

- Who are the targeted customers and what *range of choice* are they likely to want?
- How long are they willing to wait before receiving the product?
- Do they want and are they capable of participating in the product design process?
- How important is it to maintain "product freshness" in this marketplace?
- How quickly might the firm have to adjust to new competitive products?
- How important will new technologies be in future product design and development?

Supply Chain Issues

- Which market orientation will best match the value profile of the targeted customers?
- Which segments of the supply chain provide core competencies to the firm?
- Which segments of the supply chain are possible candidates for outsourcing? Why?
- Within the supply chain, which market orientations can provide the firm with the appropriate product flexibility range? What are the tradeoffs with the other value inputs?
- Which facility locations provide the needed product flexibility? At what cost?
- Which supply chain transportation options provide the needed product flexibility? At what cost?
- Is the investment in supply chain facilities consistent with the pace of change in the industry?

Shells 8 and 9 deal with the product innovation issues and Shell 10 deals with the supply chain issues. We introduce the framework here because we want you to start thinking how each of these issues relates to the value concept. Product and system designers can go overboard trying to be customer-oriented. If you don't know what the customer is likely to want, spend some time and money to find out. This is often a lot cheaper than building in just-in-case flexibilities or inventories of unwanted products.

Consider the following the types of flexibility that an operations systems can provide.

Exhibit 6
Types of Flexibility Found Within Operations Systems

- <u>Mix flexibility</u>: The ability of a system to present a wide range of products or variants with fast setups.
- <u>Changeover flexibility</u> : The ability of an OM system to introduce a large variety of major design changes quickly within existing facilities.
- <u>Modification flexibility</u>: The ability of the transformation process to implement minor product design changes, quite possibly after the product has been delivered.
- <u>Volume flexibility</u>: The ability of the transformation process to profitably accommodate variations in production quantities. Systems with high fixed costs beget inflexibility since the firm will always be striving to maintain high utilization rates.
- <u>Rerouting/program flexibility</u>: The ability of the OM system to respond to factors of product shortfalls, such as equipment breakdowns, labor absenteeism, or a delayed raw materials shipment.
- <u>Material flexibility</u>: The ability of transformation processes to adjust for unexpected input variations.
- <u>Flexibility responsiveness</u>: The ability of the firm and its managers to change strategic objectives in response to changes in the marketplace.

Each time a firm considers additional investment in plant or equipment, the firm should first address the above process flexibility issues. Selection of methods to improve flexibility should reflect how the firm competes. Each type of flexibility generates value differently, so a firm should emphasize categories of flexibility that customers value most. No firm can excel on all seven dimensions of flexibility.

Enhancing flexibility requires cooperation both inside and outside the firm. For example, a suitably designed product greatly enhances the ability of the operations manager to implement and compete using product modification flexibility. To emphasize volume flexibility, a firm needs the support of suppliers. Success in enhancing mix or changeover flexibility depends on strong links with the internal marketing function and with customers.

Lastly, we must realize that improving flexibility can affect the other elements of value. Flexibility affects lead-time and quality through the synergistic relationships among the three elements of the numerator of the value equation. Reductions in lead times affect flexibility; improvements in flexibility benefit quality; improvements in quality reduce lead times and enhance flexibility.

Dialogue Driver:
If the customer for a process is an internal customer, i.e., the operator of the next stage within one of the parts of the supply chain, should its needs for flexibility be included? If so, can you think of a situation in which the flexibility needs of an internal customer might result in an increase in the supply chain's effectiveness even though the end-use customer is unaware of it?

Cost

Having explored the numerator of the value equation, we now turn to the denominator. Operations managers evaluate cost, measured in dollars, for its contributions in two important roles: enhancing value and serving as a performance metric for evaluating business processes. Of these, most people are familiar with the second. Indeed, a major problem with prior operations management thinking has been its emphasis on cost reduction. This remains an important element of the value equation but business processes must be evaluated through the lens of the consumer.

Accounting uses cost as both a common unit of measure and a means of comparing two different operations management systems. Analysts can draw conclusions about a unit's performance by looking at either the costs it reports or the profits it generates. Cost information supports comparisons even between systems that produce different outputs and compete in different ways. Furthermore, managers can identify potential operating problems by looking at cost variances (differences between actual and standard costs).

<u>Measuring Costs and Identifying Waste</u>: In this course, we are most interested in enhancing value. Cost reductions often translate directly into increases in value if they outweigh changes in performance. Like the other inputs to the value equation, the costs are composed of a variety of different elements. For example, the costs relevant to the purchase decision could include one or more of several categories:

- Acquisition cost: The purchase price of a car, for example
- Repair costs: The cost of replacing a broken part
- Maintenance costs: The cost of oil changes and tune-ups
- Operating costs: The cost of gas and tires
- Salvage/resale costs: The cost recovered upon selling a car
- Disposal costs: The cost of disposing of a wrecked car

Furthermore, managers can break down costs to express them quantitatively (measured in dollars) or qualitatively (evaluating subjective effects).

Marketers know well that people like to buy things cheaply, but they do not like cheap things. This statement describes both the major attraction and the problem of emphasizing cost as the firm's major source of value. Customers want at least the same performance for a lower cost, not simply less for less. A cost-driven approach to value treats performance as a given and focuses on reducing cost.

To achieve this objective, the operations management system must reexamine both the product it is selling and the processes it uses to deliver and service the product. It seeks to identify product features that customers do not value highly or processes or parts of processes that contribute unnecessarily to cost. Any activity that does not add value is either waste or a necessary support activity. Unnecessary product features and process activities that don't add value are *waste*—these thereby become candidates for elimination.

Using a waste reduction approach helps reduce the potential for abuse by excessive emphasis on cost reduction. Cost reduction programs that ignore the negative effects on lead-time, flexibility and quality will not enhance a firm's competitiveness in the long run. For example, to lower cost, a firm might use cheaper material that reduces quality. In the short term, these changes do save money, but over the long haul they reduce the ability of the firm to deliver a product consumers value. They may buy once, but not thereafter.

Another form of waste is when corporate resources are used making, marketing, and servicing products that do not contribute adequately to a firm's profitability. A customer may value a firm's product because it is selling it for less than a cost-savvy competitor's price. It is fundamental that a firm knows what it costs to make, deliver, and service a product. It should know both the unit profit and the total profit for each product and product line it sells.

Customer service costs pose a problem for cost-conscious managers because they can see the expenditure but may not be able to see the value delivered. Any marketing person will tell you that it is cheaper to keep a good customer happy than to win one of your competition's good customers. Unless the firm's performance metric system is able to measure customer satisfaction, it risks being penny-wise and pound-foolish when it comes to measuring customer service costs. Marketing uses a concept called the Lifetime Value of a Customer in which it estimates the stream of income a firm can expect to receive from a satisfied good customer. This is a most useful orientation in that, like value, it forces all within a system to focus on keeping customers satisfied and coming back.

A major problem in many corporate accounting systems has been that overhead costs are precisely applied to the products that they support. Effective performance measurement requires each product to bear its fair share of all costs incurred to create, make, sell, and service it. Direct costs pose no major problem; managers simply record all of the labor, materials, and other resources used by a product. However, assigning overhead costs becomes more difficult. Unlike direct costs, these costs seldom vary with changes in output.

In the past, overhead costs did not pose major problems because they were smaller, i.e., labor costs accounted for much of a typical firm's costs. However, this situation has now changed. For one, labor has come to account for a smaller percentage of total costs, in some industries, less than 5 percent of total cost. In faster paced industries, larger investments in product development, process automation, and information have raised fixed costs. An IBM ad noted that 75% of all IT dollars go into infrastructure.

To overcome the problem of assigning overhead costs, accountants developed activity-based cost accounting. ABC tries to trace costs to specific goods and services rather than arbitrarily allocating them on the basis of some universal measurement unit such as labor hours or machine hours. It seeks to identify *cost drivers* that reveal the sources of costs for products and services.* Exhibit 7 illustrates some cost drivers.

Exhibit 7
Cost Drivers for Activity-Based Costing

Activity	Cost Driver	Rate
Material handling	Number of components	$0.25 per component
Engineering and design	Hours of engineering services	$100.00 per hour
Production setup	Number of setups	$55.00 per setup
Assembly (automated)	Number of components	$0.75 per component
Inspection	Hours of testing	$60.00/ hour of testing
Packaging and shipping	Number of orders	$4.50 per order shipped

Proponents claim that ABC helps firms to respond to changes in their product mixes, technologies, and processes. ABC forces managers to focus on activities that create costs rather than on end products. Activities for which no product or business process accepts as a necessary cost may be waste.

POSTPONEMENT, DELAY, AND VALUE

When an activity is done and where a good is placed can have a significant impact on a firm's value delivery system. In the above sections we described four different market orientations. The three *do-to-order* orientations involve a conscious decision to *postpone* doing a product transformation activity, thereby causing the customer to wait for the product. This type of postponement is designed into the system in order to enhance product flexibility and resource efficiency. The system is more flexible because by waiting for the customer to decide what it wants, the firm can offer a wider range of product. The efficiency of the system is enhanced because the firm expends resources to make goods when it knows that it will be sold. This cost to the customer of this product flexibility is increased lead times. When these delays are intended to enhance the value delivery capabilities of the system, this is called *product postponement*. Delays that are the result of poor planning and/or unreliable execution are called poor performance. This often leads to customer dissatisfaction.

A second kind of postponement occurs when a firm defers stocking goods close to the customer. Rather than guess when and where a pre-designed good will be wanted, some companies elect not to place inventory at a location where customers take possession of them. In the make to stock market orientation, this type of postponement enables firms to respond to particular unanticipated demand for the product. When done well, the result is a better utilization of a firm's resources without unduly reducing customer service. Advent of quick package delivery services, such as FedEx, may make this option acceptable to customers. This second type of postponement is called *placement postponement*. Other forms of purposeful delays occur in operations management, but these are the two practitioners normally are referring to when the use the term, *postponement*.

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* ABC is a term used in many situations within the business world. It is a common practice to classify the items a firm sells by their sales volume or value attributes. So all ABC systems are not activity-based accounting systems..

VALUE AND TECHNOLOGY

In the first shell, we alluded to the need for strategic planners to wear many hats, one which focuses on serving the needs of existing customers and a second to scout the horizon to guard against new competitive threats. This if often easier said than done. In his book, *The Innovator's Dilemma*, Professor Clayton Christensen helps explain why first rate companies that listen to their customers are not able to respond to new competitors who use *"disruptive" technologies*. Christensen uses the advent of the diesel railroad locomotive to illustrate how disruptive technologies "sneak up" on the haves until it is too late for the previously dominant firms to respond. When the diesel locomotive was introduced, it really could not match the performance of the steam locomotive. Baldwin, the leading locomotive manufacturer, scoffed at this upstart and proclaimed, "They will never replace the steam locomotive!" And they didn't for quite a while. But little by little, diesel locomotives improved and before Baldwin knew it, diesels had the lion's share of the market by 1950. By then it was too late for Baldwin to respond. Sound familiar? Recall Schwinn and think what other disruptive technologies that you have witnessed in your day. Exhibit 8 provides a list, but I am sure that you can expand on it.

Exhibit 8
Disruptive Technologies: Winners and Losers

Dominant Firm	Product	Disruptive Technology	Winning Challengers
GM and Ford	Small cars	Japanese quality & manufacturing expertise	Toyota and Honda
Gillette	Razor blades	Stainless steel technology	Wilkensen
Gillette	Cheap razors	Plastic technology	Bic
Parker	Fountain pens	Ball point pen technology	Bic
Swiss watchmakers	Time pieces	Lever-action watch technology	Timex
Timex	Watches	Electronic technology	Casio, etc.

In each case, the established companies/industries saw the emerging technology coming, but they failed to take the threat seriously. This is difficult to do when it requires a firm and its management to consider walking away from its investment in plant, equipment, and intellectual capital. But if your firm doesn't do it someone else will, so cannibalizing your core competences makes sense.

In this course, we prefer to expand this concept to include other forms "disruptive" forces, such as new supply chain structures, new organization forms, and even evolving sociological forces. Dell Computer introduced a superior way to sell to high-end personal computer. It was able to succeed in this endeavor because it developed a good product but a world-class supply chain system. Compaq was locked in with its superb dealer-based product distribution system. It saw Dell coming, but its loyalty to its distribution partners made it difficult for it to imitate Dell's approach--until it was too late.

Firms need not be blindsided. Bill Gates of Microsoft was caught temporarily off-guard by the Internet, but as soon as its Windows 95 project was completed, he marshaled his resources to respond to Netscape's threat. In 1999, Intel was caught off guard by the shift to under $1000 computers and its market share in this end of the CPU market fell to less than 50%. But not for long because Intel quickly responded with its competitively priced, Celeron chip. Soon after National Semiconductor got out of this market.

Clearly, the need to wear many hats increases with the pace of change within industry. *The innovators' dilemma is that market leaders must continue to listen to its existing customers, but if you listen to them too much, your firm will miss out on the next wave—remember, we are on a beach.* An example of a firm that has effectively cared for its existing customers while remaining organizationally flexible enough to adapt to disruptive technologies is Hewlett-Packard's computer printing business. When its folks first looked at ink-jet technology, it clearly was inferior both in performance and profitability to HP's dominant laser printer business. In fact, Christensen noted that the laser printer business referred to the upstart proponents as "ink spitters." There was no way that the ink jet business was going to grow within HP's existing organization structure. Recognizing this, HP separated the ink-jet business both organizationally and physically from its laser business. It then encouraged each business to "have at it." Both technologies have found their place in the marketplace and almost 40% of HP's profits are the result of its printer cartridge business.

Are they smug? Not really. In 1999, HP noticed that e-Machines, an upstart with less than 20 employees was sweeping the low cost market for personal computers. In its first year, this upstart sold more than million computers, albeit unprofitably. It didn't take a creative genius to see that disruptive organization structure might soon be threatening HP's printer business. Hence, it created a separate Apollo printer group with less than 50 employees to produce $49 dollar computers, which of course used special HP cartridges. It is beginning to look more like the razor blade business than the computer business. Stay tuned--the Bic printer may be coming.

SUMMARY

In this shell, we introduced the concept of value that should serve as the driver for both a firm's product innovation function and its supply chain management function. The value-driven approach requires all within the operations management function to adhere to a performance standard to measure how well each business process supports customer-focused business strategies. One way to do this is to recognize the subjective nature of the value equation. This forces the operations manager to move away from the one-size-fits-all mentality—a mentality that was developed in an era in which mass manufacturing was the means to America greatness. Now the customer is king and his or her realm is a rather small. This means that our business processes must be flexible and adaptable enough to cater to the needs of each small kingdom.

The concept of value requires a firm to develop a precise, explicit definition of what and how the firm intends to compete for market share. One cannot, for example, simply say that the firm will compete on the basis of flexibility. The earlier discussion outlined many different dimensions of flexibility. A decision to compete on flexibility defines an overall orientation and focus, but it demands elaboration to specify the type of flexibility on which to base competition. Only by specifying plans precisely can the operations manager and the OM system deliver the product promised by the firm and desired by the customer.

A firm's definition of what mix of value components that it intends to deliver defines the types of processes it builds, the investments it makes, the control systems it implements, and the way it measures performance. Without such clear and detailed definitions, the operations manager runs a very real risk of investing in unsuitable systems and processes that fail to deliver value as defined by the customer.

While pleasing the customer is the major objective, the operations manager must always be thinking about tomorrow. Customers can be moving targets. Technologies change. And a firm that you had not considered a competitor may be one tomorrow. Care needs to be taken to ensure that customer-relations processes that maximize their ability to quickly spot changes in the market place. If your firm does not get there first, you can be assured that some other vendor will be there quickly. Yes, a dose of paranoia is helpful.

References

1. Melnyk, S. A. & D. R. Denzler, *Operations Management: A Value Driven Approach*, Irwin, 1996, Chap. 2 & 3
2. Clayton Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fai*l," HBS Press, 1997.
3. Bradley Gale, *Managing Customer Value: Creating Quality and Service That Customers Can See*, Free Press, NY, 1994.

Expected Learning Competencies

Before putting Shell Two down, you should ask yourself the following questions. Am I able to explain:

1. How individuals and business transforms their needs, latent and otherwise, into wants and ultimately into demand.
2. What the model of the value equation is and how it can be used by a business to re-enforce the need to have all functions the firm focus on the needs of the customer.
3. How the needs of internal customers influences how a business unit is structured.
4. How each of the components of the value equation and how each is conceptualized and measured within a business.
5. The differences between programs that make a firm *fast to product* and *fast to market*.
6. How postponement can be used to offer either an internal or a end use customer greater value.
7. What Christensen's *Innovator's Dilemma* is and what the concepts of sustaining technologies and disruptive technologies are. Also be ready to illustrate examples of each.
8. What your instructor added to this shell and why he or she thought that it was important enough to warrant its inclusion.

Frequently Asked Questions

Instructors have been known to ask questions similar to the following:

1 You must design a product for a market segment in which group norms strongly influence individual behavior. How might this fact alter the structure of your value chain? Start by identifying the group to which your answer refers.

2 In America, the bride normally purchases her wedding dress while the groom usually rents his tuxedo. Use the value model to explain the differences in their behavior?

3 What value attributes do the following terms impact and how might each impact your decision to purchase that item?
   a. A personal computer with an "Intel Inside" label
   b. An automobile with a made in Mexico sticker
   c. A hair dye without an "animal friendly" label
   d. A newspaper that is known to use a high percentage of recycled product.

4. Which of the following products uses postponement to increase product flexibility?
   a. Hamburger meat purchased at a Safeway supermarket
   b. A White Castle hamburger
   c. Frozen White Castle hamburgers
   d. A Whopper purchased at a Burger King
5. Value is customer specific.
6. When a firm is able to develop new products faster than its competitors, it is said to be fast to product.
7. A firm uses the make to stock market orientation when customers demand fast to market capabilities.
8. The Innovator's Dilemma occurs when a firm does not see the arrival of a new technology.
9. A firm cannot be both fast to market and fast to product at the same time.
10. As a firm's market reach expands globally, it normally will need to enhance its product flexibility.

SHELL THREE

BUILDING THE CAPACITY TO DELIVER VALUE

Why Not?

A few years back, I was lying on Laguna Beach checking out the scene. On a bluff overlooking the beach was a house with a splendid view. I asked my wife, "Who do you think owns that house?" Her response was: "How would I know" and returned to reading her book. I set out to find out.

It turned out that, Geoff Fox, the current owner of the house, was a "victim" of process thinking. A few years earlier, he had been an early promoter of what came to be known as motocross racing—a sport in which fans watched talented dirt-bike racers compete on dirt tracks with hairpin turns and moguls. Fans had to love this sport because they were traveling 100 miles into the desert to watch races sitting on temporary bleachers, using portable toilets, and eating snacks from vending trucks noted for their factory gate menus. But the fans came in droves.

One weekend, |Fox was at the LA Coliseum watching the Rams football team play on artificial turf. He also took note of: the 100,000+ seating capacity, the quality of the food vendors, and the relative cleanliness of the public restrooms. He mused, "Wouldn't it be neat if we could stage our motocross racing events here?"

That thought kept reoccurring during the second half of the football game. Why not? Over the next two weeks, he reviewed the schedule of events at the Coliseum and noted that on many weekends, there were open dates. He explored the economics of building and removing dirt tracks in an urban setting. Once again he asked "Why not?" The numbers looked attractive.

Imagine the look on the face of the stadium's management when this young man presented his offer to rent the Coliseum for use as a motocross race site. But Fox had an answer for each question. He guaranteed that the stadium's artificial turf would be restored to its original condition three days after the event.* He showed a letter from a bonding company eliminating the financial risk. And his passion convinced stadium management that this youthful entrepreneur could pull it off.

Soon stadium management was saying "Why not—what do we have to lose?" They had a facility with high fixed costs and now an opportunity to gain additional revenue. The rest is history. Fox Racing has gone on to be the leading promoter of motocross racing. Visit www.FoxRacing.com to see what it has become. Or visit Laguna Beach and look up on the bluff and ask, "Why not me?"

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* In order for Fox Racing to be able to make this guarantee, it has developed a unique process capability—the ability to haul in truckloads of dirt, craft it quickly into a dirt track, and then afterwards, remove the sixty or so truckloads of material *carefully*. It hires the best heavy-duty construction equipment operators and pays them six figure salaries to perform their craft about six times a year. You might ask, "Why college?"

Shell Three

Building the Capacity to Deliver Value

Table of Contents

Shell Three Learning Objectives

After reading this shell and thinking about its contents, you should be able to:

1. Understand the important role capacity plays in enabling operations managers succeed or fail in their bid to achieving the firm’s strategic objectives.
2. Understand the concept of capacity and the four major issues that the long term capacity planning process must address.
3. Understand the concept of capability and the way this concept is used in a value-driven system design process.
4. Be able to define and provide an example of the following concepts:
    a. Product based capability metrics
    b. Process-based capability metrics
    c. Knowledge-based capability metrics
    d. Societal-based capability metrics
5. Understand the concept of a performance metric and be able to describe its role in the value-driven system design process.
6. Describe the various types of performance metrics and how performance metrics should be evaluated.

INTRODUCTION

Developing the capacity to win the wallets of customers is the essence of entrepreneurship. What Geoff Fox saw as he watched the Rams play football on Astroturf is only part of the challenge. His biggest challenge was to bring together the resources needed to pull off his dream and then to sell that dream to a skeptical stadium manager. The result was a service that offered motocross fans a better value.

The ability to deliver value from a set of resources is what operations managers do. In some cases, it involves creating new value delivery systems, such as a factory or a service institution. But in most cases, operations managers are responsible to deliver "something" to customers. Their ability to keep existing customers pleased or to win new ones is their ultimate performance metric.

As customers, we all have been victims of capacity mismanagement. The possible root causes for this displeasure are many, but they can be categorized as: *system design failures* and *system execution failures*. System design failures occur when the business processes are incapable of providing the good or service the customer wants in a timely manner. In the motocross business, having earth-moving equipment with precise blade control made Geoff's dream possible. Without the earth moving capability, no amount of dreaming will get it right.

A second type of system design failure occurs when the needs of the market shift and the firm fails to adjust its capabilities accordingly. In some instances, customers shift by themselves. But in most cases the actions of a competitor or some other external force render your previous product less valuable. Once Fox offered motocross racing in urban stadiums, the attractiveness of the outback venue was diminished.

In other situations, the cause of our displeasure is inadequate execution by some part of the operations function. Operations managers might have been given a bad forecast or key workers may have been absent. The fact that the operations function's shortcomings are caused by the shortcomings of other business processes offers little consolation to customers, but we need to know this if the problems are to be resolved.

A common system execution issue relates to understanding how much of each key resource is needed to operate the system at the needed level. Rightly or wrongly, the parties within the supply chain often blame inadequate performance on a lack of capacity. The pleas of operations managers that "We need more people, more equipment, or warehouse space" are quite common. Senior management often retorts that operations managers need to make better use of the resources they have. To quote Luke's prison guard in *Cool Hand Luke*, the classic movie, "What we've got here is failure to communicate."

Defining Capacity and Capability

Thus before we proceed, it is useful to specify exactly what we mean by capacity.

> Capacity is the ability of an organization to design, procure, make, market, deliver, and service the desired quantities of desired product in a timely manner.

This definition extends beyond the firm's legal boundaries and beyond the supply chain into the other core business process areas. This definition broadens the OM's meaning of capacity in three ways. The first is that it is customer focused. The goal of capacity planning is to assure *the entire supply chain* will be able to serve the needs of targeted customers. This focus requires supply chain system designers to be mindful of all potential bottlenecks--not just those found within the firm's legal boundaries. From a customer's perspective, the cause or location of shortfalls does not matter. These just sound like excuses to the customer.

Secondly, this definition of capacity includes the product innovation process. It would make little sense to design a product if the factors of production are not available or capable of making the designed product. For example, one would not build a power plant unless it had a reasonable expectation of having access to adequate coal, oil, or natural gas supplies and the ability to build a plant that met environmental standards. Likewise, the rate and sophistication of new products should not outstrip the ability of the sales and distribution channel to market and service new products.

The third facet of this definition creates two distinct, but related, capacity performance measures. The first measures the ability to design, make, and distribute the right products to targeted customers in a timely manner. The second measures the likelihood the firm will have the needed factors of production in sufficient *quantities* to produce and distribute goods and services in volumes the firm is likely to experience. The first question asks, "Do we have the *right stuff*?" while the second asks, "Do we have *enough of the right stuff* to achieve anticipated operation levels?" The first refers to *capability. We define capability as the ability to design, make, and distribute products reliably and with sufficient speed to satisfy target market customer needs*. The second refers to *capacity. We define capacity as the ability of the system to deliver products at the desired rate or volume per period.*

Dialogue Driver: Think for a moment how you use the term capacity. When you say that someone has the capacity to ________, are you saying that he or she is capable of doing _______?

In the following material please try to remember that our use of capacity and capabilities are tightly defined. This might help minimize confusion.

At each stage of the supply chain, the "right stuff" and the "enough stuff" questions must be asked. Inadequate "right stuff" signifies a weak structural link that requires corrective action to enhance a system's effectiveness in meeting the needs of its customers. When a link in the supply chain lacks "enough stuff," this necessitates either: additional investment in the unit's capacity, a search for alternative sources of the needed factor of production, or a recognition that the firm will not be able to satisfy all customers.

Dialogue Driver: Can you think of a situation where a firm should not try to meet all customer demand?

Managing capacity within a firm must be done both on a short and a long-term basis. In this shell, we deal mostly with long-term capacity management. Short-term capacity management is covered in Shell 11 (Short Term Operations Planning). We will refer to the short-term planning and control activities as the *capacity adjustment process* and long-term system design planning as long-term *capacity planning process.*

The long-term capacity-planning problem must address four "right-stuff" issues:

1. *Capacity sizing*—how much should the firm plan to be able to make?
2. *Process choice*—what type of manufacturing or service providing process make the most sense?
3. *Facilities location*—where should these facilities be located?
4. *Capacity-investment/divestment timing* -- when is the best time to make these investments?

While each is discussed separately in Shell 7, resolving these issues clearly must consider the impact on the other areas. Decisions made in each area must be internally consistent with the firm's strategic goals.

In designing a system, the targeted customers' values should determine the capability specifications for the firm and its supply chain. One issue that must be defined by strategic planning process is the intended buyer-seller relationship. If a firm promises its customers that "they have the right to expect that their orders will be delivered within one business day," then one performance metric must be *on time delivery*. Such clearly is the case with Federal Express.

If however, a firm's intent is to sell its goods as a commodity in a spot market, then the firm's obligation to have sufficient capacity is less critical. In this case, the producer should try to operate its facilities at the highest possible capacity in order to be able to compete as a low cost producer. In 2001, the nation witnessed the folly of previously regulated electricity producers trying to operate its plants at the highest possible utilization levels. Energy traders, such as Enron, sought to maximize the nation's energy resources with elaborate energy trades in these newly deregulated markets. In theory, this system could have worked but usual mitigating circumstances resulted in a colossal capacity management disaster.

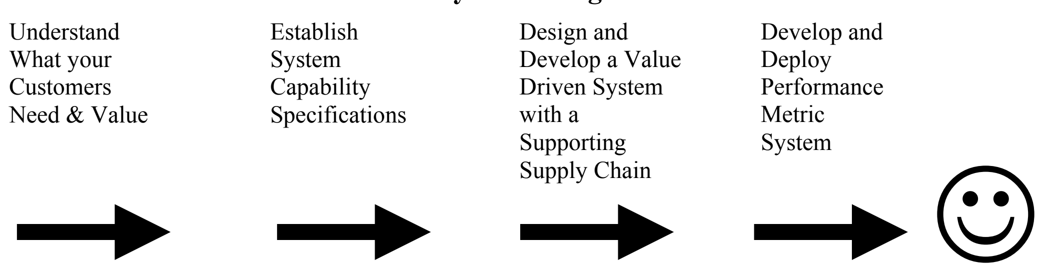
From *the Innovator's Dilemma*, we learned that even firms operating in a single business find that they may be forced to manage multiple operating systems in order to fend off emerging technologies. For example, Barnes and Noble, the book retailer, was forced operate both retail stores and its BN.com. Both sell books but the values of the individuals it serves in each business are different. Hence, the operating characteristics of each must be designed to serve the needs of these market segments.

THE CAPABILITY PLANNING PROCESS

We start our discussion with the "right stuff" issue because the value driven approach to operations management demands that all elements of the value equation be considered when designing products, the product delivery system, and the supply chain in which value generation occurs. Understanding what the targeted customers consider order winners and order qualifiers helps the system designers to understand better the tradeoffs between functionality, quality, speed, timeliness, flexibility, and costs. *Capability planning defines the performance specifications the firm's business processes must achieve if it is to successfully win over the targeted customers.*

The process used to develop the capabilities in a value-driven organization is quite straightforward. It simply starts by developing a thorough understanding of who you want as your customers and what it will take to satisfy their needs and win them as customers. This process is outlined in Exhibit 1.

Exhibit 1
A Value Driven System Design Process



When properly focused, *capability specifications* in effect define the competitiveness of the enterprise. A proven capability with strategic importance is often referred to as *core competency*. When evaluating a supply chain, it is important not to equate each capability as being a core competency. Some business processes *add* value, while others *enable* the value-adding activities within the supply chain. *But only those capabilities that provide the firm a distinct, competitive advantage qualify to be called core competencies*.

Given their importance, it is useful to classify the capabilities of a business unit as follows:

- Product-based capabilities: The ability of the business unit to provide a good or service with value attributes consistent with the strategic initiatives.
- Process-based capabilities: The ability of the business unit to manage its value adding and business-support processes in a manner consistent with the strategic plan's performance metrics.
- Knowledge-based capabilities: The ability of a business unit to grow and extend the knowledge base that supports existing and future product and process-based capabilities. This should be mapped against the future growth plan the enterprise envisioned in the strategic plan. Knowledge-based capabilities fall into two areas. The first is knowledge of the customers and consumers in your markets. The second relates to the technologies needed to support product-based and process based capabilities.
- Societal-based capabilities: The ability of each business unit within the supply chain to withstand the scrutiny of environmental and ethical audits.

A capability that can easily be copied by your competitor is not a core competence since it will not provide a lasting competitive advantage. It may be a necessary capability for success but it is not sufficient.

The output of the capability planning process is a blueprint for designing or refining the business processes used to satisfy the needs of targeted-customers. Targeted-customers are the customers the firm now has that it wants to keep, and customers it does not have that it would like to have.

Strategically focused capability development provides the advantage needed to thrive in a competitive marketplace. Developing a clear, focused definition of these capabilities provides the basis for developing the performance metrics that the firm will need to maintain and develop competitive advantage. Without measurement, you have no means to assess the performance of your people and business processes.

The ultimate performance metric for an OM system is its ability to win customers. It is important not to rely solely on sales data to measure success. Firms have long ago learned that the best time to learn what they are doing wrong is *before a customer decides to leave*. It is easier to keep a customer than it is to win one back. Effective post-sale feedback must be a critical element in any supply chain management system.

Product-Based Capability Metrics

Most operations managers are familiar with product-based capabilities. Examples might include:

- A mountain bike being able to withstand ten successive, trouble-free runs down a given trail.
- A golf ball being able to legally go further and straighter than the competitors' golf balls.
- A home cleaning service being able to routinely dispatch polite, skilled, and honest employees to its clients' homes.
- A fast food chain being able to enchant young customers with clowns and hot toys.

Just as value is customer driven, so too are product capabilities. For example, if a customer truly values having a lightweight bicycle frame, having the expertise to design and make exceptionally durable, light bike frames provides a competitive advantage. But a 238-pound couch potato might see little benefit in reducing the bike's frame weight by three pounds. His response is “Pay extra for a light weight? Get real!”

Linking performance metrics to the product-based capabilities is a crucial step in the product innovation process. Golf ball design illustrates how a product-based capability management program is created. Its designers start by listing what attributes target golfers say they want in a ball. One product capability is “It will consistently go straighter.” Designers then search for ca*pability enablers* which are things someone believes, if done well, will significantly advance the company toward achieving the stated capability goal.

In golf, the design of a ball is constrained by the United States Golf Association, which sets maximum standards for this product. For example, there is a limit on the distance a golf ball can carry when hit by a mechanized standard golf swing. Banning “superballs” is necessary because their use would endanger golfers and render existing golf course designs obsolete. While the USGA states the ball must have a certain diameter and weight and the center of gravity must be at the center, it does not specify the material used and the dimple-pattern. It is in these areas that designers can work in their pursuit of a straighter ball. A golf ball maker might define capability specifications and supporting performance metrics.

Exhibit 2
A Programmatic Approach to Product Capability Development

Product-based Capability	**Capability Development Program**	**Product Metric**
Develop World Class Golf Ball	Develop material science expertise to find superior product components	# of product innovations
	Core design	# of patents
	Outer coat design	# of top 50 pro adoptions
	Develop world-class aeronautical science in-flight expertise to enhance distance	Lower coefficient of friction and straightness.
		Increase flight directional forgiveness
	Develop world-class golf ball test lab	Ball improves 5% # of visits by pros # citations in journals

Process-Based Capability Metrics

Process-based capabilities relate to how processes within the value chain perform their tasks. Developing process-based capabilities normally involves investing in equipment, maintenance, and training. For example, Trek, the upscale bicycle maker with the strategic goal of selling state-of-the-art mountain bikes, demands the firm have a world-class product design team. It also must rely on its independent dealer network to sell and service it highly engineered product. At the other end of the market, Huffy, which sells most of its bicycles through mass marketers, has found it necessary to develop a field service capability to assist certain retailers with the bicycle assembly process. Many stores selling Huffy bikes don’t have qualified personnel to perform this task. Product liability risks dictate the need for store-level process capabilities, i.e., bicycle-assembly expertise.

Process Capabilities at Radio Shack

Leonard Roberts had developed a fine reputation in retailing as a turnaround artist, but when a headhunter called in 1993, he responded, "I thought that Radio Shack had died in the Seventies." Tandy, Radio Shack's parent, was a company making and marketing three blockbuster product lines--home computers, wireless communications, and satellite television gear. But being in the right place does not guarantee success if you lack the capabilities to hop on and successfully surf the big wave. Along the way, Tandy had made home computers which it marketed in category killer stores like their Computer City and Incredible Universe stores. Most of these "new adventures" had not done as well as planned and had been sold.

What Len saw in Radio Shack was a greatly underutilized asset in its 6800 Radio Shack stores. He liked the fact that 94% of all Americans live within a 5-minute drive to a Radio Shack store. He understood most of what it sold could be bought at big outlets, such as Wal-Mart. But customers normally couldn't get the support needed to "demystify" post-sale installation of consumer electronics.

Soon Radio Shack was advertising, "You've got the questions, we've got the answers."-- a neat marketing strategy that addresses an unmet consumer need. But slogans do not automatically create order-winning capabilities. To make sure store staff had the process capabilities to deliver the complete product bundle, Roberts initiated a sales/service training program where every employee received two hours of satellite-delivered training each Saturday.

Once he developed process competencies to service its core product lines, Roberts started to expand its customer-pleasing beachhead. In 1997, it struck a deal with Sprint so that every Radio Shack has a "Sprint boutique" where Sprint telephones and Internet services are sold, serviced, and promoted. In 1998, it struck a similar deal with Compaq Computer where Radio Shack will market their home computers and service *all computers*., not just Compaq's. When will Len stop? It is hard to say because he has figured out how to excel in the seams between the category killer computer sales giants by having product-related service delivery capabilities which its competitors seemingly have not matched.

Source: Christopher Palmeri, "Radio Shack Redux," *Forbes*, March 23, 1998, pp. 54-56.

Another important process based capability is *customer triaging*. Since each family of customers has different values, it may be necessary to direct customers to the proper service channel. In some cases, the customers do this for themselves, such as when a stock investor decides to use the computer rather than the phone to interact with the broker. One of the functions of Wal-Mart's in-store greeter is to assist customers who might be overwhelmed by the store size. In each case, the system designers must ask, "Will some arriving customers need assistance?" In services, first impressions matter so this must be effectively handled.

In Shell 1, we referred to similar process capability called *Customer Relations Management* (CRM). While this is not a new activity, the attractiveness of CRM lies in its capability to systematically stay close to your customers. Good salesmen have done this for years but now corporation want this process capability.

Process-based capabilities goals can also be found in value-supporting business processes. A CEO may want an accurate profit forecast by mid-month in order to allow time to take corrective actions. A materials manager may want to have a world-class inventory tracking system so that the firm is always basing decisions on timely, accurate numbers. While no external customer is likely to directly assign value to the firm's products, its ability to serve the market is influenced by the effectiveness of these business processes.

An external force can create the need for a process-based capability. For example, the Securities and Exchange Commission in 2000 changed the way firms "alert" Wall Street on likely sales and earnings. Prior to this ruling, financial analysts "close to the firm" were privy to early earnings warnings that they in turn used as the basis for their recommendations. Now everyone must receive “guidance” at the same time. This in turn has placed greater emphasis on the firm’s ability to accurately predict likely financial results for each reporting period. So when operations managers are asked “How are we doing?” they now mean “Exactly how are we doing?” Never before has the need to understand the accounting process been greater.

If a major customer has adopted JIT manufacturing—a type of manufacturing that demands reliable deliveries of parts in “as needed” quantities, your firm needs to minimize supply uncertainty. This means that your firm will be receiving a visit to assure them that your system has the capabilities in the product, quality, and delivery reliability areas. "Having your act together" is a process capability that becomes an order-qualifier. Not having your *act together* quickly becomes a process capability order loser.

Process based capabilities can also exist for business processes, such as the firm’s accounting, demand forecasting, and materials management systems. Solectron, a world-class electronics contract manufacturer firm, deemed cost accounting sufficiently important to invest heavily in an ABC system. Likewise, firms in the food and health care industries must have product-tracking systems that enable them to recall specific batches of product when issues of product safety occur. Not having this capability often means that all of the firm’s product must be recalled—a catastrophic action that can bankrupt a small firm. Examples of process based capability metrics are shown in Exhibit 3.

Exhibit 3
A Programmatic Approach to Process-Based Capability Development

Process-based Capability	Capability Development Program	Program Metric
Accurate Product Costing	Develop and implement ABC system	% cost over-runs
An Effective Product Recall System	Develop a system to track what specific inputs are used to manufacturer each product batch.	the elapsed time to locate where bad inputs were used
	Develop a system to track where each suspect product was shipped	the elapsed time locate shipment location # of false positives
An Effective Customer Service System	Develop system to input customer lifestyle profiles	% of customers
	Develop Internet-based customer feedback system	# of complements and complaints Elapsed time from complaint to problem resolution.

This is not rocket-science stuff but it can be just as hard to do if the organization design does not encourage its players to understand the importance of programs capable of developing organizational capabilities. Good process capabilities just don’t happen.

Knowledge-Based Capability Metrics

Knowledge-based capabilities relate to the ability of units within the supply chain to "grow" intellectual and technical capabilities. An output of the strategic planning process should be an identification of areas in which the firm believes the acquisition of specific knowledge-based capabilities that will result in a competitive advantage. This may be new knowledge that results from basic research or existing knowledge the firm now recognizes as having potential applications within the firm. This can occur when a firm elects to move in a different direction or when one of its competitors is moving into in this knowledge area.

The knowledge advantage being sought can be in many forms. It may be market knowledge, i.e., an ability to know more about what customers want, how they behave, and what they are most likely to respond to. Or at the other extreme, it may be emerging scientific knowledge, such as knowing how to graft artificial body parts into humans without adverse side effects. In each case, one needs to assess how each new body of knowledge can be used to enhance the firm's competitive posture. Knowledge for knowledge sake is the business of academia.

The resulting strategic initiatives may mean your business unit will have advanced or diminished growth opportunities based on your customers' assessment of your ability to achieve these intellectual growth objectives. Some examples of knowledge-based capability program development are:

Exhibit 4
A Programmatic Approach to Knowledge-Based Capability Development

Knowledge-based Capability	Capability Development Program	Program Metric
Capitalizing on intellectual property	Hire and/or develop intellectual property expertise.	# lawyers hired # publications by house lawyers
	Educate product development team in intellectual property area	# of copyrights # of copyright complaints
Develop State of the Art Product Miniaturization Skills	Work with suppliers to stimulate their state-of-the-art part miniaturization programs	% product size reduction
	Educate design team in product miniaturization.	# of employees trained.
Understanding What Lost Customers Value	Conduct focus groups of desirable non-customers.	-- # of product feature ideas
	Engage select non-customers in product design process	-- # of new customers won

Societal-based Capability Metrics

Societal-based capabilities are the hardest to manage because they often are directed at necessary, but-non-value-adding business processes. It requires management to map the performance of its manager, business processes, and products against the firm's environmental and ethical standards. Both internal and external audits must be considered, although a firm should weigh carefully which external groups it will strive to satisfy. Legal corporate boundaries may not be a proper basis for defining the scope of this capability since public pressure may demand a firm's supply chain partners also to adhere to high ethical and environmental standards. If a firm wants to be considered environmentally friendly, this requires that the actions of your company-owned operations, those of your supply chain partners, and even those of your customers, be internally consistent. For example, if your firm wants to be known as "family friendly," it must be capable of withstanding the scrutiny of those who have assumed the role of being society's arbiter of family values.

This is often difficult because societal norms constantly change. Ten years ago, Nike's ability to procure athletic shoes offshore was considered a corporate strength. Who wouldn't envy a firm that could buy quality shoes for less than $5 in Asia and retail them at prices more than twenty times their purchase cost. More recently, Nike has been criticized by some for the same activities that business analysts once envied, i.e., its use of third world contractors capable of making high quality products at a low cost. One wag pointed out that in 1997, Nike paid basketball superstar Michael Jordan promotional fees that exceeded the total labor paid by Nike's Indonesian suppliers. Another took issue with a Nike advertisement that encouraged women athletes to greater heights when it seemed to have little concern with the plight of women working in its contractors' factories. The point here is not to bash Nike, but to note that in a "Hardcopy-driven world," it is becoming increasingly difficult to keep your company from being the short end of negative publicity.

Thus, the strategic planning process must identify potential environmental and ethical points of contention and then be reasonably sure your firm can withstand a review by "middle-of-the-road" concerned citizens. We use this adjective because in many situations, it is not possible to please or placate some citizens short of ceasing economic activity.

THE CAPACITY PLANNING PROCESS

Long term capacity planning seeks to match the size and timing of significant changes in physical plant and equipment capacity over an appropriate planning horizon. It seeks to answer three basic questions:

- *How much* capacity should be added or deleted?
- *When* should these capacity changes be done?
- *Where* should they be located?

Each capacity decision must be mapped against the capability specifications developed in an earlier stage of the system design process. The purpose of this is to assure that any proposed investment be internally consistent with the value-driven strategic initiatives. Capability specifications provide inputs to the capacity planning process. Specifically, these inputs are:

- The *level of demand* the system should plan for, i.e., how many units of demand is there in each targeted market segment and the company's share of that market? This is the long-term demand-forecasting problem. The planning horizon used in this demand forecasting process depends on the lead-time necessary to plan, secure building permits, build and acquire, and then train plant personnel to bring the additional capacity up to speed. It should also be noted that capacity downsizing might also be an option. Downsizing can have an emotional impact, so the capacity planning process needs to include having programs to effectively deal with the human and organizational consequences of these decisions.
- The *planned level of performance*, i.e., the relationship between the projected demand and the intended rate of production. In some cases, the firm may elect to satisfy only a fraction of its demand, i.e., 90% of arriving customers. In other cases, the firm may elect to maintain a *capacity cushion* to assure the desired level of product delivery performance. This choice should be made within the strategic planning process. In addition to the percentage of demand satisfied, it is often important to define performance in terms of how soon demand is satisfied.
- The *degree of demand management practiced.* In some situations, it may be possible to manage demand, i.e., to influence the rate or timing of demand arrivals, or both. Some demand can't be postponed such as the need for whole blood in emergency rooms. But another seemingly indispensable service, electricity, can be managed by inducing certain customers to forego usage during peak periods. In a similar vein, your cellular phone service uses time of day/week pricing to influence when you use their service.

The capacity planning position must build the desired service response time into its capacity sizing and facility location decision-making process.

PERFORMANCE METRICS

The primary purpose of performance measurement is to encourage people and groups of people to do what is necessary to succeed in business. To illustrate, consider the following tale.

Schwab's Blackboard Magic

The low output of one of its plants perplexed Carnegie Steel's CEO Charles Schwab. He noted that the steel mill's superintendent was a bright, well-qualified engineer. The mill's equipment was among the firm's best. Yet the plant's output hovered close to the bottom. So on his next trip to the mill, Schwab toured the plant but was unable to identify what was holding production levels down.

Partly out of frustration, Schwab asked the plant guard to get him a chalkboard, which he placed conspicuously near the workers' gate. As the workers from the first shift left, Schwab asked, "How many pours [of steel] did you do today?" Their response was "Three, sir." Schwab placed a large number "3" on the board and left. The number on the chalkboard piqued the interest of the night shift crew. They asked, "What does this mean?" The plant guard simply related Schwab's request and subsequent action. "Well, we can beat that!" declared a night shift operator. And they did. At the end of their shift they proudly wrote a "4" over the "3" to show off their shift's output. A rivalry was created which did not end until the mill reached 12 pours per shift—a number larger than the output of the previous best mill's performance.

Source: Arthur H. Denzler, Senior

The blackboard magic story indicates a basic truth -- system performance can be influenced by:

- What is measured?
- How the measurements are taken?
- How the results are used to evaluate people in the system?

The smart system designer must recognize these realities and use them to re-enforce what needs to be done.

A basic problem of most operations management systems is that too many performance measures are cost-oriented. Accounting systems, at their worst, simply tell you how well your profit or cost center did in a given period. Your performance is often based on how well the center did compared to plan (which in many cases is the budget). More sophisticated accounting systems will use variance analysis to try to identify the causes of shortfalls and windfall profits. From accounting, you no doubt recall terms such as: volume-variance, cost-variance, and mix-variance. While this does shed some light on what happened, it does so only in terms of what was recorded within the accounting system.

A limitation of variance analysis based performance metrics is the lack of *timeliness*. Telling operations what went wrong in the last fiscal quarter often is too late since the manager is busy dealing with current problems and may not recall what happened a quarter ago. As the saying goes, the alligator-infested water is up to the operations manager's ears and if he doesn't solve today's problems, he will be history in by the next fiscal quarter. Also, last quarter's data isn't as useful as it could be to support learning since the clues along the trail have gone cold. Can you remember what was happening eight weeks ago in your life? If you can tell the manager today what is happening now or yesterday, he will have a better chance of understanding and explaining performance variances.

n a value-driven operations management system, performance measurements must be made consistent with the capabilities required by the firm's strategic planning objectives. For every capability specified, there should exist one or more ways to measure how well the organization has done. Precise measures are preferred but they may not be feasible. For example, how can you precisely determine if a pet dog is happy? This cannot be quantified. But we could observe behavior, such as tail-wagging frequency, obedience, and even the frequency at which the dog smiles. Yes, dogs smile. The point is that just as a pet's owner *knows*, operations managers also can cite a number of factors they use to indirectly measure organizational performance.

Performance measurements play a large role in organizations. Their uses include:

- They communicate to employees what the firm believes its customers value. If one measures how long the telephone rings before someone answers, this measure is a signal the firm thinks this is an important requirement of the customer service process.
- They provide employee feedback. Timely information on how well that an employee is doing can, if done right, inspire an employee to greater heights, as was the case in the steel mill story. However, if employees feel that the measure is not a fair one, they will either react negatively or find some means to give you the "right" numbers by some other means. Each of these outcomes is bad for the customer.
- They provide the basis for organizational learning. This is a three-stage process. Metrics first indicate to the employee what management thinks is important. In a learning environment, measurement data evokes curiosity, which, in turn, should lead to thought processes about how performance can be enhanced. The final stage is experimentation. Small experiments can be run to measure the impact of each factor varied. Workers might not realize it but their intuitive approach is called design of experiments in statistics.

Some benefits will result from most performance measurement programs. To capture the full potential of performance metrics, it must be systematically done and in conjunction with the strategic planning process.

Types of Metrics

There are many types of metrics, but it is useful to classify them as being either predictive or outcome based. A *predictive metric* is used to estimate performance before hand. A budget is a predictive metric. An *outcome metric* notes the actual performance. It may state a simple fact, i.e., on-time deliveries = 98%. Or it can compare the outcome against the predictive metric, i.e., Purdue's football team beat the point spread by ten points against Notre Dame.

An advantage of a predictive metric is that it may allow management sufficient time to take corrective action. This may simply be a warning that something unfavorable is likely to happen. Or it can be a set of actions designed to improve the system's performance over what is being predicted. For example, if my predictive metric implies that I will be ten minutes late to a meeting, I can either call ahead to say that I will be ten minutes late, or I can drive faster and hope that I don't get stopped for speeding.

Outcome metrics should be associated with managerial analysis and action. If we did better than was expected, at the very least, we should try to understand why we did better in order to replicate this outcome again. Wow! What a great drive off the golf tee--275 yards, right down the middle of the fairway. I wonder what I did right? Did anybody record what I did right? Without measurement, learning is less likely to occur. Great golf drives will be memorable events but not routine outcomes.

The same is true for downside experiences. But in this case, our fear is that the gremlins that contributed to a bad outcome metric will stay with us in the future. This is why it is important to track what went in to cause every outcome. Fortunately, information technology now makes it possible to have key data for problem identification and analysis.

Another way to classify metrics is by level. Earlier, we introduced the Organization/Process/Job approach (OPJ) for designing and managing business processes. As one moves down through the OPJ model, the nature of the metric changes. At the highest Organization Level, the metrics should be directly linked to strategic initiatives. Often what is measured will be aggregate performance statistics linked to the value elements considered most important. They should focus on the vital few--not the trivial many. There is always time to delve in greater detail once problems/opportunities occur.

As one moves to lower organizational levels, the performance statistics will trend toward the tactical, be reported more frequently, and quite often in greater detail. When possible, the performance metrics should be closely aligned to the sub-groups' responsibilities. Measures lying beyond the responsibilities of a group can be included for informational purposes, but care should be taken to ensure these are not used to evaluate the group or the individuals within.

At the process level, performance metrics should relate to the intended capabilities of each business process and be aligned to the stated value objectives. Key business processes should be monitored more closely than others. In a similar vein, business processes capable of creating order loss situations must be monitored closely or redesigned to minimize the chances of lost sales. For example, if corporate strategy calls for all orders to be filled within 48 hours, then all incoming orders must be time-stamped when they enter the system and when they leave. The metrics for the order fulfillment process could include:

- The number of orders processed per period
- A histogram of order fulfillment times
- Reasons for each late shipment
- The number of improperly shipped orders

This last metric is included to guard against shipments being made to maintain on-time delivery rates at the expense of customer satisfaction.

At the job/individual level, it is even more important to assure performance measurements relate to factors over which the people being evaluated have some influence over the outcomes. If a manager has little or no say over the wage rates paid to the individuals within his area, it makes sense to measure labor usage rates and overtime expended. There is nothing to prevent both the process and the job being monitored by the same performance metrics--if it fits.

Performance Metrics for Performance Metrics

Since even performance measurement is a business process, this process also should be evaluated. One way to evaluate performance measures is to cite the attributes users find important.

<u>Content Attributes</u>: Some important content attributes are:

- Were the performance metrics the most appropriate ones for the management task? In effect, did they help me run or understand the business process better? As a result, will I be able to explain why results occur?

- Did the metric portray an accurate reading of the phenomenon being measured? Was the actual value predicted or reported close to the real number?
- Was the direction of the performance metric misleading? If a performance metric is off, the consequence may not be as bad if it at least provides us with an indication of the phenomenon's direction.
- Did the performance measures used provide top management with an adequate early warning/tracking system to enable the manager to detect/understand the risks associated with disruptive technologies? Performance metrics that are strictly inward focused are not enough—especially if one is operating in an industry with a high clock speed.

<u>Style Attributes</u>: These are the traits which make an accurate performance metric more useful to the users.

- Was the data summarized in a form most useful to each user? The same report need not go to every user. The level of detail should match areas over which the user has control over.
- Was the performance metric delivered in a timely manner? Just as one can win a competitive advantage by being fast to product, you can earn a competitive advantage with internal customers by being *fast to know*. Is the data displayed in a manner consistent with the firm's organization design? If individuals are being held accountable for the effectiveness of certain business processes, it might be best if they "owned" the detailed data and be allowed to report aggregated performance metrics periodically—as needed. Performance metrics that are too visible can lead to micro-management by the individuals' supervisors.

This list could be expanded but our point was to illustrate that performance metrics should be accountable.

SUMMARY

In this shell, we introduced the concept of capacity. We noted that it had two facets: capability—the ability to do certain things right, and capacity—the ability to have sufficient factors of production to do what is wanted. We then linked both concepts to value. We introduced the concept that systems designers can use capability planning as the vehicle for linking customer values with the performance attributes of new supply chain systems. Lastly, we discussed the roles performance metrics play within OM systems and how they need to be tied to capability planning. Capability specifications are inputs to the system design process. Performance metrics seek to ascertain whether or not the system designers and/or the system operators are meeting their challenges. The next shell investigates how one builds processes to perform the needed tasks.

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2. Gleick, James, *Chaos: Making a New Science*, Penguin Books, New York, 1987
3. Kaplan, Robert S. and David Norton, *The Balanced Scorecard*, Harvard Business School Press, Cambridge, MA, 1996
4. Rummler, Geary A. and Alan P. Brache, *Improving Performance: How to Manage the White Space of the Organization Chart*, Second Edition, Jossey-Bass, San Francisco, 1995

Expected Learning Competencies

Before putting Shell Three down, you should ask yourself the following questions. Am I able to explain?

1. How the text defines capacity and a capability.
2. The capability classification categories and be able to cite examples of each.
3. What a capability specification is and how it supports both the product innovation process and the operations/supply chain management processes.
4. What the text means when using the term "performance metric" and how it is used and misused within operations management. Be able to cite examples of a performance metric for each of the four capabilities.
5. What your instructor added to this shell and why he or she that that it was important enough to warrant its inclusion.

Frequently Asked Questions

Instructors have been known to ask questions similar to the following:

1. How do expectations fit into the value equation?
2. You have been promoted to be the chief analyst for the Western Region of McDonald's and the firm has decided to decentralize many of its management processes. Your new boss has asked to you prepare the six performance measures that you think will give his fast food managers and your regional staff the best handle on how each unit is doing? What six would you choose?
3. There seems to be some confusion as when a capability is a process capability and when it is a product capability. Write a four sentence paragraph to shed light on this problem—or is it a problem?
4. If value is customer specific, how do we incorporate society-based capabilities in a corporation selling to many classes of customers in many lands?
5. A firm has developed the ability to make chips smaller than any of its competition. How would you classify this capability?
   a. A product capability
   b. A process capability
   c. A knowledge-based capability
6. Which process capability did Fox Racing use to transform motocross racing?
   a. Superior food vendor management
   b. Superior earth moving capabilities
   c. Superior marketing
7. Which term did the text used to define the capability mix?
   a. Capacity
   b. Capability
   c. Core competence
8. In the Schwab's Blackboard story, the manager of Carnegie Steel used a group pay incentive system to motivate the mill's workers to produce more steel.
9. The text argued that performance metrics can form the basis for organizational learning.
10. The text defined the short-term capacity planning as the capacity adjustment process and long-term planning as the *capacity planning process*.

SHELL FOUR
PROCESSES AND PROCESS THINKING

Shaking Up the Culture of an Old Chrysler Plant

Windsor, Ontario: Dan Hillock was flabbergasted when he heard James Bonini had been named manager of Chrysler's big van plant here. At 33, Mr. Bonini came off as an "academic nerd," with degrees from fancy universities but with limited manufacturing experience. Mr. Hillock, a 29 year Chrysler veteran, had hoped to be named manager. He figured that Bonini would barge in, make some superficial changes to impress his bosses and then get moved out to a better job. Hillock was both right and wrong. He was right in that Bonini was promoted out of the plant last November (1996), a year after arriving in Windsor. Yet, he was wrong about the changes that Bonini introduced. Mr. Bonini had completely changed the factory's culture by changing the way workers and managers perceived their roles on the shop floor and within the entire factory. He achieved this sweeping change by introducing "process thinking" -- a new way of looking at activities and at the way to approach work.

To understand this impact, you have to understand the plant that Mr. Bonini took over. The Pillette Road Plant was an 891,000 square foot plant. It was one of the least automated assembly plants, with few robots and hundreds of manual jobs. It built the full-sized Dodge van – a design that was over 15 years old. When Bonini arrived, the sales were stagnant. The most pressing task facing Mr. Bonini was that of preparing for the late 1997 launch of a new van.

However, since taking over, Mr. Bonini and his process thinking brought about a significant change. Sales have crept up for the first time in years. Customer satisfaction indicators have improved 22%. Warranty claims have also declined. Bonini brought about these changes by changing the way people looked at the way that work was done. To improve operations, everyone had to identify the underlying processes and document them. Take the operation of adding the vans' exterior trim for example. Workers had been wasting time walking to supply bins to fetch armloads of parts, some of which inevitably fell to the floor. Now, new parts racks stand near the production lines and workers can simply reach for what they need. As a result of these and other changes, the plant became cleaner and more efficient. More importantly, the work force became revved up. By the time Mr. Bonini left, about 70% of the plant's 285 assembly operations had been revised to improve ergonomics, cost and quality.

Source: Steven A. Melnyk, an unpublished material from a stillborn second edition, 1999

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* On March 4, 2002, Daimlier Chrysler announced that it will be introducing a convertible PT Cruiser in the 2004 model year.

Shell Four

Processes and Process Thinking

Table of Contents

Learning Objectives for Shell Four

After reading this shell and thinking about its content, you should be able to:

1. Understand and be able to distinguish between each of the following concepts:
    a. Processes and Business process
    b. Value chain and supply chains
    c. Process thinking
2. Describe the activities performed by each of the three major business process groups cited.
3. Understand and be able to provide an example of the three process thinking approaches
4. Understand be able to explain:
    a. Process Flow Analysis
    b. Process Flows Charts
    c. Process Flow Diagrams (Including assembly charts)
5. Be able to use process flow charts to setup and solve
    a. Capacity maximization problems
    b. Elapsed time minimization problems
    c. Shortest route problems

INTRODUCTON

If a firm wants to enhance its value delivery capabilities, it must either find more appreciative customers or change the processes used to create and deliver the product. Process thinking is a value enhancing analytical approach that is used to achieve this end. As the lead story indicates, process is an integral part of the way effective operations managers go about improving their realm. It is not about hitting home runs.

When a firm seeks a competitive advantage, it does so by using a value delivery system superior to that used by the competition. One does this by asking strategic questions, such as:

- What are the unmet needs of customers?
- How many of the customers *that you want* share these values?
- What is the profile of the value chain the competitors are using?

If customers are exhibiting a preference for a competitor's product, they clearly place a higher value on its product. Before changing your value delivery system, a firm needs to understand who these customers are. If they are cheapskates, you may not want them as customers. But purposefully walking away from customers places the firm at risk. American car companies initially minimized the loss of "those customers buying those cheap little Japanese cars." A firm must also consider the possibility that if it changes its value delivery system, a significant number of current customers will not welcome the change. In 2002, Harley Davidson Ford faced the wrath of its traditional customers when it introduced its V-Rod motorcycle—a product intended for younger customers who currently are buying European and Japanese high performance bikes. *

The challenge facing most firms today is that markets continue to fragment into smaller segments. People are less willing to accept mass manufacturing's product offerings. One size no longer fits all. In the 1990s, just about every brick and mortar retailer was trying to extend its business to protect themselves from the emerging B2C competitors. The question they faced was: "Do you create a parallel value delivery system to serve e-commerce oriented customers or do you change your existing set of business processes to serve all customers?" This is a strategic decision, but it is one in which the operations management function must be deeply involved.

Early in 2001, some began to question the rush to e-commerce. Many B2C firms folded and some bricks and mortar retailers have begun to succeed in the e-commerce arena. Realism comes with maturity. For example, most auto firms are beginning to realize that consumers primarily use the Internet to gather information about their products before they buy in a face-to-face transaction. The same auto firms have come to realize that a large segment of the buying public *will never* use the Internet. No one knows for sure but it is fair to say that B2C won't replace brick and mortar operations--nor will e-commerce go away. It is prudent to think of e-commerce as a disruptive technology, i.e., a technology that can't quite launch a competitive frontal assault but quite capable of attracting customers around the fringe.**

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* See "Love Into Money," in the *Forbes*, January 7, 2002 issue for a nice story in which this magazine names this venerable bike producer is "Company of the Year."

** For an excellent perspective on the e-commerce revolution, read "Dot-coms: What Have We Learned?" *Fortune*, October 30, 2000.

BUSINESS PROCESSES

Let us start with some definitions.

- *A process* is an ordered collection of activities that accomplishes a purpose.
- *A business process* is an ordered collection of activities that are designed to offer value to the customer by transforming inputs into outputs.
- The *value chain is the set of business processes that add value*.
- *Process thinking* is a structured approach that views a firm as a set of underlying processes that are designed and managed to obtain desired results.

Business processes that create value directly are on the value chain. Other business processes *support value-adding business processes*. For example, when you walk into Denny's for breakfast, a server offers you a menu with a range of choices and takes your order for a Grand Slam with a muffin on the side. The order goes to the kitchen, where your pancakes are made, your eggs cooked, and your muffin toasted. The prepared food is transferred to plates, which the server brings to your table with a smile and the question: "Will that be all?" Sounds simple, huh? Each of these steps directly adds value. On the other hand, Denny's advertising business process is a value-supporting business process in that it, if done effectively, will increase the flow of customers to Denny's restaurants. So too will the business process used to clean rest rooms.

Process thinking is results oriented. If you don't like the results, change the business processes until the desired end has been achieved. Process thinking brings together a number of key elements. These are:

- <u>Activities</u>: These are the means through which things get done.
- <u>Process</u>: A collection of activities that transform inputs into outputs.
- <u>Structure</u>: This refers to the way activities are configured to create processes or the way in which processes are configured to create larger systems, such as a supply chain.
- <u>Resources</u>: The factors of production, e.g., people, inventory, equipment, and information that are used by processes to create outputs of greater value.
- <u>Customers</u>: The users of the outputs of a process. The customer might be the next process in line. Or the customer could be the final consumer.
- <u>Metrics</u>: The measurements used to quantify the performance of each activity and process.
- <u>Organizational Structure</u>: The infrastructure, including the business structure that determines how we *manage* processes.

The creators of OM systems use capacity and capability specifications to acquire and configure these key elements to give the system's operators a good chance of achieving the firm's strategic objectives. The managers of these systems manage these resources with that intent. Their efforts are evaluated through the use of capability-based performance metrics.

BUSINESS PROCESSES IN THE FIRM

There are many business processes within a firm, but we will focus on three groups:

1. <u>Marketing/Customer Relations</u>: These are the set of activities that strive to locate, listen to, and analyze data from the marketplace which is then translated into information that can be used in the following two business process groups.
2. <u>Product Innovation</u>: These are the activities that transform information from the marketplace and from emerging technologies into goods and services capable of meeting the perceived needs of customers.
3. <u>Supply Chain Management</u>: These are the set of activities that manage the flow of information and materials throughout the supply chain. It manages the flow of raw materials, components, and service support in a way that hopefully will achieve the firm's strategic objectives.

Each of these business process groups interact with activities that range far beyond even our broad definition of operations management. In the interest of economy, we will only discuss those that have a significant impact on the operations function—but this is not a license to engage in stove-pipe thinking.

Market/Customer Relations Business Processes

When I was a pup, we were taught the 4Ps of Marketing, i.e., product, price, place, and promotion. [1] It made sense and marketing classes today still cite McCarthy's marketing framework. As marketing evolved, it started to distinguish between consumer and industrial products marketing. While both should be customer-centric, the number of players that we are trying to understand is markedly different. Selling to consumers involves large numbers so market research often samples target populations to glean information that will give them insights of their customers: wants, needs, and the extent to which current product offerings are satisfying them. Focus groups enabled marketers to delve in greater detail on the preferences of current or potential customers.

Industrial products marketing evolved along different lines. Business-to-business marketing often was the stepchild of marketing at business schools since instructors and their students focused on more topical consumer products. Both knew what a Big Mac was but few could relate to the marketing of a hydraulic flow meter. But as often happens, this stepchild has shined as it developed what became known as relationship marketing. Because it did not sell to as many customers, industrial marketing took the lead in the application of information technology to enhance marketing's effectiveness. Broadly speaking, industrial marketing can be categorized as being either involved with the marketing of commodities, or involved with products that require a significant service component. Commodity-oriented industrial marketing has been fertile ground for evolving marketplace-oriented B2B systems. Since exact product specifications exist, price and product availability are the most important factors. Little is gained by promoting a commodity—at least to industrial buyers.

The other wing of industrial marketing engaged in relationship management since a competitive edge could be gained by getting closer to key business buyers. Initially it was called relationship marketing since the communication links were primarily between the selling and buying players in their respective businesses. But service-centric approaches invariably lead to expanding the number of players. If the seller wants to enhance its firm's delivery performance, knowing the availability and location of goods and the status of existing customer orders means that information about these is needed. This often involves the firm's materials management system. As firms' manufacturing systems became flatter, this information need often involved the suppliers of your firm's operations. Being service-centric involves closer collaboration between the product innovation processes of the buying and selling firms. This meant that B2B applications must become involved with product and process designers within these firms. Hence the term relationship marketing has evolved into the term relationship management.

Early attempts to develop relationship management were frustrated by the inadequacies of information technology. A number of needed pieces had been developed, such as bar coding and uniform product part numbers. These facilitated inter-company identification of goods. Digital technologies made possible the transfer of pictures and engineering drawings between remote locations. Shippers, such as FedEx, developed information systems capable of knowing when a part was likely to be delivered. But most important, the development of the internet and intranets meant that many of the pieces could then be crafted into a system that had the potential to meet the information needs of those trying to develop relationship management systems. These became the building blocks of what is known today as c*ustomer relationship management* (CRM).

Product Innovation Business Processes

The purpose of a *product innovation process* is to generate new products and/or new product models. Its activities include: to identifying ideas for new products, describing appropriate product concepts, and developing product designs. The development includes three sub-processes:

- *Product design* involves the design of the product itself,
- *Process design* involves the design of processes capable of making and delivering product bundles; and
- *System design* involves designing value-supporting systems, such as the new shop floor control system to enhance manufacturing *management* capabilities.

The appropriate performance standards for each of these sub-processes depends on the pace of the industry and the way its business strategy defines how it wants to serve customers.

Supply Chain Management Business Processes

The purpose of the *supply chain management process* is to transform the firm's factors of production into goods and services in an effective manner. We measure effectiveness as being the extent to which the firm's business strategy is accomplished. Supply chains consist of the following major business processes:

- C*ustomer service*---interfaces with customers, especially with external customers. With the make-to-stock market orientation, much of this process may fall within marketing jurisdiction, except for that part involving orders or reorders from the retail or distributor. This process can involve such activities as: accepting customer orders, tracking orders, customizing orders, managing engineering changes, and resolving customer complaints. This process has four primary sub-processes:
  - *Order entry and processing*—accepting orders and generating order due dates
  - *Forecasting*—predicting what customers will demand
  - *Demand management*—influencing customer demands better match up with capacity
  - *Product customization*—creating customized products to match customer needs
- *Operations planning*--combines the outputs of the strategic management process and the customer service process to determine the resource needs (capacity, labor, tools, and materials). Sub-processes of this process are:
  - *Long term resource planning*—estimating what capacity and capabilities the firm will need to successfully achieve its strategic objectives
  - *Operational Planning*—transforming short-term forecasts into estimates of resource requirements needed to successfully satisfy demand in a manner that is consistent with the firm's strategic objectives. When gaps between what is needed and what is on hand are identified, these are relayed to the purchasing/procurement process. If the gap indicates excess resources, then this information is fed back to marketing to see if additional sales can be generated or if operational resources needs to be "right-size". This latter action involves the personnel function.
- *Purchasing/procurement*--this consists of two sub-processes:

  Vendor selection—once it is known what is needed, this sub-process evaluates the capabilities and the value of the products offered by potential vendors. This may also involve selection of a contract manufacturer to perform all or most of the activities previously done by operations.

Acquisition—the process that orders the resources to meet planned activity rates.

- O*perations*—this set of activities actually transforms inputs into outputs of value. While we normally might think this relates to manufacturing, it also includes services—many of which involve transforming data into useful information. Operations includes the following activities:

  Scheduling—setting priorities on orders and assigning resources to orders

  Execution—implementing the decisions identified in the other processes by releasing orders and working on them to provide the needed goods and services

- P*erformance measurement*-- determines appropriate measures for the firm's processes and assesses their performance as discussed in Shell 2. Metrics communicate to everyone what it is they, as sell as the processes, must do well for the firm to deliver value.

The above profiles the role of processes within a firm but a firm may have other major business processes.

PROCESS THINKING

The first step in process thinking is to provide a profile of the business processes active in your firm, including how they relate to each other. In reviewing these processes, observe that each oprocess consists of smaller and more focused sub-processes. One of the objectives of process thinking is to eliminate any gaps between what management believes the process is and what it actually is doing. It is management's job to coordinate the activities of the smaller sub-processes, and their interfaces. Interfaces that cross department boundaries create a process thinking challenge. Fortunately, advances in telecommunications technologies now enable system designers to provide information to support this goal. The challenge then becomes "What is the best information flow structure for managing across the white space of the organization chart?" This is an organization design issue that should not be left strictly in the hands of MIS practitioners.

Process Analysis

Once a fundamental understanding of the parts of an operations system has been gained, the manager can proceed to the process analysis. The purposes of process analysis can be categorized as:

- *Process documentation*: Here the user is seeking to record how a business or part of a business is functioning. This may be at variance with what the firm's formal organization chart might indicate. These variances may indicate an undocumented process improvement or a dysfunctional organization.
- *Process monitoring*: As an integral part of the management process, it is necessary to monitor how the system is working. Often this is done with a narrow focus, such as tracking the rate of new orders or the number of quality defects experienced. Process monitoring uses a management by exception approach, i.e., it does not call for management intervention until events trigger a need for corrective action.
- *Process improvement*: The need to improve either the efficiency or effectiveness of business processes is an ongoing challenge. Process improvement often is a three-stage process. The first seeks to identify the areas with the greatest need or potential for process improvement. This is often called the discovery stage. The second stage seeks to identify alternate ways to perform the business tasks. This stage may be inward oriented or it may involve looking outside the organization to study how others do similar tasks. When done with an outward orientation, this is called *benchmarking*. The third stage seeks to implement a process improvement in order to evaluate how well the "improvement" is performing.
- *New system design*: A process-oriented approach allows systems designers to take a holistic approach when building entirely new systems. It allows them to include all of the key factors of production, i.e., people, raw materials, information, and organization structure into their business innovation process.

As is the case with clothing, one size does not fit all—at least not well. In the following paragraphs, we introduce a number of tools that are used by OM practitioners. It is not necessary to use any of these tools exactly as we have presented. They are templates that can be modified to meet your specific needs.

Let us now revisit each of these sub-processes in greater detail.

Process Documentation

This activity seeks to answer the question: “What do firms do?” In the simplest terms, it performs value-adding activities for customers. There are many ways to document what you observe, but operations managers have found it useful to explain what they have observed by using a symbolic language. In Exhibit 1 the most common process documentation language is shown.

Exhibit 1
Activity Classification Symbols

○ Operations activities *change* stuff—they transform inputs into outputs. Operations include changes in tangible inputs such as raw materials and components. Denny’s cooks, for example, perform an operation when they fry bacon, and Chrysler’s line workers perform an operation when they add the trim to the Durango’s exterior.

➔ Transportation activities *move* stuff—they relocate inputs and outputs without transforming their characteristics. When Chrysler loads finished vans on trucks and ships them to local dealers, it’s transporting them; and when workers use carts to convey trim parts from the stock room to shop-floor storage bins.

□ Inspection activities *check* stuff—they make sure that the results of another activity meet standards.

D Delays *hold up* stuff—they make work wait under uncontrolled conditions. If, for example, a Denny’s server doesn’t bring your coffee for 20 minutes because he’s dealing with the party of 17 in the back room, you’re experiencing a delay. Or if the Chrysler trim line stops because the parts bins are empty, this is also a delay.

▽ Storage activities *hold* stuff on purpose—they keep or safeguard items for later use. The key here is control. Stored items are counted and tracked. Access is limited to authorized users. The location of storage activities varies. Items can be in stockrooms located on the shop floor, warehouses on or off site, or holding/receiving areas.

Exhibit 2 gives examples of these different kinds of activities in several industries.

Exhibit 2
Examples of Activities in Bicycle Manufacturing

Classification		Activity	Performance Metric
Operation	○	Bend steel and assemble	Capacity in bends per shift Conformances to standard Part flow lead-time
Transportation	➔	Transfer parts within plant work stations	Avg. inter station move times Total distance traveled
Inspection	□	Inspect parts	Inspection accuracy Cost of inspection
Delay	D	Assembly units waits for transportation	Number of delays recorded Length of delays
Storage	▽	Finished goods stored	Cost of inventory stored Number of dusty units

Once the activities have been identified and categorized, the next step is to document how they are linked together. Links provide the *ordering* of activities, i.e., which activities must be done before others are started. The order in which some activities are done may be subject to choices. Whether we put on our wristwatch before or after putting on our shoes does not really matter. The order one puts on his shoes and socks matters.

When one activity must be complete before another one can begin, it is called a *precedent activity*. In addition to order, our description of the process's structure is also defined by stating how the activities are linked together. Once again, there are a number of ways to do this. One way is to define the *spatial links,* i.e., the distance between two activities, measured in feet, meters, inches, or similar units. If you look at a Rand McNally map, cities and major highways are drawn to scale. Many roadmaps also indicate the spatial distance and time difference between major cities.

Within the OM function, blueprints typically define the spatial links of a factory or service operation. In many situations, having certain activities closer to each other may influence the behavior of the individuals involved. Locating related activities closer to one another can enhance the value-adding capabilities of the system because travel and interplant lead times are reduced. In other situations, the noise or noxious fumes may dictate that certain processes be isolated from the others.

A second way to define process links is to define the *physical links* between related activities. Physical links often involve mechanical means to transfer things from one workstation to the next. For example, in an assembly line, conveyors often create physical links between workstations. This may be a mixed blessing. While a close physical link reduces manufacturing lead-time, it can also limit flexibility. If a new product requires activities to occur in a different sequence, this may necessitate tearing up existing production lines and build new ones. This consumes considerable time and money.

Informational links are a third way to define the interconnectedness of business processes. The advent of telecommunication networks now allows systems designers to bring individuals who are separated by considerable distance much closer. This often allows firms to relocate people-intensive work to locations far removed from the customer. Microsoft just opened a customer service center in Coos Bay, Oregon—a town far from both corporate headquarters and MSN's customers.

Finally, it is important to understand the *organizational links* used to manage the system. This is especially useful since it forces system designers to ensure that the performance metrics used to evaluate the sub-systems are internally consistent. Dysfunction will occur if one business process within the supply chain is being managed to minimize cost while another's goal is to achieve high on-time delivery metrics.

The purpose of process documentation will dictate which other attributes need to be recorded. If the focus is to better understand the capacity of the business process, then the *capacity* of each activity needs to be determined. Once this is done, there are analytical tools that can determine where the *bottlenecks* are in the system. *A bottleneck is an activity that constrains system throughput, i.e., if the capacity of that activity could be increased, the capacity of the entire system could be increased***.**

If the purpose of the documentation is to focus on the *speed* at which a business process can get something done, then we are interested in the lead-times each activity requires. Once these are known, then procedures exist to determine which activities actively limit the speed at which the entire business process could be done. One might call them time-bottlenecks. These activities are said to lie along the *critical path*. As is the case with bottlenecks, a decrease in how long it takes to perform an activity on the critical path decreases the time it takes to complete the entire business process.

In order to distinguish between these two orientations, we will refer to the first as *capacity-focused*. The second orientation will be referred to as *time-focused*. When time-focused, the goal is to determine the set of linked activities that limit the speed at which a business can perform a given task. The activities along this path must be managed closer since any slippage will cause the entire process to slow down. Time-focused analysis often refers to these bottleneck activities as *critical activities* and the connected set of activities that limit a process' time performance is call the *critical path set of activities*.

In either case, when management encounters a bottleneck, some actions need to be taken to relieve these constraints. In most instances, management must either: change the structure of the process, assign more resources to the constraining activities, or relieve some of the demands being placed on the system.

PROCESS-THINKING TOOLS

Process flow analysis (PFA) is a technique for documenting activities in a detailed, compact, and graphic form to help the manager to understand the process and highlight potential improvements. It is used to generate the information that an analyst needs to understand the process. PFA consists of six steps:

1. Identify and bound the process of interest
2. Identify and categorize the process activities
3. Document the process
4. Analyze the process and identify opportunities for improvement
5. Recommend appropriate changes to the process
6. Implement the changes

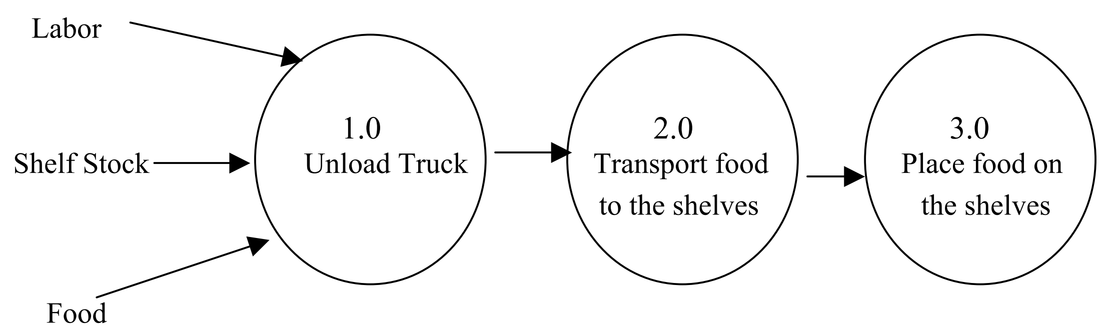
This shell examines the first 3 steps in detail. It gives a general overview of the last 3 steps.

Step 1. Identify and bound the process: The first step is to identify that portion or specific part of a process that you are interested in studying and documenting. It may not make sense for us to study the entire process of filling an order from the receipt of the order to the shipment of the order if we think that the problem lies in the process of recording the orders received from our customers. It is more efficient and effective to focus on the order entry process. If we do not bound the process or identify what specific portion of the process we will study then we may find ourselves faced with a task that keeps growing without bounds, until we find ourselves studying the entire process under all possible conditions. By bounding the process, we ensure the task is feasible *and that the people involved have a clear focus on what it is that they are to do.*

This step determines whether or not we are going to examine those processes that deal with exceptions and unique conditions. Every special condition that requires different handling identifies a possible need for a different process. One good starting point is to look at either the best case or the worst-case scenario for the operation of the process. A common starting point is to examine the process for a "typical" order.

A useful technique is to create a *Level 1 Process Flow Graph* as shown in Exhibit 3. This is much like viewing a process from 50,000 feet up. It captures only the macro activities and not the detail. The analyst uses it to identify which portion of the process to investigate in greater detail.

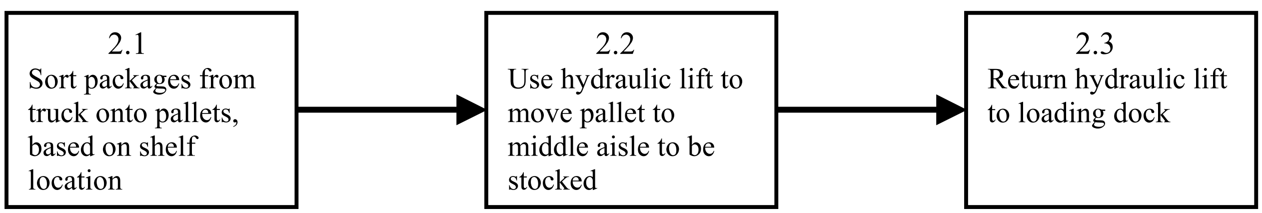
Exhibit 3
A Level 1 Process Flow Chart for Stocking Supermarket Shelves



Analysts use a Level 1 diagram to determine that the best spot to focus on in order to improve the process of unloading the truck. This identified process boundaries, as well as the inputs and outputs of the process.

Detail is provided in the *Level 2 Process Flow Graph*. This takes one of the boxes from the Level 1 flow graph and provides the internal detail for that process as shown in Exhibit 4.

Exhibit 4
Level 2 Process Flow Graph of Transporting Food to Shelves



If our goal was to improve the productivity of the process, we might suspect that activity 2.1, the sorting of the packages, could be done more effectively. We would then obtain more information about activity 2.1 and prepare a more detailed Level 3 process flow graph. Note that we have quickly and clearly set our boundaries and we can communicate that with these process flow graphs. This provides documentation to track the work in order to not repeat work we have already done.

Step 2: Identify and Categorize Process Activities: Here we classify each activity as being one of the five categories shown in Exhibit 1. This is not always easy since crafty system designers may have activities that do two tasks. For example, a bagel firm may have the bagel slugs rising while being transported to the bagel shops for finishing and sale. Two transformation steps are occurring at once. Likewise, wine fermenting in barrels may appear to be a storage activity but is actually an operation. The point is, think twice before classifying.

Step 3. Document the Process: To document a process the analyst traces the activities, identifies the type of each, and assigns the proper symbol to each, placing the symbols in the order in which the activities occur. PFA uses five different but interrelated charts to document and describe a process:

- Flow Diagram
- General process chart
- Process flow chart
- Process diagram
- Assembly process chart

All of the charts are not used in each process flow analysis, but they are all part of a manager's tool kit. Each chart focuses attention on a different aspect of the process, but all describe the process in terms of the same set of attributes:

- Number of steps (broken down by category)
- Distance covered (both vertically and horizontally)
- Time required (minimum, maximum, average, variance)
- Value orientation of the activities (value-adding or not)
- Number of departmental boundaries cross
- Number of departments involved in each activity
- Number of people who touch or come into contact with the order or process.

Each measure relates to the four components of value: lead time, cost, quality, and flexibility. For example, a long distance may increase expected lead time and reduces the flexibility of the process.

Many templates have developed over the years. While there is no reason to do your analysis strictly in these forms, doing so has the advantage of communicating to other practitioners with a familiar document.

A **Process Flow Chart** is a tool that categorizes each activity and provides operation details to further our understanding of the process. Generally, the operations are summarized in sequence so that the pattern of operations can be observed. If no pattern exists, i.e., the sequence of activities varies from one job to the next, then that too provides useful information to the operations analysis. It tells the analyst that the operations being observed are too complex to be summarized strictly through the use of this tool. The information provided in a typical process flow chart is shown in Exhibit 5. Note that more space is provided to enable the analyst to provide a more detailed description of the nature of each operation.

Exhibit 5
Sample Process Flow Chart

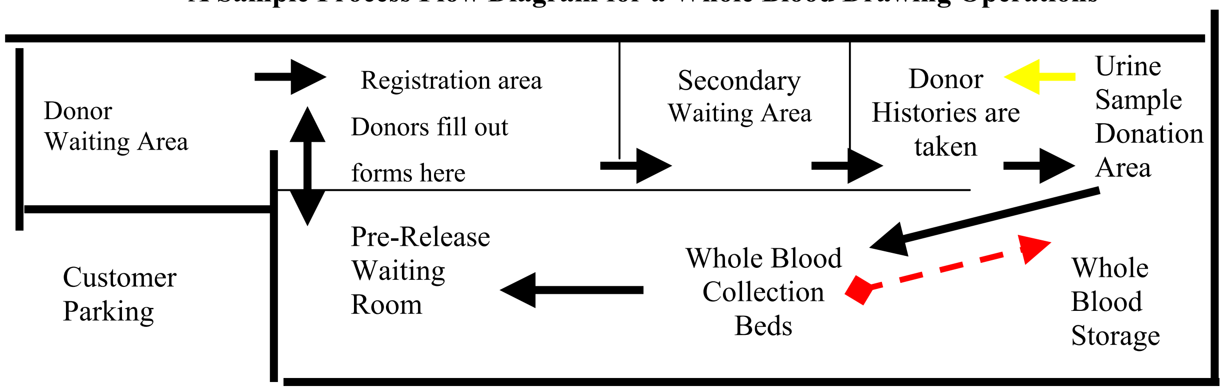
Process Flow Chart for:____ Page __of __
Overall Description of Process Charted: ____
____
Date Charted_______ .... Charted by: ______________________
Check appropriate box: Current Process: ( ) .... Proposed Process: ( )

Distance Traveled	Time (avg.)	Symbol	Person Involved	Value Code	Description of Activity (indicate outcome)

A **Process Flow Diagram** is a tool that emphasizes spatial relationships. Most processes move something tangible from one activity to another activity. So physical layouts determine the distance that each activity must cover and its lead-time. This can be a useful transition into an examination of the detail of a process. It allows the analyst to focus in greater detail on specific activities. In many organizations, orders traveled through a maze of departments, consuming time and increasing the potential for errors at every step. You may have experienced something like this when you matriculated at a large university. On the shop floor of large organizations, similar confusion may exist as production orders move from workstation to workstation.

The process flow diagram offers a tool for this kind of analysis by presenting a picture of a plant layout on which the analyst draws movements of orders from one activity or area to another. The resulting diagram measures process performance in units of time and distance. This fairly straightforward analysis must take care to measure all distances over which activities move work, both horizontally and vertically when activities occupy different floors or levels of a facility. Labels on the process flow diagram indicate areas or activities that correspond to the list on the process flow chart, creating a strong, complementary relationship between these tools. The process flow chart details the nature of process activities while the process flow diagram maps out their physical flows.

Exhibit 6
A Sample Process Flow Diagram for a Whole Blood Drawing Operations

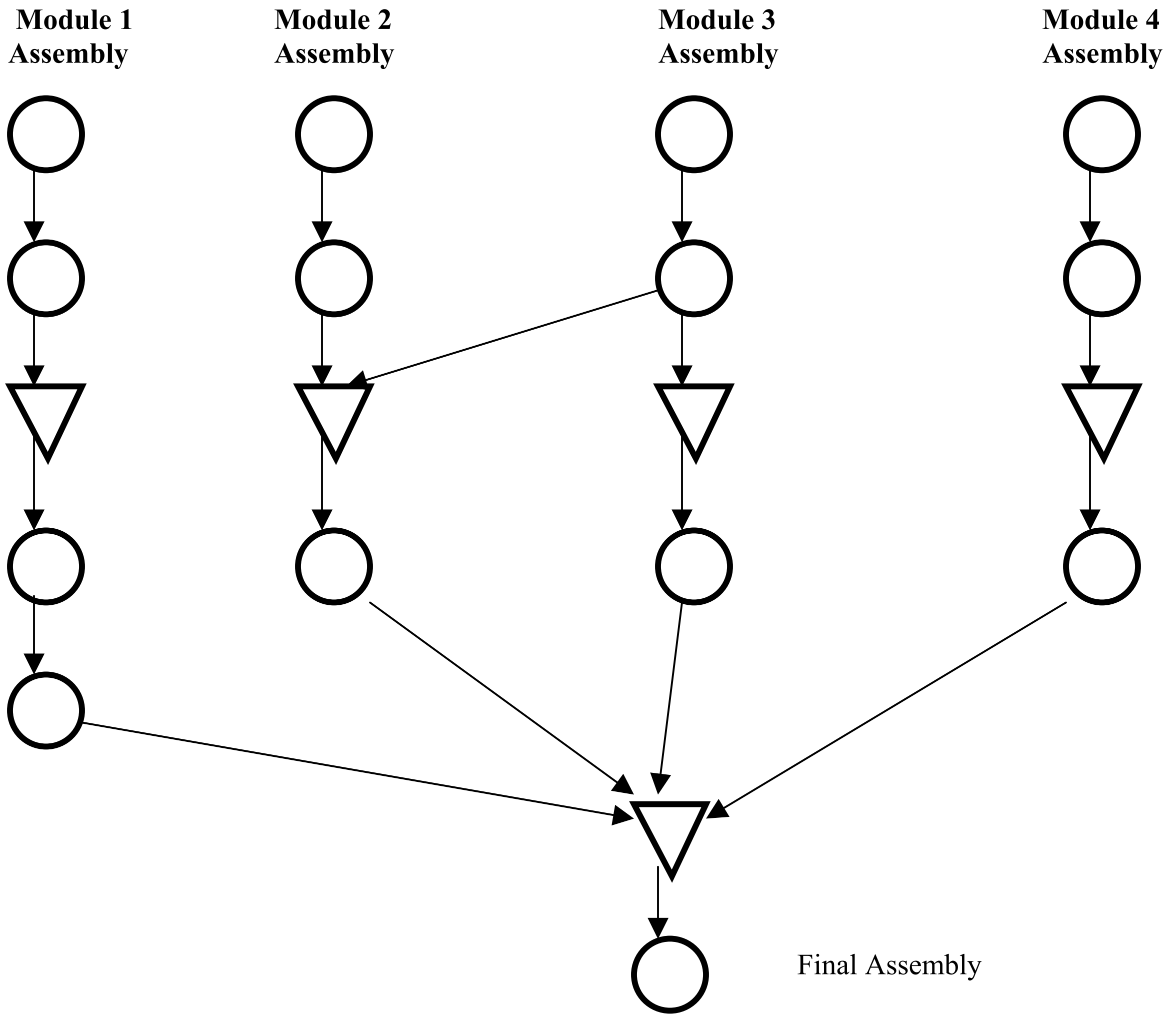


The black arrows depict the path of the individual drawing blood. The location of the employees and equipment are not shown. The dotted arrow was added to show the flow of the drawn units of blood.

A blood bank practitioner can now look at this diagram and ask, “Are any inefficiencies evident?” One might ask whether or not it is necessary to have three waiting rooms? Do you want post-drawing customers waiting next to anxious incoming donors? The path of a donor in this simple operation seems quite good. But in larger organizations, process flow diagrams often reveal instances of waste.

An **Assembly Process Chart** is another way to incorporate operations level information into one diagram. It provides a schematic overview of multiple streams of activities in a way that enables the analyst to see how the activities relate. It is called an assembly chart because it is often used to depict how and when fabricated parts are combined to create another part. Consider the diagram shown in Exhibit 7. Note that each activity is denoted with an operations code, i.e., a circle is used to denote an operation, a triangle to denote storage, etc.. Also notice that the locations of the circles and triangles on the diagram indicate the order of the activities but not necessarily the physical relation of each relative to each other.

Exhibit 7
Sample Assembly Process Chart



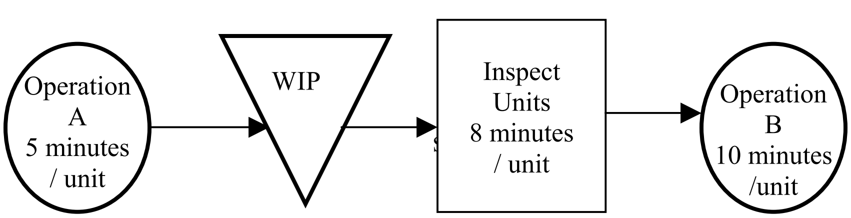
Other types of process flow charts are used and you might even invent one of your own if your particular problem needs to be documented and highlighted differently. The performance metric for process flow tools is "Does it help your or your client understand better the process being studied?"

USING PROCESS THINKING TO SOLVE PROBLEMS

How one proceeds with a process flow analysis depends on the purpose of the study. In the following sections, we have classified the use of process flow analysis by end-goal.

<u>The Capacity Maximization Problem</u>: Here you try to get the most product out of an operation.

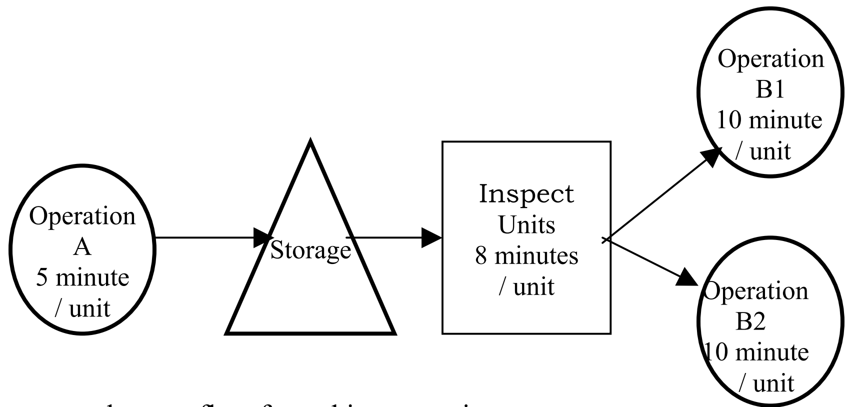
Exhibit 8
A Maximum Flow Production Problem



Where is the bottleneck? Or put another way, which of the three activities that use the resource time requires the most time per unit. Clearly Operation B can produce only six units a minute which is slower than the other two. The bottleneck is B and the maximum capacity within this plant is six units an hour.

If the firm had the opportunity to sell more of this item, then one could add an additional workstation B.

Exhibit 9
Same Diagram with Dual Operation B



Now the maximum amount that can flow from this system is:

Minimum {60/5, 60/8, 60/(10/2)} = min{ 12, 7.5, 12} = 7.5 units per hour

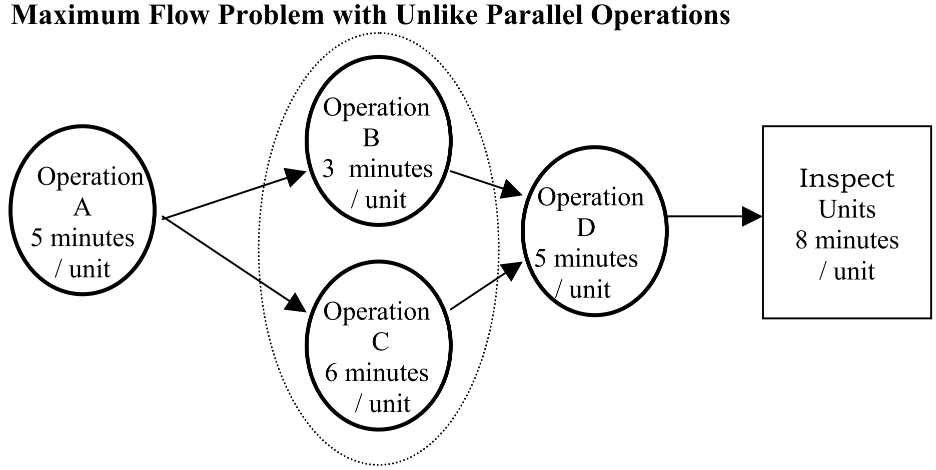
Even though operations A and the two Bs can produce twelve units an hour, the system is limited by its new bottleneck operation—inspection.

In the above example, the addition of a second operation B arranged in parallel enabled this system to double capacity for that stage of the process. We could place a circle around the two operation B circles and replace it with an equivalent process with a capacity of 12 units an hour. The use of equivalent units is a useful means for simplifying networks.

If we can find a part of the network with only one line going into it and one line going out of it, then we can determine the capacity of that subset of activities and then replace them with an equivalent node with a capacity that equal to that of the subset. If we need the detail, we always have the original diagram to refer to.

In other situations, parallel activities are interpreted differently. Consider the following network.

Exhibit 10
Maximum Flow Problem with Unlike Parallel Operations

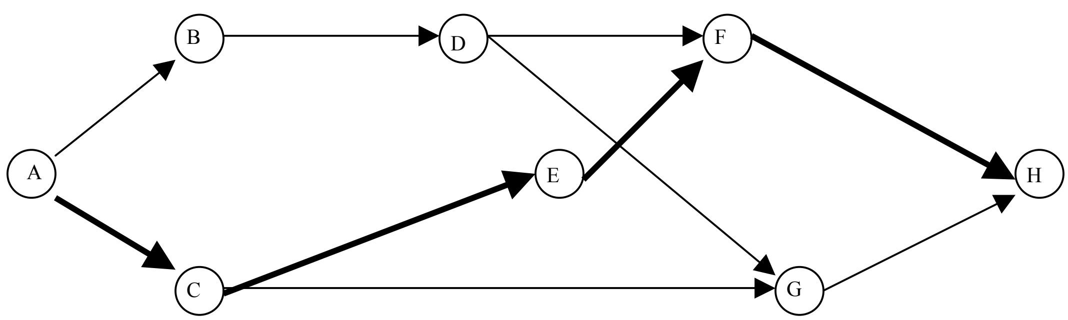


In this case, the capacity across the parallel units is the lesser of the two since operation D requires one unit each of what operations B and C make. Operation B can make 20 units an hour but operation C can only make 10. So the most that operation D can make is ten units. Operation C is the bottleneck activity.

The Elapsed Time Minimization Problem: Here the goal is to complete *all* activities in a certain network in the shortest possible time. Problems with this form are common. An equipment operator must do a number of tasks during a machine setup. The sooner setup is done, the sooner the machine is used. This is an *elapsed time minimization problem*. One often finds larger problems with this trait. Product innovation processes strive to complete all product development tasks in the shortest possible time. Manufacturing seeks to complete each job in the shortest possible part flow time because the longer a job is being worked on, the higher the work-in-progress inventory. When building a ship or a new plant, we usually benefit if the project is done quickly, or at least on time. All are elapsed time minimization problems, differing mostly in scale.

Elapsed time minimization problems consist of a network of tasks, each of which requires time, and a amount of resources. Most tasks have predecessor activities, i.e., one must pour a foundation before starting the walls. One major difference is that many OM practitioners prefer to designate the activities as lines and the completion date of an activity being a node. Consider the network:

Exhibit 11
An Elapsed Time Problem



The data for this problem is provided in Exhibit 12.

Exhibit 12
Elapsed Time Sample Problem Data

Activity	Predecessor Events	Time Required	Earliest Start	Earliest Completion
A-B	None	10 days	Day 1 *	Day 10 **
A-C	None	8 days	Day 1	Day 8
B-D	A-B	5 days	Day 11	Day 15
C-E	A-C	12 days	Day 9	Day 20
C-G	A-C	8 days	Day 9	Day 16
D-F	B-D	6 days	Day 16	Day 21
D-G	B-D	7 days	Day 16	Day 23
E-F	C-D	8 days	Day 20	Day 28
F-H	D-F and E-F	9 days	Day 21	**Day 37**
G-H	C-G and D-G	12 days	Day 22	Day 34

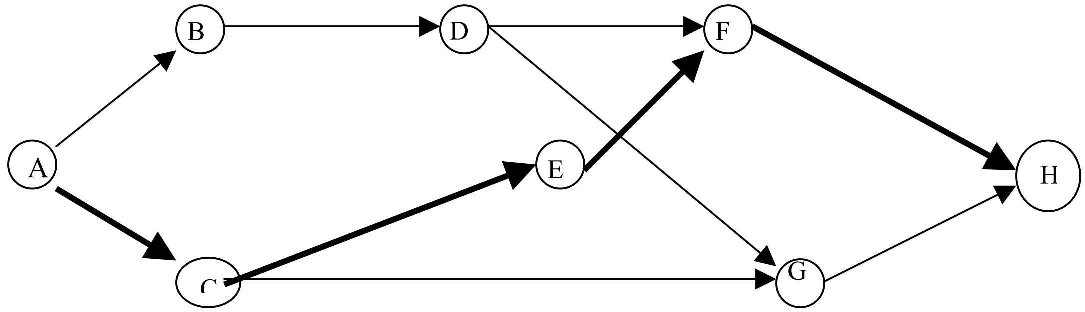
* denotes the start of day ** denotes the end of day

One way to solve this problem would be to calculate the length of each path from A to H and then select the longest one. How many paths are there? Four. The critical path is:

Maximum Path Length {ABDFH=30, ABDGH=34, ACEFH=37,ACGH=28} = 37 days

The activities on the critical path are AC, CE, EF and FH. The dark line denotes the critical path.

Exhibit 13
A Shortest Route Problem



<u>The Shortest Route Problem</u>: If you had a network with the structure shown in Exhibit 10, but the task was to travel across the network in the shortest time. Starting from the left node, you ask, "What is the shortest route from all incoming arrows. For node B, this is simply how long it takes to go from A to B. For node F, this would be the shorter of two times: The time it takes to get to node D plus the time to go from D to F and the time it takes to get to node E plus the time it takes to get from E to F. Select the shortest path and record this route. Use this logic to proceed across the network. The calculations are as follows:

Exhibit 13
The Shortest Route Problem

Activity	Predecessor Events	Time Required	Node	Shortest Time
A-B	None	10 days	A	
A-C	None	8 days	B	A-B= 10
B-D	A-B	5 days	C	A-C= 8
C-E	A-C	12 days	D	B +BD=10 + 5 = 15
C-G	A-C	8 days	E	C + CE = 8 + 12 =20
D-F	B-D	6 days	F	Min{D+DF, E+EF}
				Min{**15+6**, 20+8}=21
D-G	B-D	7 days	G	Min{D+DG, C+CG}
E-F	C-D	8 days		Min{15+7,**8+8**}= 16
F-H	D-F and E-F	9 days	H	Min{F+FH,Min G+GH}
G-H	C-G and D-G	12 days		Min{21+9, **16+12**}= 28

When done, we see that the shortest path requires 28 days. Working backwards, we see that the minimum time past is from H to G to C to A. Let's check. 8 + 8 + 12 = 28 days. The shortest route is ACGH.*

SUMMARY

Note the process that we are using. We first tried to diagram the structure of the processes and the nature of the linkages between them. We then sought to develop a tool that would aid in our attempt to enhance one or more of the elements of value. We then tinkered with some logic to find some means for estimating the performance of the network *as we have modeled it*. Up to this point, we have improved nothing except possibly our understanding of the processes.

In the next shell, we will spend more time on the methodologies used above. The point that we wanted to make here is that process analysis can be adjusted to meet the needs of the organization. In the first case, we focused on getting the most product from a given network. Once we understand which activity is the bottleneck, we then have a basis for deciding which activity warrants increased management attention. This approach is useful when we are trying to maximize the value produced from a given amount of resources.

The elapsed time minimization problem is most useful when we are trying to get something done quicker, such as a setup or a project. It tells us which path of activities is limiting the speed at which all activities can be completed. Working to reduce the time of activities not on the critical path will not reduce the project's duration. This means that management should be directed at those activities on the critical path.

We might note that the length of the critical path functions like a predictive metric. It tells management that this is the likely outcome of the endeavor if no further actions are made. This is useful information both in the operations scheduling and the project management areas. More of this will be covered in the next shell.

The above tools also serve as a foundation for learning. Each is a model of what we see happening within the operations of interest. There are many ways to learn, but we suggest the following:

1. Analyze the process and identify opportunities for improvement.
2. Develop alternative ways of running the process. Consider the merits of securing additional resources or changing the structure of the processes.
3. Use either the model or even the plant to explore avenues of potential improvement.
4. Recommend appropriate changes to the process.
5. Evaluate the effectiveness of the implemented changes.
6. Go to step 1—you are never done!

In the next shell, we will introduce a number of tools that operations managers use to solve these and other problems. They are important but they will be useless if you lack the framework for studying them. That is what process thinking is about.

End Notes

1. McCarthy, R., *Marketing Management*, Irwin, Homewood IL, 1962.

References

1. Imai, Masaaki. *Gemba Kaizen*. New York, NY: McGraw-Hill, 1997.
2. Maskell, Brian H. *Performance Measurement for World Class Manufacturing*, (Cambridge, MA: Productivity Press, 1991).
3. Melan, Eugene H. *Process Management: Methods for Improving Products and Service*. New York, NY: McGraw-Hill, 1993.

Expected Learning Competencies

Before putting Shell Four down, you should ask yourself the following questions. Am I able to explain?

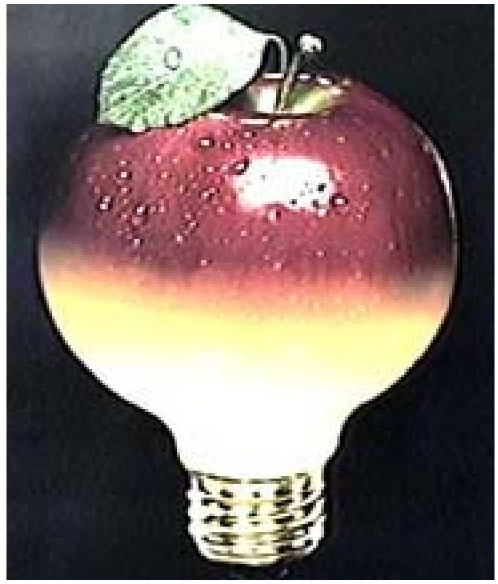
1. What a business process is and how they are used to document the activities occurring within a firm.
2. What are the three business processes that relate most to the operations function.
3. What the text calls process thinking and how it is used to better understand activities within the operations function.
4. The role of process documentation in the product innovation and supply chain management processes? What benefits accrue from process documentation? Is there anything wrong with doing the same tasks different ways?
5. Each of the process thinking tools introduced in the text, i.e., process flow analysis, process flow charts, process flow diagrams, and assembly process charts.
6. The three forms of network problems that were introduced, how each problem can be solved, and then be able to relate them to real operations problems.
7. What your instructor added to this shell and why he or she thought that it was important enough to warrant its inclusion.

Frequently Asked Questions

Instructors have been known to ask questions similar to the following:

1. Of the OM Toolkit items discussed in this shell, which ones have you used in your life without realizing that it was included in the Toolkit?
2. Explain how the advent of information technologies, such as bar coding and the computer, have had on identifying and solving problems.
3. Explain why the value approach is superior to marketing's 4P approach—or is it?
4. Compare and contrast the business processes that go on within the product innovation and the supply chain management process.
5. When a project is expressed as a network, the length of the project is the longest path through it.
6. Which process tool best documents the spatial particulars of a process?
    a. A process flow diagram
    b. Process flow analysis
    c. A process flow chart
    d. An assembly process chart.
7. If a network consists of four activities arrange in series, the maximum capacity of that system is the smallest of the capacities of each of the four activities.
8. The primary purpose of industrial engineering practices of classifying activities as being either operations, transportation,.etc,is to enable the firm to optimize its cost structure.
9. A good can increase in value when it is purposefully stored.
10. If an activity is not on the critical path of project network, increasing the duration time for that activity a small amount normally will not increase the duration of the project.

SHELL FIVE
MANAGING FOR PROCESS IMPROVEMENT



The Cable Guy's Friend

When President Clinton announced a goal of having all of America's schools wired for the Internet, he probably had not counted on getting help from an unexpected source. In 1997, Hal, a Silicon Valley volunteer who was working to help a California school achieve this goal, applied some "fresh thinking" to a vexing problem. The crews that string computer cable through the innards of old urban schools often encounter two problems: cramped corners and rats. One day as Hal was doing a particularly tough job stringing cables through a rickety crawl space lined with asbestos, he encountered a rat crawling out of the tight space through which the cable was to go. As he backed off and waited for the rat to vacate his workspace, he recalled that a friend had been spending a lot of time training rats in her medical lab. Hal wondered, "Maybe she could train a lab rat to tote wire through old buildings."

Shortly thereafter, Rattie, a trained control animal from the radiation oncology lab was rescued from his "dead-end" job and taught to carry string through pipes. His trainer created tapping sounds at the far end of the pipe. The rat soon learned that a Gummi Bear was the reward at the far end. Once Rattie was rewarded and placed back in his cage, the strung string was used to pull computer cable through the conduit. Since then, Rattie has gone on to be the star "stringer" at ten other schools.

Of late, Rattie's manager has been receiving inquiries from commercial enterprises that want to hire her crew to do similar work in other buildings. At the moment, he is not biting since this is a volunteer thing. There is a rumor that she is worried about possible asbestosis. You know that rats are prone to having cancer.

Source: David L. Wilson, "Ex-lab rodent is trained to thread string through pipes for computer cable," *The San Jose Mercury News*, September 27, 1997

Shell Five

Managing for Process Improvement

Table of Contents

Learning Objectives for Shell Five

After reading this shell and thinking about its contents, you should be able to:

1. Understand the importance of organizational learning to process improvement
2. Describe how operations managers involve themselves in the process improvement process
3. Understand the basics of problem identification, i.e., to be able to use the problem structure outline introduced in this shell to serve as the basis for formulating problem for ultimate solution.
4. To understand the three ways to dispatch problems, i.e., problem solving, problem resolving, and dissolving problems
5. Understand and be able to illustrate the use of each of the tools in the OM Toolkit

INTRODUCTION

In the first shell, we started out with the Lexus and the Olive Tree metaphor in order to emphasize the importance of being able to adapt to an ever-changing environment. Our Rattie story is intended to re-enforce this theme. Rattie's presence would have sent many of us scurrying up the stairs. Not Hal. He saw the possibility of using his friend's unusual vocational skills to solve an immediate need. And he was sufficiently persuasive to convince others of the merits of his weird proposal. Hal was wearing the bifocals that we discussed earlier. We might be stretching it a tad if we referred to Rattie as a disruptive technology.

In this shell, we extend our discussion of process thinking by adding four additional facets: problem identification, problem solving, solution selection, and solution implementation. We start with a brief review of Peter Senge's seminal book, *The Fifth Discipline* because it provides an excellent framework for process improvement in an operations management environment.

THE LEARNING ORGANIZATION

The third goal of performance measurement was to provide timely inputs to an organization's learning processes. All types of firms have learning processes, but in the Lexus lane, the need to have effective learning processes is critical. As Senge puts it:

> "Learning disabilities are tragic in children, but they are fatal in organizations. Because of them, few corporations live even half as long as a person—most die before they reach the age of 40." [1]

To check the validity of this statement, we suggest that you make a comparison of the firms that made Fortune magazine's list of the top 100 companies this year with those on the list five years ago.

Creating an organization that is capable of adapting to change is a difficult task. Saying that organizational learning needs to be done is the easy part. Yet some firms succeed in learning how to do what most think is impossible. Unfortunately, people and companies often confuse the terms "experience' and 'learning.' Consider the following episode.

> **The High Cost of Success**
>
> In a discussion with a Detroit automobile firm, a consultant was trying to explain the implications of just-in-time purchasing—a management tool that many Japanese firms were using to gain a competitive advantage. He suggested that they might want to review the underlying assumptions of the firm's cost control systems. After he concluded his presentation, a crusty executive said: "Young man, are you suggesting that we scrap a management control system that we have developed and refined over the past fifty years?" The consultant thought for a brief moment and said, "I think that you should keep it if nothing in your industry has changed in the last ten years."
>
> Source: Personal conversations with one who shall remain anonymous to preserve his client base.

While this response was not designed to maximize the likelihood of having future consulting engagements, his point was right on target. A firm must not blindly assume that the best practices that contributed to prior successes will be appropriate in the future. All too often, success is a root cause of corporate and individual learning disorders. As Intel's former CEO has said, "Only the paranoid will survive."

The concept of the learning organization provides a conceptual understanding to help explain why it is difficult for some organizations to adopt a team-oriented, change-accepting management style. Senge notes that "the team that becomes great didn't start out great—it learned how to produce extraordinary results." Senge argues that a firm that learns faster than its competitors can truly gain a competitive advantage. He further notes that learning occurs most in an organization *when it exists throughout the organization*. This would especially be true in the Lexus lane.

Peter Senge argues that five *component technologies* are required to create an organization that "truly learns." He describes these five prerequisites as:

1. *Systems thinking*: A conceptual framework, a body of knowledge, and tools that have been developed to make possible a fuller understanding of patterns or events. Put another way, the ability to see the big picture and beyond the clutter in an organizational thicket.
2. *Personal mastery*: The learning organization's spiritual foundation which affords it the enabling discipline to:
    a. continually clarify and deepen its vision of its realm,
    b. be able to focus its energies to those areas that matter,
    c. develop the ability to see reality objectively, and
    d. have the patience needed for timely decision making.

    Personal mastery involves a reciprocal relationship between the individual and the organization that Senge calls "a special spirit of an enterprise made up of learners." Personal mastery focuses our energies to work toward achieving the things that really matter by "living our lives in the service of our highest aspirations."
3. *Mental models*: He defines these as "the deeply ingrained assumptions, generalizations, or even pictures or images that influence how we understand the world and how we take action." Mental models form many barriers within our mind. They are embodied in sayings like "You can't teach an old dog new tricks" or worse. An open, disciplined mind is required to look inward at our own assumptions, to look around us, and to judiciously probe the underlying assumption supporting our mental models. "Maybe we can find a use for that rat's conduit navigating capability." Senge notes that "learningful" conversations occur "when people expose their own thinking effectively, and make that thinking open to the influence of others."
4. *Building shared vision*: The practice of shared visions involves the building of shared "pictures of the future that foster genuine commitment and enrollment rather than compliance." In this dimension, leaders learn that trying to dictate a vision, or a solution, no matter how heartfelt, is counterproductive.
5. *Team learning*: This discipline starts with a dialogue in which the members of the team have the capacity to suspend assumptions and enter into a genuine "think together." Others call this an open conversation.

In the learning organization, all five building block disciplines must be present. His use of the term discipline is apt since each involves humans behaving in a matter that most mortals have a difficult time achieving.

But Senge argues that y*ou must learn how to achieve extraordinary results*. And listening is the key ingredient that is often missing within the corporate world. Senge notes that the term dialogue comes from the Greek word, *dialogos,* which is a free flow of meaning throughout a group, allowing the group to discover insights not attainable individually. The word *discussion* has its roots with percussion and concussion, literally a heaving of ideas back and forth in a winner-takes-all competition.

Senge cites the following laws to guide those seeking to develop a disciplined, systems oriented approach to an organization's problems.

Exhibit One
The Laws of the Fifth Dimension

1. Today's problems come from yesterday's solutions.
2. The harder you push, the harder the system pushes back.
3. Behavior grows better before it grows worse, i.e., there often is a time lag between the short-term benefit and the longer-term disbenefit.
4. The easy way out usually leads back in.
5. The cure can be worse than the disease.
6. Faster is slower, i.e., all natural systems, from ecosystems to animals in organizations, have intrinsically optimal rates of growth. The optimal rate of growth is far less than the fastest possible growth rate.
7. Cause and effect are closely related to time and space.
8. Small changes can produce big results—but in the areas of highest leverage, they often are least obvious.
9. You can have your cake and eat it—but not at once.
10. Dividing an elephant in half does not produce two small elephants.
11. There is no blame.

Source: Peter Senge, *The Fifth Discipline*, Chapter Four, Doubleday, N.Y., 1990

Before leaving Senge, we should note that mental models can be models that are currently in vogue. All too often, Americans enthusiastically adopt popular causes, such as just-in-time, total quality management, and employee empowerment. We don't mean to say that these causes are bad *per se*, but we all know people who so fully buy into a program that they develop *tunnel vision*. Effective systems thinking demands that the organization see the whole picture of its world—not just the functional perspective. As great as W. Edwards Deming was, there is more to effective management than total quality control.

OBSERVATION AND MEASUREMENT

Often, when a formal reporting system fails to provide a manager with the information that is needed, humans in organizations create their own information systems. Many operations managers create a morning report so that they can succinctly learn what is or has transpired. Many operations managers supplement their morning report inputs with visual inputs gained by walking around the operations. If done correctly, walk-around-management can bridge the communications gap that may exist between management and employees.

Consider how the following two individuals met their *need to know* requirements.

Two Visual Information Systems

Long before video cameras existed, one manager used an unusual approach to gain a better read on how his plant was operating. Asa Banta, the legendary Czech industrialist, had his office placed in the elevator of his 16-story shoe factory. Checking things out was just a button away. One might consider this turn of the century (1900) industrialist an early practitioner of micro-management.

In the 1960s, Kawasaki had one of the pioneering applications of just-in-time in America. Its first general manager had a legendary practice of just standing at various locations within the Lincoln Nebraska plant. For hours at a time, he stood there "like a cigar store Indian." One might ask him, "What are you looking at?" He would tersely respond "There is something wrong but I can't quite get a handle on it." Ultimately, his sixth sense and his historical perspective would lead him to the problem.

As great as these two individuals were, they weren't creating learning organizations. In today's operational environments, employees should not expect top management to identify and define the problems.

That is what employees are paid to do—and are best able to do it if properly trained and empowered. As Senge noted, organizational learning can only come about if the employees believe that performance measurement is being used to benefit the well being of the organization as a whole.

In 1987, I had an opportunity to visit the Kawasaki plant and saw an example of what is possible when labor-management mistrust is not present. On the plant tour, we were told that their business plan assumed that the plant's productivity would increase by 1% each month. We asked, "How many time study persons do you employ in the plant?" Their answer, "None." "Then how do you know how long it takes to perform a given task?" Their response was "Oh, we just ask our workers."

The point is that every organization has a choice. It can decide to build a shared vision with its employees, i.e., relationships that challenge employees to use their backs, hands, and most importantly, their minds, in a team learning endeavor. Or the firm can maintain an organizational design with traditional management-labor adversarial relationships, most of which are founded on a mental model of distrust.

From McGregor's Theory Y, we learned that most individuals want to contribute in a participative way to the success of the organization.[2] Organizations that don't encourage individuals to make contributions within the formal organization may discover that employees initiate their own innovations in the informal organization. This may be counter-productive. The resulting loss of the individual's potential means the organization is walking away from some of the best and least-costly sources of expertise.

As we progress through this course, we ask that you perform a Sengelian audit of the organization by asking questions such as:

- To what extent does this organization need to continually adjust to a changing environment?
- In which areas of the firm is this need most critical?
- What practices and procedures has the firm used to disseminate these needs to its employees?
- To what degree do the key players, which may include individuals outside of the organization, understand and accept the importance of the firm's strategic goals?
- Which performance metrics are being used to assess the extent to which progress in achieving the strategic goals has occurred?
- What activities do we perform because we do not trust others? This includes measurement activities.
- What could be done better? If so, is it in a strategically important area?

These are difficult questions. In the following sections, we will address some of the tools effective operations managers use to address these issues.

The Operations Manager as a Problem Solver

Too often, operations managers act if they exist to *make decisions*. There are two problems with this swashbuckling approach. The first is that the speed at which the manager acts often leads to an attack on a symptom but not the real problem. *A symptom is an indicator of a problem*. For example, when a person who habitually drinks too much is viewed as having a drinking problem but it may be a symptom of the real problem--the person's underlying state of unhappiness. *A problem is defined as a gap between a present state and some desired state*. A manager needs to pause long enough to be sure that he is expending his energies toward solving the problem and not a symptom.

The second problem is that swashbuckling decision makers have not included others in their decision making process. The solution may be a correct one, but no one has *bought in* yet. Solutions are easier to implement when those affected have agreed before hand to what the problem is. Building a consensus should occur in the early stages of the problem identification process.

The Nature of Problems

Problems exist in many forms. One way to gain a better understanding of a problem is to categorize problems by their traits. For example, we might ask:

- How structured are they?
- Are they strategic or operational problems?
- How fast must the solution be found?
- How often do problems of this nature occur? Why do they come back?
- What is the nature of the activity involved?

In the following sections, we will briefly discuss how each trait influences how best to deal with problems.

<u>Problem Structure</u>: A *well-structured problem* involves clear goals, reasonably complete and accurate information, and a well-understood means of achieving these goals. Let us consider a simple example first. Good car maintenance calls for its oil to be changed every so many miles. The data needed to achieve this goal can be found by comparing the mileage on your odometer with that on the sticker the prior oil-changer placed somewhere in your car. If the difference is greater than the recommended oil change mileage, then a change is called for. The means to do this can be found at your local oil change specialist.

Let's consider the three traits of a well-structured problem in greater detail. Ideally there will be one single goal but this is not always the case. If multiple goals exist, then a more advanced form of decision analysis will be required. A goal should be measurable. If your goal is to have satisfied customers, then some means is needed for measuring this customer attribute. If you cannot find a measurable attribute, then your problem is ill structured.

Secondly, for a well-structured problem, the data used to define the structure of the problem needs to be accessible. In the oil change example, this was not a problem. But when the operations research group at Weyerhaeuser wanted to model one of its lumber remanufacturing plants, it knew that the information needed existed, but it existed mostly in the heads of factory and sales people. In order to transform this ill-structure problem to a well-structured one, the OR group took the knowledgeable individuals to a nearby resort and conducted group sessions to quantify the lumber yields, machine speeds, processing costs, and the market-related traits that the model builders needed to fill in its database.

Lastly, well-structured problems need a feasible way to implement the problem's solution. In the oil change problem, there were a number of ways to implement the needed action. But for a more challenging problem, let's once again visit Weyerhaeuser for an illustration. In the 1960, an operations research group's study indicated that it was possible to cut felled-trees into shorter logs better, i.e., how a felled tree is cut into logs is a most important yield decision. If all trees were straight and equally sound throughout, there would be no problem. But nature doesn't always cooperate, so it matters how the tree is cut into logs. This decision is called log bucking. It was being made in the forest by logging crew personnel. Prior studies indicated that

10% to 20% more value could be recovered from a typical tree if the log bucking decisions could be done in an environment in which the attributes of a log could be accurately measured and fed into a computer model which would tell how best to cut the tree-length log into smaller log segments. In the 1960s, this was not feasible since tree-length old growth logs were too big to be transported to a site where they could be measured accurately before being cut into shorter logs.

Twenty years later, the means to do log bucking near the forests exists. Weyerhaeuser now harvests smaller, second growth trees from its tree farms. These lighter tree lengths can be hauled to sites located near the harvesting where they are accurately measured and observed before they are cut to lengths that are best for value recovery. Logs best suited for plywood manufacturing have one length whereas logs best suited for lumber have another length. You might even call this a felled-tree triaging process.

But before this approach could be implemented, they needed to convince the people that this hi-tech approach would indeed work. So a test was developed in which pairs of nearly identical trees were selected. The first set of tree-length logs were cut into shorter logs using existing log bucking practices. These logs were then sent to their respective processing centers and the value of the products produced was recorded. The second set was sent to a prototype "log merchandiser" which accurately measured each logs using laser technology. This information was then fed into a computer model to determine where best to cut the tree-length logs into shorter logs. They were then sent to their respective processing centers and the value of the end product produced was recorded. The results indicated that about 15% better yield could be realized. The model had won.

At the other end of the problem structure spectrum are *ill-structured problems*. A problem is considered ill structured if it: does not have a well-defined goal, it lacks sufficient data to support product-understanding activities, or it is unlikely that the means for implementing a solution are not available. With a poor understanding of appropriate goals, a manager will have trouble assessing the size of the gap between the current state and the desired state—or even if a gap exists. Without data or the means to measure what is going on, most managers are reduced to using intuition and/or what has worked adequately well in the past. In an Olive Tree environment, this may work well but in the fast lane, one proceeds with peril.

Perhaps the worst type of ill-structured problem is when you know what your goal is and you know how to solve the problem, *but you lack the means to implement a solution*. An example is the horrible spread of HIV infections in Africa. Known solutions exist, but the will or the means to get the message out and implemented it do not exist. Can you think of a personal problem for which you know the goal and the solution, but for some reason, the solution does not get implemented?

<u>Strategic versus Operational Orientation</u>: Strategic problems affect how the firm formulates and manages its resources to implement its plans to deliver value to targeted customers. Operational problems include such things as: equipment breakdowns, employee absenteeism, and supply chain disruptions. Operational problems tend to have a shorter term perspective, although continued failures at the operations level can result in a failure to implement one of the firm's strategic objectives.

Urgency of the Problem: The urgency of a problem may dictate how management deals with the problem. Most strategic problems allow management to dwell on the implications of them and to spend sufficient time to analyze them before deciding on the best course of action. Strategic problems can also possess urgency, such as deciding what a firm should do to respond to an unforeseen challenge or business opportunity. Firms operating in the Lexus lane will confront urgent strategic problems more frequently.

Urgent problems at the operations level must also be dealt with swiftly. If the problems are well structured, then quick analytical solutions may be possible. Urgent ill-structured problems will call for experienced-based, seat-of-the-pants approaches.

Frequency of the Problem: Problems that frequently occur present a challenge to managers. Frequent fixing may indicate that either the process remains out of control or that the actions taken have been directed at the symptoms and not the root causes of the problems. All too often, managers confuse effectiveness in quickly dealing with problems with control. Their Japanese counterparts would most likely see recurring problems as an indication that they had failed in to achieve appropriate levels of control over their environments. At the very least, managers should ask of recurring problems, "What can we do to prevent this problem from occurring again?"

Problem Orientation: In an attempt to avoid reinventing the wheel every time a problem is encountered, operations managers often seek to categorize problems into classes for which known problem solving techniques exist. Ackoff and Rivett identified most operations problems as being one of the following: [3]

1. *Queuing problems*: Queuing problems arise when people arrive at a service. When customers arrive at a bank, they often have to wait in line for a teller. The managerial challenge is to assign resources in order to balance the costs associated with employing people against the costs of giving poor service. Providing the "right" level of customer service of course depends on the values and patience of your customers.
2. *Allocation problems*: The problems require managers to assign resources (labor, machines, materials, and so forth) to competing jobs in a way that optimizes the goal of the firm.
3. *Inventory problems*: These require managers to control investments in material resources in a manner that balances the needs of both internal and external customers and the cost minimization goals of the firm.
4. *Sequencing problems*: These arise when jobs must wait for a resource, such as a machine. Managers must determine the order in which jobs should be done based on the structure of the work, the urgency of the jobs, the workload existing within the system, and the availability of productive resources.
5. *Routing problems*: These arise when a resource (such as vehicle or a machine) must "visit" a number of sites during a given time. The manager must set the order in which the resources tours the sites on the resource's schedule with the goal of minimizing costs or maximizing operational efficiency. Your tour through a supermarket with your spouse's grocery list is an example of this problem. Backtrack much?
6. *Replacement problems*: These require managers to balance the cost of acquiring new, additional, or different resources against the likely costs associated with depreciated sale value, breakdown costs, or even reduced emotional joy.
7. *Competition problems*: These arise when managers must weigh the consequences of its actions against the likely response of other players. If one raises the price of your product, what are the likely responses of your customers, your competition, or even some part of government?
8. *Search problems*: These problems involve efforts to gather information or to enhance understanding about a process. It may be a pursuit of a better way to do something, such as hitting a golf ball. Or it could involve sampling to find out the true state of nature about an entity—such as our giving quizzes to find out if you have been doing the reading.

We suggest this categorization scheme for two reasons. The first is that it may work, thereby saving you time and effort. Many of these problems have useful software programs that are designed to solve these problems. But this advantage is only an advantage if it fits. Often, individuals with proven skills in one area falsely see problems as being one in which their talents can be used. The second reason for using this approach is that it facilitates communications with operations management and operations research professions. Saying that a given problem is essentially a queuing problem helps communicate the nature of the problem.

Solving, Resolving, and Dissolving Problems

Once a problem has been correctly identified, the corrective actions can take one of three forms. An operations manager may:

- Solve the problem which means that an *optimal* solution has been found and implemented.
- Resolve the problem, which means that an acceptable solution to the problem has been found. There may be a better solution, but we either have not been able to identify it or we are not able to effectively implement it.
- Dissolve the problem, which means that we have effectively eliminated the causes of the problem, thereby eliminating the need to find a solution.

To illustrate the differences, consider a firm that stocks a product with a sales rate of 1200 units a month. The inventory holding costs are estimated to be about $1 per unit per month and the cost of production setups for this product is $150 per setup. This is the classic inventory order problem in which one asks, "How much should be made in a batch?" When this problem is solved mathematically, the least cost batch is 600 units.

Suppose that this product is normally shipped in bins that hold 500 units. If we plug this number in the total cost model, we see that the annual costs that would result if lots were ordered in batches of 500 is only about 5% higher than the least cost solution. This solution is good enough so it is ***resolved*** that production will be ordered 500 at a time. We know that this action is not optimal but it is good enough. The problem can be dissolved if we can find a way to eliminate the $150 product setup cost. If our industrial engineers find a way to eliminate product setup costs, then the most economic order quantity now is whatever the market demand is for that period. Before one optimizes, it always pays to ask if there isn't some way to *dissolve* problems. It should be noted that problem dissolution works best on the job but is not a recommended approach on the home front.

THE OPERATIONS MANAGERS' TOOL KIT

At the start of this shell, we introduced you to a creative problem solver. Hal found a solution to his cable-wiring problem by keeping an open mind. We conclude this shell with a brief introduction of some analytical tools that have proven useful to operations management practitioners. In some cases we will be able to provide you with an adequate understanding to get you started. With some of the others, a basic operations research text will be useful. In the OM Toolkit, we classify tools by their capabilities.

- **Investigative tools**: These tools are most useful in the early stage of a study. The toolkit includes:
  - Informal methods
  - Walk-around management
  - Brainstorming
  - Process Documentation
  - Process flow analysis

    - Maximum flow analysis
    - Minimum project time analysis
    - Shortest route analysis

- **Data Collecting Tools**
    - Check sheets
    - Cause and effect diagrams
    - Plan-do-check-act
    - Statistical methods
        - Histograms
        - Scatter plots

- **Organization-wide explorations**
    - Benchmarking
    - Attribute Mapping

- **Tools to Glean Meaning from Data:** These tools seek to find meaning from the data**.**
    - Simple regression
    - Multiple regression
    - Hypothesis testing
    - Acceptance sampling procedures
    - Control charts
    - Design of Experiments

- **Models**: These seek to solve or resolve problems with the use of mathematics and or computers.
    - Unconstrained single goal models
    - Constrained single goal models
    - Lagrange multiplier models
    - Linear programming
    - Integer programming
    - Waiting Line Models
    - Queuing models
    - Monte Carlo simulation models

- **Work Sequencing Models**
    - The Gantt chart
    - PERT/CPM models

This is a partial list of the tools and methods available to the operations management practitioners. In the following section, we provide a brief overview of each of these tools.

Investigative Tools

Investigation is the focused facet of monitoring—an ongoing management activity. Managers monitor what is going on with their daily walk through the plant, their chats with employees in the coffee room, and when they review their reports. Here we deal with an activity that is focused on getting to the bottom of a perceived problem. Investigative activities can include:

Purposeful walk-around management: All good managers visit their troops. This key operations management activity can assume an additional objective when managers want to get a clearer picture as to what is happening before launching a more formal investigation. It is important that operations managers not dilute their plant level goodwill with unnecessary witch-hunts. One must take care not to vary too much from your routine lest you arouse suspicions that your verbal interactions are not genuine.
Brainstorming: This involves getting key knowledgeable individuals together to discuss the dimensions of a perceived problem. It is best done early in the investigative process lest you give the impression that you just want them to confirm what *you* have already decided is the problem. For example, a store manager might start off a meeting with an anecdote, such as "I was talking with a

person at a cocktail party the other day, and she told me that she never shops at our store any more because we are always out of stock. Do we have a problem here?"

The next stage in developing a better understanding of operations-level problems is *documentation*. The above tools shed some light as to what might be going on, but the need to document what *is going on* or is being said quickly becomes apparent. In verbal situations, it often is useful to have someone prepare a written summary of what was said. If you ever have been asked to do this, you can replay what was said in a linear fashion (i.e., in the order in which the comments were made) or some type of categorization. Categorization has the advantage of highlighting similar and dissimilar comments.

In other situations, pictures can do much to illuminate what has been observed. In the previous shell, we introduced a number of process flow tools that were useful in documenting business processes. Note that each did not immediately identify a problem or a solution to a problem. What they did do was to describe the situation in a light that led to an enhanced understanding of the problem. It did this by doing things, such as locating the bottleneck operations or the activities along the project's critical path. Given that information, management can now take some actions.

Data Collection Tools

Investigations benefit from having pertinent data. Some of the most useful data collection tools are:

Check Sheets: A check sheet is a device that is intended to allow the observer to systematically collect data in a way that enhances our ability to understand what might be happening. Check sheets exist in three basic forms:

- Attribute check sheets categorize data by attribute, i.e., male or female, young or old, etc.
- Variable check sheets categorize data by the values of its variables amount. Rather than young and old, we might record actual ages.
- Location check sheets categorize events spatially. We all have seen maps with pins denoting the location of events such as: fatal accidents, customers, or sexual assaults.

The purpose of each of these tools is to enhance our understanding of the situation being studied. The technique, in and of itself, does not solve anything. It presents data in a way that leads to a solution.

Consider a situation in which we need to study why a child's sand castle is disappearing on a beach. Over the next thirty tides, we ask our son to build a sand castle pretty much as he has done in the past. After each tide change, we observe whether the castle remains and records the observation as follows.

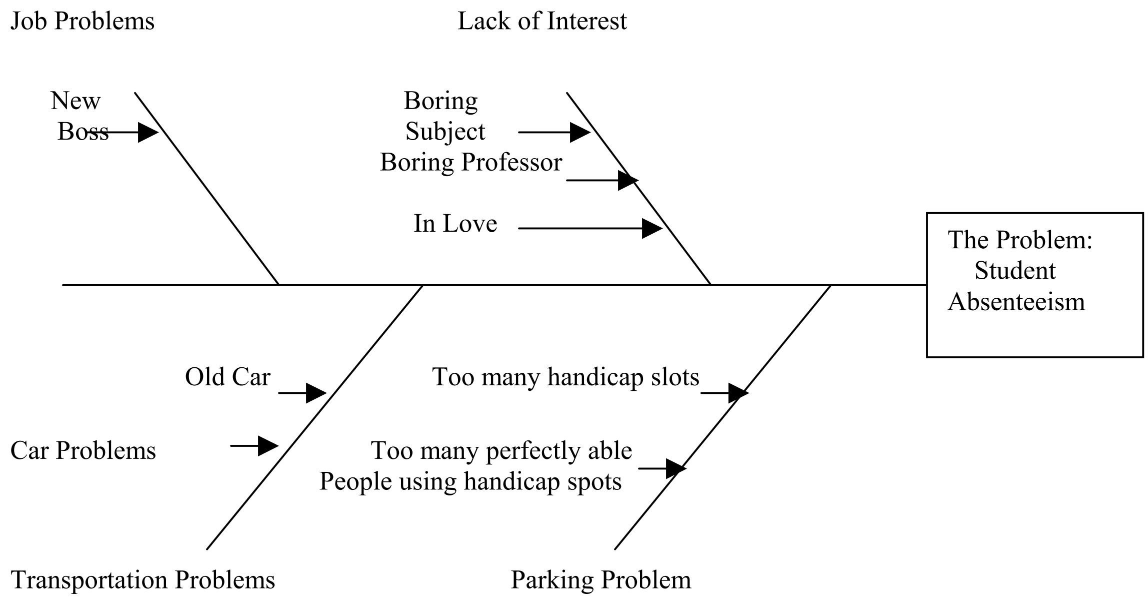
Exhibit 2
An Attribute Check Sheet

Attribute	High Tide	Low Tide
Sand Castle Remains	**xxxx**	xxxxx xxxxx xxx
Sand Castle Disappeared	xxxxx xxxxx xx	**x**

It seems likely that the major culprit is the high tide, but not always. We have learned something but we have not been able to explain the five outcomes denoted with bold print. The search should continue because we have lost something. As it turns out, in four instances, our son built the high castle above the high tide line. That explains the four outcomes in the upper left box. The one in the lower box remains a mystery, we did have a storm one night, but our records did not record which day this outcome occurred.

Cause and Effect Diagrams: Problem solvers often face problems with unknown dimensions. Hence it is too early to create mutually exclusive categories as we did with check sheets. When this situation exists, Cause and Effect Diagrams provide a useful mechanism for extracting from the knowledgeable people, some of the possible causes for the problem or symptom. We start with a situation for which we need to know more about why it is occurring. It could be classroom absenteeism. On a blank sheet of paper, we write Problem: "Student absenteeism." We then ask, "what are some of the possible causes for students being absent?'

Exhibit 3
Cause and Effect Diagram



Care must be taken not to exclude possible causes. For example, in the above, it may be politically incorrect to suggest that there are too many parking slots reserved for persons with handicap stickers.

When it appears that most of the possible causes have been elicited from the participants, then it makes sense to seek a consensus as to what might be the major points. Some consultants ask the players to place stars next to those causes that they think are the most important. Once this has been done, the causes with the most stars can then be used to prioritize future management actions. But care must be taken to focus on causes that are susceptible to management actions. Knowing that earthquakes are a cause for tidal waves is important, but in reality, there is little humans can do to prevent their occurrence. Focusing on buildings erected close to the shoreline might be more productive.

<u>Plan-Do-Check-Act Cycle (AKA The Deming Cycle)</u>: The scientific methods is alive and well but of late we have given it special names. One of these is called the PDCA Cycle, one of the investigative tools associated with the TQM movement. It consists of four separate but linked activities that are designed to identify opportunities for continuous improvement. The activities that spell out the name of this tool are:

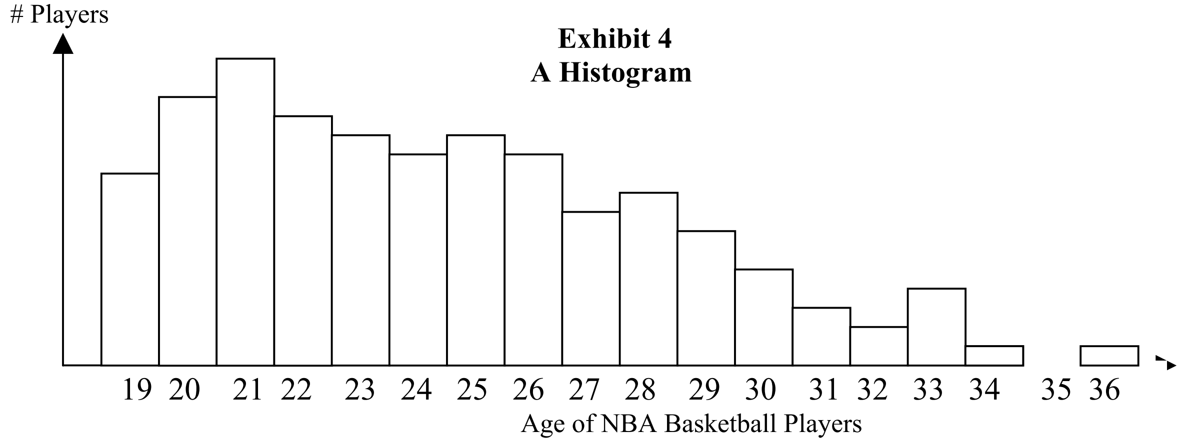
- *Plan*: Managers identify a problem by studying the current situation to detect a gap between it and the desired future situation. A large gap is worthy of considering a major corrective action. A small gap makes it suitable for a firm's continuous improvement process. During this stage, the manager must identify actions that might close the gap. This step culminates with a decision to try one or more of the gap-closing procedures.
- *Do*: Managers then proceed to implement the proposed gap-closing procedure. If possible, this is done in a setting in which all other things are kept equal. The intent is to try to isolate the effects of one or more of the key process variables. If this cannot be done online, then some other form of experiment must be tried. This may be a lab model or a prototype process.
- *Check*: The results of the experiment are then compared with what was expected. At this step, the manager compares the actual results with the desired results. If the process's results are moving in the right direction, should additional experimentation be conducted?
- *Act*: Here managers review the results and take appropriate corrective action. The objective is to take corrective measures that will prevent reoccurrence of the problem being studied.

This is an ongoing process. Once we are convinced that the problem has been corrected, we need to determine that the solution is not causing any other problem. Once the solution has been institutionalized, we can go on to the problem with the next highest priority.

Statistical Methods: With the advent of spreadsheets with graphical display capabilities, descriptive statistics has come back into its own as an investigative tool. Two of the most used statistical tools are:

- *Histograms* provide an efficient way to display the range and pattern of data. The range (i.e., the width of the distribution) tells the likely highest and lowest outcomes *if the future is like the past*. Knowing the mean and median quantifies also helps with process planning.

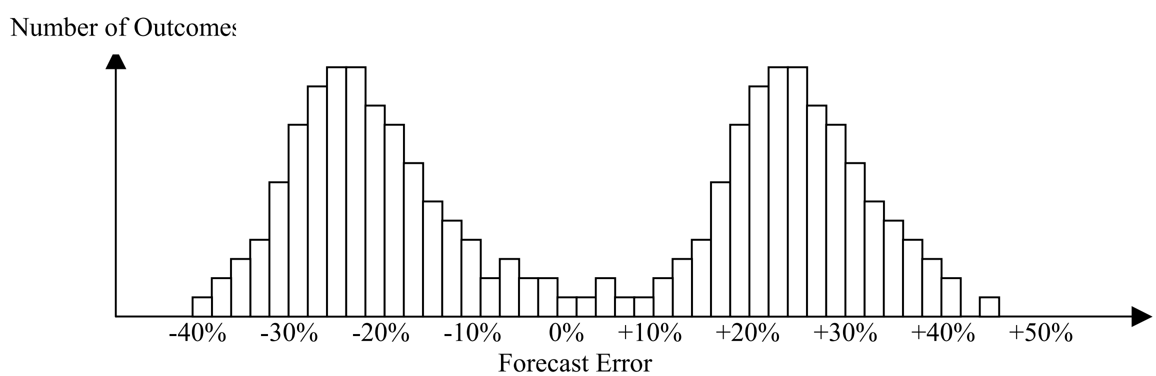
Exhibit 4
A Histogram



Consider the above data set showing the number of NBA players by age. An observation of this distribution may indicate a number of things. One is that most players enter the league immediately after college but that their careers seemingly last about five years. The other is that so-called hardship cases, i.e., those who quit college early or who never go to college, are becoming a significant factor in professional basketball.

The pattern of the distribution offers managers some insight as to the underlying processes that are generating this profile of outcomes. If one encounters a pattern approaching a normal, bell-shaped distribution, then this may indicate that the outcomes are being generated from a single stable process. In contrast, if the manager encounters a pattern with multiple peaks, then this may indicate the presence of more than one process. For example, if we had two individuals making demand forecasts. The first individual is a pessimist so his forecasts are always about 20% below actuality. The second is an optimist and his forecasts generally run 30% higher than that which actually occurs. If we were to record the forecast errors of each individual and then create one histogram of the forecast errors encountered, the distribution would have the following pattern.

Exhibit 5
A Histogram with Twin-Peaks

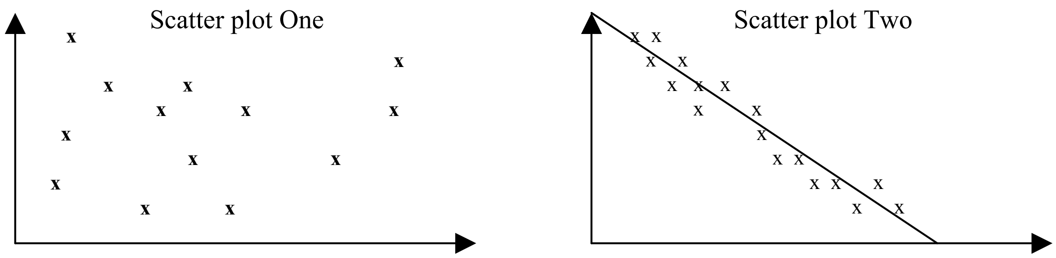


An insightful manager may try to solve this problem by giving individuals additional training in forecasting or he might resolve the problem by using both of their forecasts in an equation that adjusts for their known bias.

When the shape of outcomes shows no readily identifiable pattern, the manager may fail to glean insights—other than the factor that his world seemingly is unfathomable. "Thanks." But in actuality, this may be a sign that not enough is known about the process--or the way we are measuring performance. Don't shoot the messenger, dig deeper.

- *Scatter plots* offer a way of displaying two-dimensional data in an insight-building way. Using the graphic display capabilities in Excel, one can create a scatter plot by displaying one variable's measurement along the x-axis and the second along the y-axis. If one suspects that one measurement is causing the other's measurement, then the perceived independent variable is placed on the x-axis and the dependent variable on the y-axis. If you really don't know which is which, just plot the data. Consider the following two scatter plots.

Exhibit 6
Two Scatter plots



In scatter plot one, we do not see any pattern, i.e., the values along the y-axis do not seem to follow the values on the x-axis. Scatter plot two does seem to indicate a relationship. The higher the values of the x-axis, the lower the value of the y-axis. Indeed, we might even "fit" a line to illustrate how measurement 1 and measurement 2 relate. *Caution: we have not affirmed causality.*

If one calculates the difference between the line value and the observation point values, the magnitude of these deviations indicates the strength of the relationship existing between these two measurements. Small deviations indicate a strong relationship. Large deviations indicate the reverse. Lastly, if the pattern of these deviations is not consistent over the entire range, then this may be indicative that the relationship is not consistent over that range.

Organization-Wide Investigative Tools:

One common weakness is that we fail to investigate outside our organizational domain. Just as marketing should seek feedback from its non-customers along with its existing customers, operations managers have long understood the importance of studying the business processes of other firms—especially those with leading-edge activities. Within OM, these are called best practices.

- *Benchmarking*: One way to learn more about a firm's best practices is a learning process called—benchmarking. A benchmark is a standard for others to strive to achieve or exceed. Benchmarking is a process-oriented management activity in which the company creates a team to study a business process with the intent of improving it. It involves four stages:
  - <u>Stage One</u>: Identify a business process deemed needy of improvement. It may be something as simple as the order entry process. Spend time to know exactly how your process works and how well it is contributing to the overall effectiveness of the firm. Measure its performance using value-based metrics.

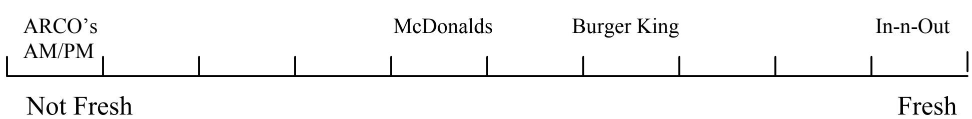
- Stage Two: Search the world for others with like business processes. Try to identify those who, in the estimation of benchmarking experts, are considered world-class performers of *that activity*. Caution: do not assume that world class companies consist entirely of world-class processes. A process worthy of being studied may reside in a firm with mediocre performance. Also, do not limit your search to firms strictly in your industry. You may not be in the mail order business, but your firm might want to study the way L.L. Bean handles its order entry. The focus is on the process—not the industry. Also, do not rule out the possibility that somewhere in your firm, a world-class process exists.
- Stage Three: Once a world-class process has been identified and the firm has agreed to let you benchmark its process, prepare a systematic observation plan for your tours of the facility being studied. The purpose of the visit is not a plant tour--it is a process inspection. Upon completion of the visit, your team should have: completely documented the process, understand how its process capability specifications differ from those of your firm, and identify those areas in which the process studied has capabilities superior to those of your plant.
- Stage Four: Develop a process improvement plan for your operations based on what was learned. These may involve a full-scale redesign, but in most cases it will result in a refinement of the existing processes.

One secondary benefit of benchmarking is that employees who are not normally included in management activities get to visit other plants, talks to their operators, as well as some managers within their own firm that they might not normally have significant interactions. You can almost hear a plant level worker thinking: "Humm, they bought me a ticket to Iowa to study John Deere's order entry system. *They must value my experience and opinions*." Respect works.

- *Attribute Mapping*: A more general approach to studying the characteristics of your competitors is called attribute mapping. The purpose is to objectively compare the attributes of your operations with those of other like operations. You might be comparing your division and how it performs viz-a-viz with that of other within your firm. For example, Weyerhaeuser's corrugated box division might want to compare the plant and customer profiles of the five best performing converting plants with its five worst under-performing plants. Looking externally, McDonalds might want to compare the attributes of its Class A locations with those of Burger King or In-n-Out Burger.

Mapping is an excellent way to include subjective data into your investigations. It starts by defining which attributes you think important and a decision of how best to measure each attribute. Two common forms of attribute mapping are linear maps and the radar diagram. A linear map has the form:

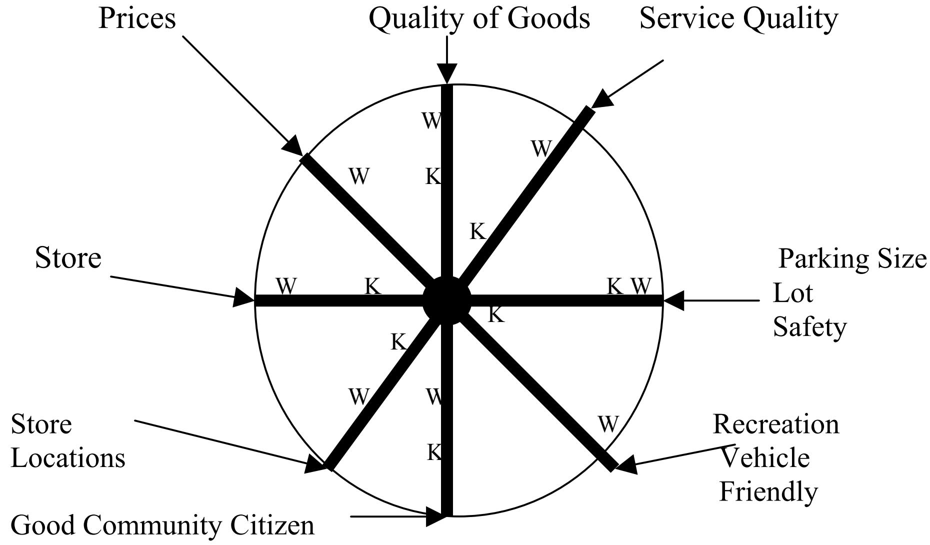
Exhibit 7
Attribute: The Freshness of the Food



It should be noted that this subjective estimate was made before McDonalds changed its processes.

A radar diagram does essentially the same thing but in a more compact form. Whereas a linear map has a line for each category, radar diagrams have a spoke for each attribute, as can be seen below.

Exhibit 8
A Radar Diagram



Here we are going to compare the performance attributes of two major discounters, Kmart and WalMart. Prior to the start of the investigation, we have identified eight attributes of interest. Marks closest to the hub denote weak performance whereas those closest to the outer circle denote excellence. Some practitioners go one step further and connect all of the Ws and Ks with a line to create a spider web like diagram.

When the process is complete, you have a concise diagram that displays the investigator's estimation of the firm. The points on this chart can be single point estimates or they can be statistical medians or averages if the observations come from many individuals. We recommend it as a concise way to display attribute data—one diagram fits all eight dimensions.

Tools to Glean Meaning from Data

In a sense, the act of collecting and displaying data should provide some meaning. But there are a number of statistical tools that enable the operations manager to make more definitive statements. Yes there is a difference—but is the difference significant or just random noise? The use of mathematical statistics enables the operations manager to answer such questions. The following are some of the tools that operations managers use to better understand what is happening.

- Simple regression: As we saw in our discussion on scatterplots, it may be possible to discern a relationship between two variables. In simple regression, we try to formulate a model in which one tries to explain the behavior of an assumed dependent variable, (normally placed on the y-axis), as being "driven" by an independent variable, (normally placed on the x-axis). A simple linear regression model seeks to determine the line that best fits the data. Using the least squares method, it seeks to determine those constant values, a and b, that will result in the best fitting line $y = a + bx$.
- *Multiple regression*: This form of regression extends the above model to include the multiple variable case, i.e., we try to find those values of constants which will provide the best fit for the expression: $y = a_0 + a_1x_1 + a_2x_2 + \ldots + a_nx_n$ where y is the dependent variable and the x_js are the independent variables.
- Hypothesis testing: This technique involves sampling from a population to create statistics, such as a sample mean, which then can be used to prove or disprove a hypothesis. For example, we need to know if the percentage of product defective in a shipment is higher than the 2% upper limit the firm

has established as its acceptance standard. A sample is taken and each unit sampled is tested. Based on this information, we can infer whether or not the lot meets our quality standard. When control charts are used, the hypothesis being tested is "Is the process under control?" Based on our sample statistics, we make that judgment.

- Design of Experiments: Just as in the case with PDCA, design of experiments seeks to systematically explore for more desirable areas of the operating surface. Consider it the multiple regression equivalent of the Deming Cycle. With this method, investigators systematically plan how they want to explore a system in search of better results.

Model Building

A model is an abstract representation of reality that simplifies actual events or situations. Some of the earliest models were built for salespeople to simplify the task of explaining what a product looked like or how it might function. These were physical models. Today many of the models use mathematics, computers, and computer-assisted graphics to reflect reality. In the operations management realm, models have been used to solve many of the eight forms of problems discussed earlier. Usually, the model builder represents reality as being a set of decision variables whose values determine the level of achievement in reaching our goal(s). Some of these applications are:

- Unconstrained single goal models: Here our goal is either minimization or maximization. In the classic inventory problem, our goal is to pick that level of the decision variable (the lot size) that will minimize total inventory holding and production setup costs. This is a deterministic model. In the classic newsboy problem, one must decide the number of newspapers purchased on a one-time basis that will maximize expected profits. This is a problem with uncertainty. Unconstrained single goal models can be solved using calculus, spreadsheet searching, or graphical methods. The method that you use should be based both on your level of comfort and the ability to explain the results to the interested parties. For simple problems, spreadsheets offer a truly flexible approach. Costs don't have to be continuous.
- Constrained single goal models: In the real world, limitations exist. The task of the operations manager is to find values for each decision variable that will optimize a goal while observing one or more constraints. Usually constraints exist in either the form of resource limitations or marketing requirements. In the classical economic lot size model, we did not concern ourselves with warehouse space. If the resulting lot size means that we cannot fit all of the goods into a warehouse, then we must either get more warehouse space or reduce the size of the lot. Both will lower the value of the goal. In this case, it will mean that the production and inventory costs associated with that product will go up.

There are a number of ways to solve constrained single goal models. Three ways are:

- The Lagrangian multiplier approach: This method takes the constraint, such as warehouse space, and places it in the objective function. What it does in the inventory model is to systematically raise the cost of holding inventory until the lot size is reduced to fit the warehouse. This method can only be used for relatively small problems, i.e., problems with only one or two constraints.

- Linear programming: Linear programming selects those values of the decision variables that optimize a linear objective function subject to a set of linear constraints. Computer programs exist that are capable of handling problems with thousands of variables and constraints.

  Linear programming problems typically are found in material flow type industries, i.e., oil refinery and shipment problems, mix problems, and unit fractionation processes, such a slaughter houses. Mathematically, linear programming problems can be expressed as:

$$\text{Max or min } z = c_1x_1 + c_2x_2 + c_3x_3 + \ldots + c_nx_n$$

  Subject to:

$$a_{i1}x_1 + a_{i2}x_2 + a_{i3}x_3 + \ldots + a_{in}x_n \ \{ <,=, \text{ or } >\} \ b_i \quad \text{for } i = 1,2,3,\ldots,m$$

  and

$$x_j >= 0$$

For a cost minimization problem, the decision variables are the x_js. Each unit of decision variable j costs a_{ij} dollars and uses a_{ij} units of resource i. Relax, you will not be asked to solve this problem with the Simplex methods in this course because the ability to solve this problem exists within Excel's Solver option.

- Combinatorial Methods: The power of the computer makes it easier to solve allocation problems such as the one discussed earlier. It would be fairly easy to find the largest integer value for each variable by dividing the amount of resources available by the resource usage coefficient a_{ij}. If the maximum integer value for variable x_j is UB_j If one does this for every variable, then the number of possible solutions is $(UB_1 + 1) * (UB_2 + 1) * \ldots..* (UB_n + 1)$. For each of these combinations, we need to see if it violates one or more of the constraints. If it is feasible, we then determine its total objective function value. If it is better than any one we have found yet, we store it and continue the search until we have evaluated all possible combinations.

Work Sequencing Methods:

As we saw in the previous shell, there are a number of problems that ask us to find the best "something" through a network. Our goal could be to maximize flow, minimize project duration time, or select the shortest path through a network. Some tools that are used in this area are:

- Gantt Chart which is a graphical way to arrange work in a feasible least time way
- PERT and CPM which are project management application packages

During the remainder of the course we will refer frequently to these tools and ask you to learn more about them. I hope that we have given you a good start. Happy surfing!

LINKING ORGANIZATIONAL LEARNING TO CORPORATE PERFORMANCE

Learning how to do something better does not always result in better results. Many an American company has failed to see bottom-line results from all of the initiatives carried out within the organization. In *Jack: Straight From the Gut*, Jack Welch, GE's former CEO provides a profile of how one leading edge company has gotten results by integrating strategic initiatives within a performance driven management system.[4] The GE way differs from the old HP Way in that an individual's or a business unit's survival depends on its ability to meet specific quantifiable goals. Individual managers that are assessed as being in the lowest 10% performance class are purged from the system—both in good years and bad. Individuals deemed to be in the upper 20% are richly rewarded with promotions, raises, and stock options. But to survive, even these Class A managers must subscribe to organization values.

An equally important facet of GE's people factory is the creation of a culture that is "boundaryless." While benchmarking has been around a long time, GE has made it an integral part of its management system. Because an individual's reward is tied heavily to the performance of GE stock, managers are encouraged to share what has worked and not worked for them.. The *Not Invented Here* learning disorder is not tolerated.

Once Welch discovers a best practice with organization wide potential, he develops what he calls "Game Changer" initiatives. For example, while they tried most of the Japanese TQM programs, he never saw the significant improvements in product quality that he expected. But when he saw what Allied Signal was realizing from its Six Sigma Quality programs, Welch initiated Six Sigma as one of the firm's key initiatives. Soon, Class A managers were being judged by their success in developing Six Sigma within their business units and *by their measured results*.

Lastly, Jack Welch has created an organization that initiates and supports results-oriented learning. It is a culture that rewards corporate-focused passion. The term "corporate-focused" is used because while individuals are the stars within GE's world, it is the wellness of GE and its shareholders that matter the most. Even golf comes in second or third. I didn't say second out of respect for his talented, understanding second wife who had to share her honeymoon with a mind that never was far removed from the GE way—his way.

SUMMARY

This shell builds on our development of process flow analysis begun in Shell 4. It started with a macro-level discussion of what organizations must do if they are to learn. The shell starts with Peter Senge's Learning Organization concepts—including a discussion of his five component technologies of learning.

Since learning relies on observation and data gathering, we discussed how organizations collect and use data. This then lead to a discussion of problems, their structure, and a categorization of some of the classic forms of problems. The purpose of categorization is to avoid having to reinvent the wheel whenever problems that have previously been encountered are found. The concept of solving, resolving, and dissolving problems is discussed.

The shell introduces a taxonomy of some of the tools operations managers use to identify and solve problems. These tools are categorized as: investigative tools, statistical tools, organization wide exploratory tools, tools to glean meaning from data, and model building. It concludes with a brief overview of the contributions of my secular god, Jack Welch—the individual that many consider the greatest manager of the 21st century. Forgive my bias but studying the GE way is a good place to benchmark management processes.

End Notes

1. Peter Senge, *The Fifth Discipline*, Doubleday, New York, 1990, p.18.
2. Douglas McGregor, *The Human Side of Enterprise*, McGraw-Hill, New York, 1960, p.45.
3. Russel Ackoff and Patrick Rivett. *A Manager's Guide to Operations Research*, Wiley, 1967, pp. 34-56.
4. Jack Welch, *Jack: Straight from the Gut*, Warner Books, New York, 2001.

Expected Learning Competencies

Before putting Shell Five down, you should ask yourself the following questions. Am I able to explain?

1. Explain why organizational learning is important, especially for firms operating in the Lexus lane.
2. The essence of Peter Senge's Learning Organization concepts.
3. Explain the difference between the text calls problem: solving, resolving, and dissolving. Be prepared to give examples of each.
4. How the nature of a problem influences how a manager should deal with the problem.
5. Be familiar with what each tool in the Operations Manager's Toolkit can do and be prepared to illustrate how each can be used.
6. What your instructor added to this shell and why he or she thought that it was important enough to warrant its inclusion

Frequently Asked Questions

Instructors have been known to ask questions similar to the following:

1. Explain the nature of data that operations managers receive and how many of them transform it into information capable of being used in their decision-making processes. How have information technology advances enhanced the OM managers decision-making capabilities?
2. What did Peter Senge call "deeply ingrained assumptions, generalizations or even pictures or images that influence how we understand the world and how we take action?"
   a. Systems thinking
   b. Personal mastery
   c. Mental models
   d. Shared learning
3. When a frustrated batchelor elects to rid himself of the single sock problem by throwing out all existing socks and by three dozen identical pairs of black socks, this is an example of"
   a. Problem solving
   b. Problem resolving
   c. Dissolving the problem
4. Which of the following is not a data collection tool?
   a. An attribute check sheet
   b. A variable check sheet
   c. A Scatter plot
   d. Attribute mapping
5. Which of the following items from the OM Toolkit would you use if you wanted to understand what relationship exists between two variables?
   a. A scatter plot
   b. A histogram
   c. A Gantt chart
   d. A queuing model
6. PERT is an approach that is used to manage large projects.
7. Linear programming can be used to find the optimal solution to a queuing problem.
8. Adding a constraint to an allocation problem can improve the value of the objective function.

BUCKET TWO
OPERATIONS SYSTEM DESIGN

The five shells in this bucket deal with system design. As was stated in Shell One, if you don't like the values being generated by your system, you must either change the system or the way the existing system is operated. Shell Six deals with demand forecasting. This is a key input to the system design process since one must know how big a market can be before starting to design a value-delivery system. This shell also deals with designing a firm's demand forecasting system—a key input to anyone trying to operate an existing system. All too often, perfectly good systems fail to satisfy customers because their operators were fed incorrect demand forecasts.

The second shell deals with long-term capacity issues. Knowing how much capacity is needed is not enough. System designers must decide the type of processes the firm will use to satisfy customers with quality products in a timely manner. This decision set includes: what type of processes should be used, where should they be located, and when is the best time to invest or divest in these facilities?

Shells Eight and Nine relate to product innovation—the processes a firm uses to design goods and services and their product delivery systems. We start with services because most students are intimately involved with firms that are mostly providing services. But services extend far beyond Big Macs. Indeed, services are the part of operations management that is experiencing the greatest impacts from information technology breakthroughs and from globalization.

Shell Nine focuses on the product innovation processes that deal with the manufacturing of goods. As is the case with services, designing great goods starts with a fundamental understanding of the values of target customers. It also involves the application of emerging technologies as their use becomes feasible. Creating a truly great product just doesn't happen—it is usually accomplished in an organization that fosters "structured creative chaos." In this shell, we study how great product design and development companies do it.

Bucket Two concludes with Shell Ten, Designing Supply Chain Management Systems. Emerging technologies, evolving management practices, and increasingly global sourcing have had a dramatic impact on that part of operations management called purchasing. Managing the flow of information and materials within a supply chain can have an impact far beyond that of securing the needed materials at the lowest possible cost. One only has to look at Dell Computer to see how a supply chain it can give a firm a competitive advantage.

SHELL SIX
DEMAND FORECASTING

How Many Ernies?

Each year toy makers, such as Mattel, must make a set of important decisions that will decide the economic performance of their firms. Many months prior to the Christmas season, they must decide which toys will be "hot" and which will not. Toy retailers must also make the right decisions or they will face unhappy customers and be stuck with slow moving merchandise. How could anyone have known in time that a pajama-clad doll called “Sing & Snore Ernie” would be a hot item? In December of 1997, parents were willing to pay $400 for this scarce $30 doll. It was “Tickle Me Elmo” all over again.

A root cause of this problem is long manufacturing and distribution lead-times. Toy manufacturers must ramp up production by mid-year to ensure that they have a sufficient number of the best sellers and few of the dogs. A more important root cause is that adults really can’t predict what children will want. In short, what parents’ value has little to do with what their little tyrants will demand.

While nobody knows for sure, Mike Domaine of Digital Research, Inc. has a demand forecasting process that seems to work. This year, this Kennebunk, Maine firm was able to predict in July that “Sing & Snore Ernie” would be a winner. How did Mike know this? Partly because a three year old, named Caitlyn Gearin, confided to him that she "liked to tuck Ernie into bed."

This was not a chance conversation. Mr. Domaine's market research firm uses a two-stage process. Each year, toy manufacturers submit their new products for evaluation by the ultimate consumers. In the first stage, a specific mix of 100 children is selected from child-care centers to evaluate the new toys. The children are divided into focus groups with "equal representation from those who like action figures, board games, construction toys, dolls, and arts and crafts." In June, the children are gathered to rate their top three choices in each category. By the end of June, the focus groups have reduced the 380 candidate-toys to 63 finalists--the top three in each of 21 categories.

In the second stage, the finalist toys are shipped to KinderCare Learning Centers around the country where specially trained teachers observe how children "take to the toys." This year, the 550 children cast secret ballots ranking their favorites. After 32,000 kid-hours of research, Ernie won in his category with the low score of 1.86. *Family Fun* magazine then uses these results as the basis of its Toy of Year Award that is the equivalent to an Oscar in the toy industry.

Source: Joseph Pereira, "To These Youngsters, Trying Out the Toys is Hardly Kids' Play," *WSJ*, 12/17/97, p.1.

Shell 6
Demand Forecasting

Table of Contents

Learning Objectives for Shell 6

After reading this shell and thinking about its contents, you should be able to:

1. Understand the important roles demand forecasting as an input to operations management system design and operations planning activities.
2. Understand the system design phase of demand forecasting, i.e., the building of a business process that transforms customer and marketplace data into information that can be used to forecast, track, and management demand.
3. Define the following terms and describe their roles in operations management:
    a. Demand forecasting
    b. Demand tracking
    c. Demand management
    d. Qualitative demand forecasting
    e. Quantitative demand forecast
    f. The use of intrinsic time series
    g. The use of extrinsic time series
    h. A leading indicator
    i. A moving average
    j. The components of time series
4. Describe to role of performance metrics and some of the major ones that are used to track the performance of demand forecasting processes.

INTRODUCTION

The challenge of "How Many Ernies?" illustrates the two demand forecasting related tasks that system designers must confront. The first is that of determining the magnitude and timing of the demand the firm should plan to satisfy. The system designer needs to know this to ensure that the firm's supply chain will have sufficient capacity to meet planned "sales objectives." The term, sales objectives, is used instead of demand because the firm's strategy may not call for it to satisfy all demand. If the firm's sales objectives are higher than the demand forecast, then the firm needs to rethink its product, pricing and promotion plans.

The firm needs to know the pattern at which demand occurs if it hopes to have the capacity to make and deliver goods when and where it is needed. Having snowboard making capacity in May is not that useful. Nor is snowboard inventory in Alabama. The system designers need to know these demand attributes because what they design will be judged on how well it expends scarce factors of production to support the firm's marketing programs. In short, it needs to enable the firm to have the right product at the right location at the right time. This system design challenge is called the how much, where, and when challenge (AKA the HMWW Capacity Challenge).

The second demand related system design challenge involves building an information system that collects data and transforms it into useful inputs to the demand forecasting processes. This is called the demand information system challenge (DIS Challenge). The nature of what needs to be forecasted with this challenge is quite different. Specifically, the DIS task is that of deciding how best to gather information on the market and customers in order to enhance the firm's demand forecasting capabilities. The performance metrics for these processes are:

- Does it provide the demand information in the detail needed to make it useful?
- Do they arrive in a timely fashion and in the most useful format?
- Does the system tap the best sources of information as inputs to the forecasting process?
- Is the forecast reasonably accurate—especially when the pattern of demand is changing?
- Does the process understand the sources of uncertainty?

Since reduction of variance is an important goal of most business processes, operations managers need to understand the causes for this uncertainty. To understand uncertainty better is useful to categorize it as:

- *Demand uncertainty*: To what extent will the market for the firm's existing and future products grow or shrink over time? Will the firm's market share increase or decrease as other competitors enter or leave the market?
- *Technological uncertainty*: What new technologies are likely to impact the firm's product innovation process and its supply chain management process? Are there any technologies that the firm should consider as potential disruptive technologies? Are there technological innovations in other fields/markets that might migrate to your marketplace?
- *Factors of Production Uncertainty:* Will adequate quantities of reasonably priced raw materials and labor be available? How many of current employees are likely to retire or move on over the next five years? Will their replacements necessitate additional human resource training and/or a redesign of the firm's organizational structure? Will the supplies of natural resources and parts components being able to keep up with the anticipate growth?
- *Societal Uncertainties***:** Will future societal change necessitate changes in the way the firm currently does business? What impact will inter-government treaties, such as NAFTA, have on the markets the firm serves and the supply chain it uses? What post-WTC uncertainties should a firm consider as its plans to

operate on a global basis? And most importantly, how will increased environmental concern impact the way products are designed and manufactured?

While this shell will focus primarily on demand uncertainties, we do not mean to diminish the importance of the other three uncertainties.

DEMAND FORECASTING—SOME STRATEGIC ISSUES

Both the HMWW and the DIS challenges face important information sourcing issues. They are:

- Should forecasts be based on historical data or are there better inputs for predicting future events? For a stable product, past sales may be a good basis for predictions. Management need not intervene except when something unusual and significant happens. But for a new product or a product experiencing rapid change, the past will not do. What is needed is a model that will enhance the firm's understanding of its customers and the marketplace.
- How much detail is necessary to serve the needs of the firm's internal customers? Should the forecast be aggregated sales or do we need to predict demand in greater detail, i.e., the number of 8-ounce tubes of Crest toothpaste sold at the Gilroy Wal-Mart during the first Monday of July. Don't laugh, companies are collecting data in this detail. But detail is not always useful.
- What are the best sources of information? If historical data is used, should we use intrinsic data, i.e., data from the same phenomenon, or extrinsic data? Using weather to predict soccer game attendance would be an example of extrinsic data. The extent to which a firm uses sources outside its legal framework is a strategic issue. Some of the extrinsic data that firms use are:
  - *Generic data* on the well being of global, national, or business sector of the economies. Since the demand the firm experiences is driven by economic activity, it makes sense to explore the relationships that may exist between your company's sales and some national statistic. If a relationship exists, hopefully the generic time series leads your time series.
  - *Industry specific data* often provides useful inputs. Within the electronics industry, the bill-to-book ratio gives an indication of whether the rate reporting firms are booking new orders is more than the rate they are billing for shipped product. A ratio above one is a positive sign. In a similar vein, the nation's purchasing agents provide an index that indicates the likely purchasing rate for industrial goods. When using indices, the challenge is to find industry specific data that provide timely insights as to what is likely to happen in your industry.
  - *Situation specific data* may provide the most meaningful input to the operations planning process. As the manager of a firm selling gardening-related products, we found it useful to study the weekend weather forecast, the number of retailers selling like products on promotion, and any significant weekend event that might give potential users of the product a reason to not work in their garden. As an operations manager, you use what works best.

    Another source of information lies within the organization. Sales persons and other employees who work closely with customers or the marketing channel often possess information that would be useful to the demand-forecasting task. The challenge is to gain access to their knowledge since they often have many other activities claiming their time. .

  - Should the forecasting business process be centralized at the corporate level or done on a decentralized basis? Just about every software vendor has demand management and demand forecasting modules that are linked to a firm's order entry processes. Strong arguments can be made for using these, but I fear that they may also lose fuzzy information that the field level folks sense but either can not or are unwilling to quantify as required by the formal system.

These are strategic issues. As is the case with most other facets of strategy, if demand-related forecasting processes are not designed right, the rest of the organization will suffer.

Dialogue Driver: Can you identify any aspect of your life where you bought something or did something that you might not have done if you knew then what you know now?

DEMAND FORECASTING, DEMAND MANAGEMENT AND DEMAND TRACKING

In everyday life, the terms, forecasting and predicting are often used interchangeably. Such is not the case in operations management. We define *demand forecasting as the business process that attempts to estimate sales and the use of products so that they can be purchased, stocked, or manufactured in appropriate quantities in advance to support the firm's value adding activities.* Note that the term "use of product," is included in this definition since at each stage of the supply chain, some internal or external customer is placing a demand on the upstream business unit for goods and services.

David Ross, a forecasting guru, defines the terms forecast and prediction as follows. [1]

"A *forecast* is an objective estimate of future demand attained by projecting a pattern of events of the past into the future."

Literally, the word forecast means to "throw ahead, to continue what historically has been happening.

"A *prediction* is a subjective estimate of what events will happen in the future, based on extrapolating or interpreting data that occurred in the past."

Prediction, or "saying beforehand" is the process whereby management uses subjective judgements to decide whether events will be repeated based on past experience or to anticipate changes arising from new environmental, geographical, political, or demand patterns."

BugOff demand = 500,000 units + 1200 times the average rainfall two months earlier

This would be a forecast. If however, BugOff's sales manager thought for a minute and said, "Given the rain we've had, I think our sales in June will be 550,000 units," then this is a prediction. Clearly, the distinction between what Ross calls a forecast and a prediction can get a bit fuzzy. *

The second definition is for the term ***demand management,*** which is a business process that seeks to coordinate and/or influence the pattern of demand arrivals to achieve a mutually satisfying sales transaction. This proactive approach is based on the premise that the customer either will or must accept having the timing of the product delivery transaction influenced by the capacity limitations of the selling organization. In services, this is routinely done by businesses that ask customers to schedule an appointment, such as is done when booking a flight on an airplane or setting a time to get your hair done.

The third definition is for the term *demand tracking*. In some business situations, there are just too many items to expend significant managerial resources to forecast the demand for each individual item. Firms, such as Caterpillar, stock hundreds of thousands of different spare parts in its distribution warehouses. Demand tracking is a business process that systematically records *what has just happened*. Often a business will assume that what has just happened is an acceptable basis for making short-term forecasts of what will happen in the next period. Demand tracking systems use the *management by exception principle* to focus the firm's scarce managerial resources to those product where demand tracking is not working well.

Dialogue Driver: Is there any aspect in your life where you track demand or usage rather then forecast what will happen in the future? Why don't you spend more time doing a forecast?

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* These subjective predictions are sometimes call SWAGs, which is an acronym for Scientific Wild Ass Guess. The origin of this term is unknown but it clearly implies the source of the forecast.

Service firms often seek to *dissolve* the demand-forecasting problem by asking their customers to make an appointment. This allows the firm to bring in only those resources needed to meet schedule service demand. When overt demand scheduling is not possible, some service firms use their understanding of their customers' values to covertly cause them to "volunteer" to change their buying patterns. Some firms seek to manage customer behavior by providing system congestion information and by offering off-peak prices. Health clubs inform their customers when their facilities are least crowded. Food stores time their promotional ads to induce cost-conscious customers to shop on slow days. Others advertise their capacity constraints as does Bekins, the household moving firm, which uses the slogan, "We would rather turn you down than let you down." Airlines and hotels offer off peak prices. Service firms discovered demand management to be just good business.

In the manufacturing arena, make-to-order firms adjust "promised delivery dates" to schedule a customer's order within the plant. When the firm is busy, some firms quote a due date that is further out rather than adjust their system's capacity. This is done when short-term capacity adjustment is not feasible. Customers with urgent needs can often get an earlier delivery date--but this may involve higher prices--as is routinely done by Hewlett-Packard and Federal Express.

Some Guiding Philosophies

Two quotes from Oliver Wight, an early operations management guru, guide our thinking. [2]

"There is no such thing as a reliable forecast."

"Unless the system is 100 percent reliable, it must be made simple enough so that the people who use it will know how to use it intelligently."

The first quote guides both the designers and users of demand forecasting processes that they should avoid seeking the impossible. Demand forecasters should try to improve their processes and provide more reliable predictions, but their decision-making processes must remain flexible enough to accommodate "reasonable forecasting errors." Waiting for the perfect forecast is folly.

The second quote urges the designers of demand forecasting system to identify the users of their forecasts, explain the strengths and weaknesses of the analytical tools, and then work to delight those in need of accurate demand forecasts. Effective employee involvement in demand forecasting requires accessible analytical models that help users to understand and take ownership of the process.

A key concept in demand forecasting is *pattern recognition*. Herbert Simon's studies on decision-making led him to argue that pattern recognition is critical, i.e., "the more relevant patterns at your disposal, the better your decisions will be."[3] In earlier times, successful managers crafted forecasts by assimilating their experiences the data on hand was scarce. Today, information technology presents managers a different problem—they have too much data.

Once relevant demand patterns have been observed, management often is faced with three choices:

- Doing something quickly to capitalize on this knowledge before the competition can.
- Doing something to correct the patterns if they have an adverse impact on the firm's well being.
- Using your knowledge of the patterns to enhance the firm's decision-making processes.

The first two of the above relate to the strategic capabilities of the firm. Note the importance of agility, i.e., the organization's ability to quickly recognize an emerging pattern and being able to quickly decide what response is prudent and then to implement the action plans. Having analytical skills to quickly recognize changing demand patterns but not having the capability to respond in a timely manner is waste.

A FIVE-STEP FORECAST SYSTEM DESIGN PROCESS

In the system design phase, the demand forecasting process must address the following issues:

1. Identify the internal customer and decision-making processes that the forecast will support. An implicit part of this step involves determining:
   a. What is to be forecasted?
   b. What level of detail is needed to support the decision making process?
   c. Within reason, when does the user need this information?
2. Identify the likely sources of the best data inputs.
3. Select forecasting techniques that will most effectively transform available data into timely, reliable forecast information over the most appropriate planning horizon.
4. Apply the proposed technique to gathered data for the appropriate business process. State assumptions explicitly in writing.
5. Monitor the performance of the forecasting process, as for any continuous-improvement or quality-management process. Periodic reviews of the basic assumptions that underlie forecasts help to keep the process for future forecasts on target.

A word of caution: no forecasting process, however well conceived and carefully implemented, can consistently provide perfect forecasts. Any perfect prediction should raise serious suspicions. Investigation may reveal that demand for an item is being "managed" by an upstream process. This situation dissolves the need for the demand forecast. A perfect forecast may also indicate more sinister developments, e.g., someone is "cooking the books" or reporting performance data that shows conformance with plans rather than actual events. Wall Street analysts may love this but the operations manager must be suspicious.

In Step 1, the forecaster evaluates the needs of the internal customers for a forecast. The specific organizational situation must dictate the choice of forecasting process to align it with the information needs of decision-makers. Makridakis and Wheelwright have summarized six characteristics of the forecasting environment that drive this decision: [4]

- *Time Horizon*: The forecasting process should suit the period of time over which the decision-maker's current actions will affect business performance. As discussed earlier, the time horizon of an operations management forecast depends on the OM system's market orientation and its lead times. If a system takes 10 weeks to build an ordered product, then its forecast demand is 10 weeks after the current date or longer. An operation that can respond in 2 weeks can work with a shorter, probably more accurate forecast. This suggests yet another benefit of fast-to-market production.
- *Level of Detail*: The level of detail needed depends on the user's needs. Demand data aggregated over many products, markets, or time periods may make a forecast more reliable as variations offset one another; i.e., this can smooth the process, as long as users do not need data for more specific segments of demand. Forcing sources to provide more precise data may jeopardize cooperation by busy participants, especially if the data reporting system provides them with useless aggregated demand forecasts.

  A lumber company vice president made this point vividly, saying, "I don't want to know the aggregate price of lumber. I need a near-term forecast of 2x4s price relative to the price of 2x6s so I can tell my people how to saw the logs." Clearly, this manager saw little value in a forecasting process that told him that the average price of a certain grade of lumber would be $16 higher. Aggregate information is most useful to a higher-level corporate planner trying to predict the firm's profitability.

- *Number of Demand Segments*: The amount of effort to devote to a forecast clearly depends on the range of demand covered by the forecast. To forecast demand for a single, critical product, a firm may want to expend considerable resources to get the best possible forecast. A demand forecast for 1,000 products should rely on methods for manipulation of mass data to exploit economies of scale in computation; a detailed forecast for each product would raise costs more than its addition to value.
- *Control versus Planning*: A forecasting process should meet users' needs for management control or planning functions. Control uses *management by exception* methods to generate early-warning signals when some aspect of operations varies significantly from planned performance. Hence, control wants forecasts to be sufficiently accurate to detect material performance variations. In contrast, planning often assumes that current patterns will continue. It needs forecasts to identify patterns that may not continue.
- *Constancy:* Reliable performance permits a forecaster to extrapolate past patterns to predict the future. Without constancy, the forecaster needs to adjust projections based on judgments of likely variations.
- *Existing Business Processes*: Current users of demand forecasts should provide strong input about any changes to the system. Organizational inertia often dictates continued reliance on familiar tools.

Another influence on the choice of a demand forecasting process comes from the conflicting demands of system designers and system-users. System design normally needs broader, longer-term forecasts to support resource management and capacity planning. Aggregated demand information helps firms to determine a configuration of people, plant, and equipment that provides suitable capabilities and capacity to serve customers in the targeted market segment. Demand forecast errors in this area usually leave the firm with either underutilized or over-extended operational resources.

If the system designers need a forecast for an existing product, then many of the traditional forecasting tools can be used. In these systems, one often either tries to use historical patterns of demand to project when is likely to occur over the time period in question. In other situations, demand forecasters search for times series that have in the past proved useful to predict demand. These often are generic time series, such as tons of corrugated medium shipments—a public statistic that has in the past proven to be a leading indicator.

System-users often need forecasts that support more detailed intermediate and short-range decisions about staffing, producing, purchasing, and work scheduling. The operations-level consequences of short-term forecast errors are excess inventory, lost sales, and increased job-expediting costs. Operations managers often respond to systemic forecast errors by creating additional buffers in the form of safety inventory stocks, reserved capacity, or longer than necessary planned lead times.

After the designers of a demand forecasting system have identified the internal customers and their informational needs, they can proceed to Step 2 that seeks to determine the best sources of input data. The choice is often between the use of subjective inputs, numeric inputs, or some combination of both. In this state, each potential source of information using three performance metrics:

- How well will it add to the reliability and accuracy of the forecast?
- How timely will the information be?
- How much will it cost to secure and use this information?

Having accurate, timely, low-cost forecasts is the goal, but system's designer normally has to accept tradeoffs.

A consideration that arises when using subjective inputs is that the most informed persons may not always have the time or the temperament to provide meaningful inputs to the demand forecasting process. The busy schedules of the best-informed managers may not allow them time to provide detailed inputs needed. Least-informed sources, often found at corporate headquarters, may be quite willing to undertake this responsibility, but their ability to make reliable forecasts should be questioned.

Indeed, three leading experts within the forecasting field claim, "judgmental forecasts are not necessarily more accurate than statistical ones, particularly when many forecasts are required on a frequent basis." [5] Their studies indicate that managers' subjective predictions tend to underestimate future uncertainty considerably and consistently. Hence they argue that subjective inputs are most useful when they can indicate "forthcoming changes" especially changes in direction.

Information-age technology can help provide statistic-based systems with managerial inputs. For example, an interactive dialog between business planners and line personnel can help them collaboratively come up with a better forecast. Marketing guided by sales data has enhanced the selling capabilities of some companies. In the same way, emerging sources of market-level information can enhance the operations manager's database to improve demand forecasting. Further processing can transform input data into critical nuggets of both detailed and aggregate demand data that satisfy the needs of decision-makers. Never before have companies brought together so much data with such powerful analytical capabilities to provide such meaningful, timely information to managers in such useful formats.

Effective use of this technology will, however, require designers of information systems and forecasting processes to understand the needs and capabilities of working managers. The human-resource management function must support this potential by training corporate and field managers in techniques for mining a information database. The ideal image of such a data-rich forecasting system shows a regional sales manager sitting in a motel room each night feeding the latest market-level insights back to headquarters and reflecting on the current state of the firm's database with a focused, analytical mind. Technology may replace frank discussions over martinis with in-depth interactions over the Internet.

In Step 3, the forecaster selects the most appropriate demand-forecasting tool. The criteria for this choice must, of course, reflect the needs and comfort levels of the internal users of the forecasts. Gene Woolsey, the noted management iconoclast, has warned that forecasters should avoid technology overkill, advising forecasters that, "A manager would rather live with a problem that he cannot tolerate than use a solution that he cannot understand." [6] A manager must make this choice if the designers of the forecasting system have not done their jobs. They may fail to understand their internal customer's needs or to provide enough training to make the user comfortable with the forecasting process and its output. As always, let the customer decide.

In Step 4, the forecasting system designer applies the chosen forecasting tool to develop data that will support decision-making. As in the application of the Deming Wheel, the process must track and study the accuracy of its output and continually help users to take ownership of the forecasting process. Subsequent refinements of the forecasting process should be done at the behest of the internal customer.

In Step 5 the user should decide which measure of performance is most meaningful for business decisions. One goal is clear: demand forecasting is most meaningful when its users understand and own the demand forecasting tools. If it is too complicated to understand, one should question a tool’s appropriateness. Forecasting should not exist solely to provide jobs for staff.

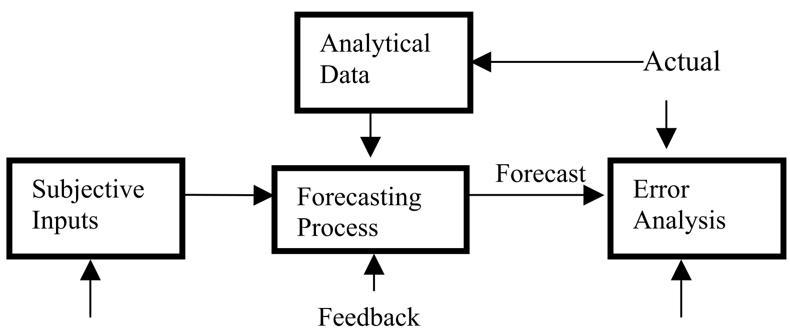
Forecasting as a Process

Forecasting has been described as a process that transforms historical time-series data and/or qualitative assessments into statements about future events. This process can yield either quantitative or subjective projections. Familiar numerical forecasts include news reports of economic data such as, "Sales of automobiles in 2002 will be 20.1 million cars." Another forecast could just as easily predict the occurrence of some event, such as when the civil aviation industry will commit to composite-fiber aircraft fuselages.

The most effective blend produces forecasts that meet decision makers' needs for accurate and timely information. Qualitative or subjective inputs suggest likely environmental conditions such as people's opinions about whether it will rain today. This simple forecast may meet a manager's needs, as when someone wants to predict attendance at the community swimming pool. However, farmers prefer a quantitative projection such as a predicted rainfall of 1.2 inches today. Indeed, the farmer might well prefer a mix of qualitative and quantitative data such as an expectation for 1.2 inches of steady rain during a 3-hour period this afternoon. Again, effectiveness begins with a clear image of the user and the use of the forecast.

Exhibit 1 illustrates that forecasting is a process that combines quantitative with qualitative inputs.

Exhibit 1
Basic Forecasting Process



Performance Metrics for Demand Forecasting Tools

As the case with all business processes, managers use a number of performance metrics to evaluate the effectiveness of a demand-forecasting tool. A key piece of information is the forecast error. Forecast errors are defined as the difference between what actually happened and the number that was forecasted. Mathematically, the forecast for period "t" error is denoted as:

$$e_t = \text{Actual demand in period t less period t's forecast} = d_t - F_t \qquad (1)$$

In the subsequent sections, we will use these three symbols to denote forecast errors, actual demand, and the forecast in period t. A positive e_t indicates that the forecast was low. A negative e_t indicates that the amount forecasted was high, i.e., actual sales did not make the forecast.

To learn more about the effectiveness of a forecasting tool, we normally record two sets of data. The first is a record of the amount that was forecasted and the second is a record of what happened. Using Equation 1, we can then construct a time series of forecast errors, which then will be used to assess the performance of the forecasting tool. Common sense dictates that three questions need to be asked:

1. How accurate was the forecasting tool?
2. How effective was to tool in detecting significant shifts in demand?
3. Does the pattern of forecast errors indicate a bias or other interesting traits?

Before the first question can be answered, we must decide if we want to measure how much the forecast was off or the percentage it was off. Off is the difference between the amount forecast and what actually occurred.

Operations managers like to measure forecast errors *in units* since the consequences of deviations from plan are best understood in terms of how much of a capacity adjustment the OM system must make. Hence, in this text, e_t will be measured in units.

Secondly, note that a straight numeric average of the forecast errors will mask the deviations since a positive e_t will be partially offset by negative e_t . For example, in a two period time series with forecast errors of +4 and -4, the average of the forecast errors would be zero. Clearly, some information has been lost.

To avoid this problem, business forecasters created a statistical measure called the *mean absolute deviation* (MAD). It is defined as:

$$MAD = \sum | d_t - F_t | / n \quad \text{for } t= 1,2,3,\ldots, n \quad \text{where n is the number of periods.} \qquad (2)$$

The absolute value symbol, i.e., the vertical symbol before and after the forecast error term, denotes that negative amounts are made positive. Thus in our two period example, the MAD would equal the average of -4 and + 4, i.e., its MAD would equal 4.

If the forecast errors are normally distributed, the relationship between the standard deviation of forecast errors and its corresponded mean absolute deviation is:

$$\text{One standard deviation} = 1.25 \text{ MAD} \qquad (3)$$

If you wanted to construct a control chart to see if your forecasting process is "under control," the equivalent three standard deviation control limits would be 3.75 MADs above and below the average of the forecast errors. Being able to track which forecasts are under control permits managers to use the management by exception rule to focus their attention only on those units whose forecasts are *out of control*. Out of control is not necessarily a bad thing because it may mean that the firm is experiencing higher than anticipated sales.

The originators of MAD were also concerned that this measure of accuracy would miss major forecast errors, so they created another term, which they called the ***mean squared error***. They defined this term as:

$$MSE = \sum(d_t - F_t)^2 / (n-1) \quad \text{for } t = 1,2,3,\ldots,n \qquad (4)$$

Each of these terms is the same as was used when we defined the MAD.

Some readers may confuse the MSE with the variance of forecast errors. From statistics, we know that this term would be:

$$\text{Forecast error variance} = \sum (e_t - \bar{e})^2 / (n-1) \quad \text{for } t = 1,2,3,\ldots,n \qquad (5)$$

Where $\bar{e}$ is the mean of the forecast errors. While the square root of the MSE does not correctly state the standard deviation of forecast errors, many practitioners use it as a decent approximation.

The second forecast-tool -performance metric relates to its ability to detect significant shifts in demand. If we are forecasting a pattern of events based solely on past patterns, our ability to detect shifts in demand will be limited to seasonal and cyclic phenomena that we have observed in the past. For example, we might be able to predict that December's sales will be higher than November's because we have observed this to be the case in most prior years. But forecasting techniques will not be able to predict events that are not directly driven by the intrinsic data in our forecasting model.

As we will see, some forecasting models are able to detect shifts in demand when the forces driving demand are leading indicators. For example, it has been observed that manufacturers order corrugated containers in advance of their outbound shipping activities. Hence, an increase in corrugate container orders within the economy will normally foretell an increase in domestic national production. Likewise, when forecasting the national crime rate, some make the assumption that crime is proportional to the number of teenage youths in the population. Since people normally age one year each year, knowledge of the age distribution within our population allows us to predict the fluctuations in the crime rate in our society.

In most business situations, neither our forecasting nor our predicting tools are able to foretell shifts in demand. When this is the case, the next best alternative is to have a tool that can quickly detect a shift. Models to do this are discussed later in demand tracking section.

The third performance metric of demand forecasting tools is its ability to promote early recognition of demand patterns. Forecasting tools should provide insights as to what is happening so that either we might better understand the market or be able to refine the tool to eliminate patterns of forecast errors. As we shall see, studying patterns of forecast errors often leads to insights of how a forecasting process can be improved. Getting a number from a black box or an analytical model fails the forecast user if it does not promote a better understanding of the behavioral patterns of the firm's customers.

Dialogue Driver: How might the systematic use of forecast errors enhance a firm’s learning processes?

QUALITATIVE DEMAND FORECASTING

Qualitative forecasts reflect people's judgments. They are used to incorporate individuals’ inputs into the forecasting process. Emerging demand patterns may not be stable enough for a numeric approach. Intimate knowledge of the market then becomes the data source of choice. If a qualitative approach is to be used, one needs to identify reliable sources as the inputs used to make projections.

The following represent some of the more common qualitative approaches:

- *Grass-Roots Forecasting* seeks input from people at the level of the organization that gives them the best contact with the phenomenon under study. A marketing study might ask sales representatives for their readings of current market conditions. A potential fault of this tool is that it is subject to the short-term perspectives of its sources. Some people, especially sales persons, often suffer from *recency,* which is the tendency to base their forecasts on their most recent experiences. If a sales person had a good day, his forecast for the future may be unduly influenced by the day's events.
- *Historical Analogy* explores the possibility that past events can give insights for predicting the future of some related or similar product. For example, the pattern of early sales of black-and-white TV sets may have helped the developers of color television sets. Economists have relied extensively on this kind of model to forecast business cycles and related developments. News reports frequently cite economists' comparisons of current economic trends with similar stages of past business cycles.

  This method risks inaccuracy if the forces that drove past events are no longer present. Someone who forecasted market acceptance of citizens-band radio sets based on that of color television sets would have been stuck with a warehouse full of CB radios.
- *Market Research Forecasting* is by marketers to evaluate purchasing patterns and attitudes of current or potential buyers of a good or service. Marketing texts explain in detail how to develop, conduct, and analyze consumer surveys, interviews, and focus groups. Product designers use these tools to understand their current customers and the buyers they would like to serve.

One marketing research method, panel consensus, invites a panel of knowledgeable people to craft a forecast by engaging in an open dialogue over a relatively short period of time. This technique assumes that no single group or person is likely to have access to all of the key inputs in a demand-forecasting process. Instead, a group of individuals from sales, marketing, and engineering meet in a brainstorming-like session to make better forecasts jointly, rather than having an isolated staff person at corporate headquarters doing it.

- *Delphi Method*: The Delphi method compiles forecasts through sequential, independent responses by a group of experts to a series of questionnaires. The forecaster compiles and analyzes the respondents' input and develops a new questionnaire for the same group of experts. This sequence works toward a consensus that reflects input from all of the experts while preventing any one individual from dominating the process. The Delphi approach tends to be used to address long range forecasting needs where historical patterns may not apply.
- *Collaborative Forecasting*: Within the past few years, a number of consumer good firms have begun to go beyond passive electronic communication technology (EDI) to develop more collaborative supply chain management tools. Benchmarking Partners, Inc. has been working with Wal-Mart and Warner-Lambert to apply a software package called CFAR (collaborative forecasting and replenishment). Their efforts has enable them to provide more reliable medium range demand forecasts for consumer items, such as Listerine mouthwash.[7] Another consulting company, Kurt Salmon Associates, is working with the Food Marketing Institute on a project called ECR (efficient consumer response) to create a more rational way to distribute goods throughout grocery supply chains. The emerging role of collaboration is reinvigorating the role of people in large-scale demand forecasting process.

QUANTITATIVE FORECASTING

Quantitative tools range from the simple to the complex. The need for complexity is influenced by:

- The number of data sources, i.e., the number of variables used as inputs to the forecasting process. These may be intrinsic as is the case with simple time series analysis, or it may include extrinsic inputs.
- The forecast planning horizon, i.e., the number of periods into the future being projected.
- The decomposition factors used. The simplest ignores seasonal, trend, and cyclic factors.

Quantitative forecasting techniques transform input in the form of numerical data into forecasts using methods in one of three categories:

1. *Historical time series studies*, which use past data as inputs for analysis to infer future events.
2. *Causal studies*, which look for *causal relationships between leading variables and forecasted variables.*
3. *Mathematical or simulation models*, which try to represent past behavior in a valid mathematical relationship and then alter data to project future events.

Each category of methods assumes that past events provide a good basis for enhancing our understanding of likely future outcomes.

Recall that the second step in the five-step demand forecasting system design process was to identify the likely sources of the best data inputs. With quantitative forecasting, responding to this challenge often involves developing the best database architecture. Thus before we proceed, it is useful to spend a moment to discuss the nature of demand variables.

Demand variables often are aggregated numeric variables. For example, if a firm needs to project the demand for its products in the month of December, this estimate is a function of the items that go into creating the aggregate variable and the number of sub-periods within December. It can be expressed as:

$$\text{Demand}_{\text{December}} = \Sigma_i \Sigma_j \; d_{ij} \quad \text{for } i = 1, m \text{ and } j = 1, \ldots, n \qquad (6)$$

where m is the number of days in which demand occurs and n is the number of items being sold.

. There are three basic reasons for choosing to collect data in a more detailed form. The first is that it provides a level of detail that is consistent with the forecast user's decision-making needs. Forecasting monthly supermarket sales in dollars is meaningless to the person deciding how many bananas to order. A second reason is that there may be some historical relationship between as subset of Equation 6 and the aggregate variable of interest. Political analysts long have studied bell-weather political districts to infer election outcomes prior to the ultimate election tally. So too can business if they find a predictive component within aggregate statistic. For example, it may be that the number of artichokes sold in the first five days of a month provides a good basis for total monthly artichoke demand. Improbable as it may seem, artichoke sales during the first five days might even be a good indicator for total store sales for that month. If such is the case, one can track a predictive component more intensely and use it as the basis to project store demand.

A third reason for collecting data in a more detailed form is to enhance corporate learning. If something unexpected occurs, the logical question is: "What has happened?" If the demand is expressed only as an aggregated number, i.e., sales in December will be $423,000, then if sales fall $50,000 below that amount, it is helpful to know the details in a search for an explanation.*

In addition to having a database with the appropriate level of detail, the length of the time span over which the data is collected must be sufficiently long to allow detection of repetitive patterns. A key question is: "Have we collected data long enough to permit reasonable inferences about the presence stable demand patterns." Since the goal is to find demand patterns that we can use to assist our forecasting process, the effectiveness of this process will be largely influenced by the significance and stability of demand patterns.

Discovering and Describing Relationships

Once the needs of the user's problem have been defined and the form of a desired forecast is specified, the task then becomes one of deciding if historical data points can be used to create effective forecasts. The purpose for trying to discover relationships is twofold. The first is to better understand the nature of demand and the customers who are creating it. This is fundamental to understanding our customers, their needs, and idiosyncrasies. This leads to identifying ways to improve the firm's value delivery system.

The second reason for trying to discover demand patterns is to build improved demand forecasting models. Our goal is to identify demand patterns that have occurred in the past that can be used to project future demand. There are two basic types of patterns that often are used in demand forecasting models. They are:

- Trends--these are patterns that are influenced by time. Three common types of patterns are:
  - *Linear trends* which can be expressed as $y = a + bt$ where "a" is a y-intercept and "b"is the slope of the straight line. This occurs when demand increases by a *constant amount* each period.
  - *Exponential trends* which are expressed by $y_t = y_0 (1+b)^t$ where y_0 is the initial demand value and b is the percent the demand is increasing each period. This situation exists whenever demand is increasing or decreasing by a like percentage each period.
  - *Unstable trends* occur when there is a general drift in the demand function but it seemingly defies being described by an equation.

* The sophisticated tools used in data mining software offer forecasters new ways to gleam meaning from the massive amounts of data that is routinely be collected and stored by some companies.

- Cyclic factors are patterns that seemingly occur on a repetitive basis. Cyclic factors are most helpful when they occur with fixed cycle lengths but there is no guarantee that this trait will be found. Some of the more common cyclic factors found in demand forecasting are:
  - Within hour cycles
  - Within shift cycles, i.e., patterns that occur with an eight hour work shift
  - Within day cycles
  - Within week cycles
  - Within month cycles
  - Within year cycles
  - Business cycles—yes we still have these.

  When cycles have uncertain frequencies, this limits their use as an input to a forecasting model. When television was in its infancy, certain programs, such as the Milton Berle Show had such a following that the local utility could predict the surges in the usage of water by knowing when commercials would take place. Since television commercials were every 15 minutes, the within hour usage was predictable.
- Residuals are the part of the demand pattern that is *unexplained* by trend and cyclic factors used in the forecasting model. Unexplained does not necessary mean that we don't know why they occurred but just that our trend and cyclic factors do not capture their happening. For example, in 1998, General Motors experienced a long labor strike that had a material impact on the Nation's economy. The decline in economic activity could partially be explained by this event, but there would be no need to try to include future strikes into the factors used in our quantitative forecasting model.

  Within forecasting, the term residual is often used during the data analysis phase. Analysts study the pattern of the residuals to help identify what needs to be included in a model. Once a model has been constructed, the results are compared between the forecasted amount and the actual sales experienced in period t. This difference is called the *forecast error*, a term that we defined earlier as Equation 1.

Once these factors have been observed, we can then construct a demand-forecasting model. To illustrate, let us assume that a study of past demand has indicated the following:

- That demand seems to be growing by 15% per year
- That within each year, demand has the following cyclic pattern:
  - 10% occurs in Quarter One
  - 15% occurs in Quarter Two
  - 25% occurs in Quarter Three
  - 50% occurs in Quarter Four

If the actual demand in 1999 were 5,000 units, then our forecast for the next three years would be:

2000 annual amount = 5,000 x (1 +0.15) = 5,750 units

Then our forecast for each of the next four quarters is:

Quarter One = 5,750 x 0.10 = 575.0 units
Quarter Two = 5,750 x 0.15 = 862.5 units
Quarter Three = 5,750 x 0.25 = 1,437.5 units
Quarter Four = 5,750 x 0.50 = 2,875.0 units

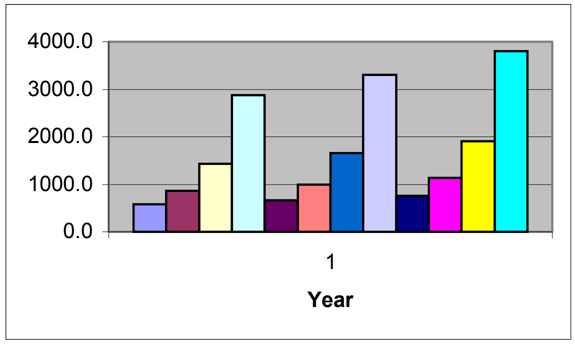
To forecast demand in years two and three, we need only extend this approach using the formula"

$$F_{\text{year, quarter}} = 5{,}000 \times (1 + \text{Annual Trend})^{(\text{year - 1999})} \times (\text{Cyclic Factor}_{\text{Quarter}}) \qquad (7)$$

Where t=2 and 3 for the years 2001 and 2002 respectively. These calculations are shown in Exhibit 2.

Exhibit 2
A Three-Year Demand Forecast

Year	Annual Forecast		Cyclic Factor	Quarterly Forecast
2000	5750	Qtr. 1	0.10	575.0
		Qtr. 2	0.15	862.5
		Qtr. 3	0.25	1437.5
		Qtr. 4	0.50	2875.0
2001	6613	Qtr. 1	0.10	661.3
		Qtr. 2	0.15	991.9
		Qtr. 3	0.25	1653.1
		Qtr. 4	0.50	3306.3
2002	7604	Qtr. 1	0.10	760.4
		Qtr. 2	0.15	1140.7
		Qtr. 3	0.25	1901.1
		Qtr. 4	0.50	3802.2



Starting with a set of data and the task is to discover the patterns and the parameters used to define them

The data shown in Exhibit 2 clearly demonstrates:

- A definite cyclic pattern with sales rising constantly with approximately half of the company's sales occurring in the fourth quarter of each year.
- A trend. Each quarter is approximately the same percentage larger each year.

To illustrate this process, consider the data shown in the left half of Exhibit 3. A number of questions need to be answered. They are:

- Is there a trend, a monthly cyclic factor, and/or a weekly cyclic factor?
- If they exist, how stable are they?

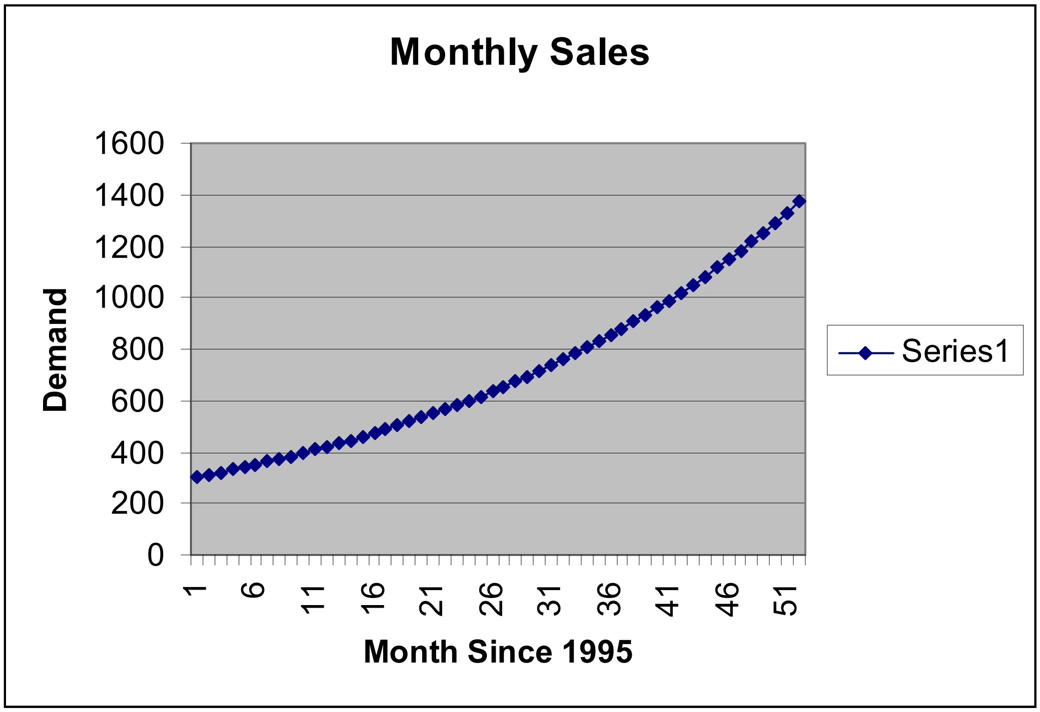
We begin by restructuring the database to facilitate visual inspection. For each month, we total demand and then express each week's demand as a percentage of the monthly total. When we do this for each month over the four-year period, we can note a consistent pattern. In the last column, we calculated how much each month increased over the prior month. Is there a trend?

Exhibit 3
A Demand Database

			DEMAND					Cyclic Factor			Month	%
Year	Month	Week 1	Week 2	Week 3	Week 4		Week 1	Week 2	Week 3	Week 4	Total	Increas
1996	1	47	72	105	79		15.5%	23.8%	34.7%	26.1%	303	
	2	45	78	107	82		14.4%	25.0%	34.3%	26.3%	312	2.97%
	3	47	79	107	88		14.6%	24.6%	33.3%	27.4%	321	2.88%
	4	47	82	119	83		14.2%	24.8%	36.0%	25.1%	331	3.12%
	5	46	82	120	93		13.5%	24.0%	35.2%	27.3%	341	3.02%
	6	56	87	119	89		16.0%	24.8%	33.9%	25.4%	351	2.93%
	7	59	95	122	86		16.3%	26.2%	33.7%	23.8%	362	3.13%
	8	52	89	132	100		13.9%	23.9%	35.4%	26.8%	373	3.04%
	9	61	98	131	94		15.9%	25.5%	34.1%	24.5%	384	2.95%
	10	59	101	142	94		14.9%	25.5%	35.9%	23.7%	396	3.13%
	11	65	99	142	102		15.9%	24.3%	34.8%	25.0%	408	3.03%
	12	63	106	149	102		15.0%	25.2%	35.5%	24.3%	420	2.94%
	13	63	107	152	111		14.5%	24.7%	35.1%	25.6%	433	3.10%
1997	1	67	108	156	115		15.0%	24.2%	35.0%	25.8%	446	3.00%
	2	69	119	158	113		15.0%	25.9%	34.4%	24.6%	459	2.91%
	3	68	122	163	120		14.4%	25.8%	34.5%	25.4%	473	3.05%
	4	70	119	174	124		14.4%	24.4%	35.7%	25.5%	487	2.96%
	5	73	124	177	128		14.5%	24.7%	35.3%	25.5%	502	3.08%
	6	73	133	180	131		14.1%	25.7%	34.8%	25.3%	517	2.99%
	7	77	134	188	134		14.4%	25.1%	35.3%	25.1%	533	3.09%
	8	78	140	190	141		14.2%	25.5%	34.6%	25.7%	549	3.00%
	9	82	136	195	152		14.5%	24.1%	34.5%	26.9%	565	2.91%
	10	92	141	208	141		15.8%	24.2%	35.7%	24.2%	582	3.01%
	11	86	149	209	155		14.4%	24.9%	34.9%	25.9%	599	2.92%
	12	89	153	220	155		14.4%	24.8%	35.7%	25.1%	617	3.01%
	13	92	162	219	163		14.5%	25.5%	34.4%	25.6%	636	3.08%
1998	1	103	162	229	161		15.7%	24.7%	35.0%	24.6%	655	2.99%
	2	103	164	231	177		15.3%	24.3%	34.2%	26.2%	675	3.05%
	3	101	177	241	176		14.5%	25.5%	34.7%	25.3%	695	2.96%
	4	103	181	247	185		14.4%	25.3%	34.5%	25.8%	716	3.02%
	5	109	187	260	181		14.8%	25.4%	35.3%	24.6%	737	2.93%
	6	112	188	267	192		14.8%	24.8%	35.2%	25.3%	759	2.99%
	7	121	197	276	188		15.5%	25.2%	35.3%	24.0%	782	3.03%
	8	120	198	281	206		14.9%	24.6%	34.9%	25.6%	805	2.94%
	9	123	207	294	205		14.8%	25.0%	35.5%	24.7%	829	2.98%
	10	128	209	297	220		15.0%	24.5%	34.8%	25.8%	854	3.02%
	11	132	217	307	224		15.0%	24.7%	34.9%	25.5%	880	3.04%
	12	138	225	314	229		15.2%	24.8%	34.7%	25.3%	906	2.95%
	13	135	235	329	234		14.5%	25.2%	35.3%	25.1%	933	2.98%
1999	1	143	242	334	242		14.9%	25.2%	34.8%	25.2%	961	3.00%
	2	148	243	345	254		14.9%	24.5%	34.8%	25.7%	990	3.02%
	3	156	259	354	251		15.3%	25.4%	34.7%	24.6%	1020	3.03%
	4	155	262	371	263		14.7%	24.9%	35.3%	25.0%	1051	3.04%
	5	159	266	378	280		14.7%	24.6%	34.9%	25.9%	1083	3.04%
	6	164	282	390	279		14.7%	25.3%	35.0%	25.0%	1115	2.95%
	7	172	290	402	284		15.0%	25.3%	35.0%	24.7%	1148	2.96%
	8	179	300	416	287		15.1%	25.4%	35.2%	24.3%	1182	2.96%
	9	187	305	430	295		15.4%	25.1%	35.3%	24.2%	1217	2.96%
	10	189	316	440	309		15.1%	25.2%	35.1%	24.6%	1254	3.04%
	11	198	325	455	314		15.3%	25.2%	35.2%	24.3%	1292	3.03%
	12	195	333	468	335		14.7%	25.0%	35.2%	25.2%	1331	3.02%
	13	204	347	480	340		14.9%	25.3%	35.0%	24.8%	1371	3.01%
							14.9%	24.9%	34.9%	25.3%	avg.	2.79%

We started by calling the monthly demand totals that are plotted in Exhibit 4.

Exhibit 4
Monthly Demand Over Time



From this chart, we can observe the following patterns:

- That the trend seems to be curvilinear and stable. In the last column of Exhibit 3, it can be seen that monthly demand increases as a fairly constant rate--approximately 3% per month.
- The smoothness of the line in Exhibit 5 indicates little within year cyclic pattern with monthly demand.
- The smoothness of the curve also indicates an absence of noise.

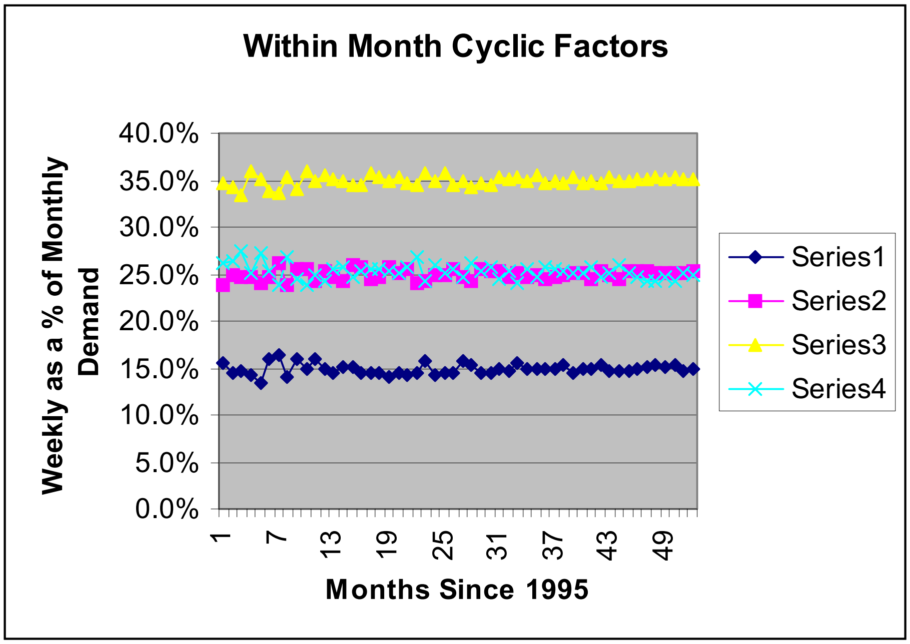
But we have filtered out the effects within-month cycles. Let us now turn our analysis to this factor.

The outcome of this analytical phase will be either:

- No discernable patterns exist
- Discernable patterns exist but they may be too unstable for forecasting purposes
- Stable discernable patterns exist.

If the first outcome occurs, then the question becomes: "Is the last outcome or an average of the last few outcomes the best demand estimation procedure or might use one of the qualitative tools?" If the firm needs to forecast demand for a large number of items, say in excess of 100, one must be sure that the most informed sources have the time and temperament to participate in either a within firm qualitative approach or a multi-firm, collaborative approach.

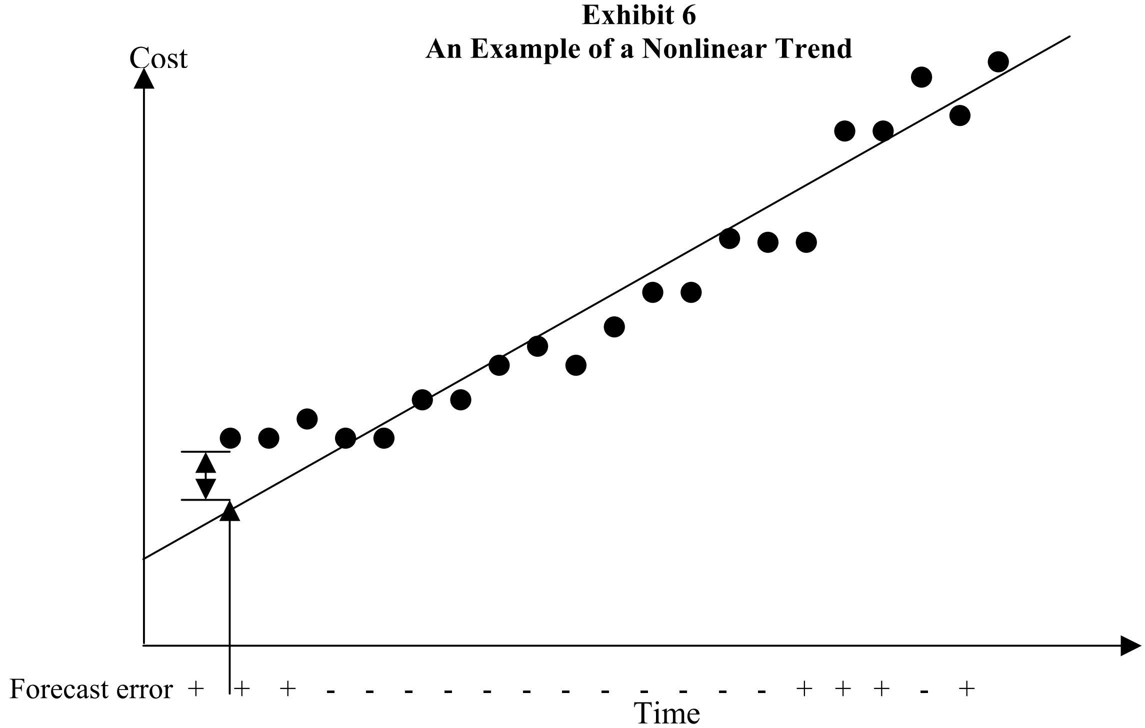
Exhibit 5
Within Month Cyclic Factors



If patterns exist but appear to be unstable, then further analysis is needed to try to better understand the causes of demand pattern instability. A favorable result might permit the firm to proceed with a quantitative forecasting approach but with a high level of management oversight. If the ensuing periods result in satisfactory forecast errors, then the firm can lessen the level of oversight. If not, then the firm needs to either study the situation more or revert to either a demand tracking or a qualitative demand forecasting approach.

Trend: Many time series exhibit long term tendencies in one direction or the other as is shown below.

Exhibit 6
An Example of a Nonlinear Trend



Trends can be linear or nonlinear. It is easy to spot the difference by plotting the data and then seeing if a straight line provides a good approximation. Suppose one assumes that a linear function, such as the equation shown in Equation 8 can approximate demand.

$$\text{Demand} = a + bx \qquad (8)$$

Where demand is the dependent variable, a is the y-intercept, b is the slope of the line, and x is the independent variable (which in time series often is time).

If one applies a quick-and-dirty eyeball estimate to create a good fit line. This may provide the analyst a rough-cut pattern of the forecast errors. Consider the pattern shown in Exhibit 6. The pattern of the signs of the forecast errors indicates that a curvilinear pattern might provide a better fit. If a pattern of the residuals exists, then this is a cause for further analysis, i.e., something significant is happening but it is unknown. The cause mostly likely is due to the omission of material factor which has not been included in the model. If however, the pattern of the residuals exhibits no discernable pattern, then that may be the best that you can do.

SUMMARY

As you may have already noted, demand forecasting is part art and part science. It starts with an understanding of your internal client's decision-making needs. It then proceeds to a study of the data to see how the best forecasting tool can be developed to serve the client's business needs. There is a lot more to forecasting, but what we have provided should be enough to get you started.

End Notes

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5. Woolsey, R. E. D., and H. F. Swanson. *Operations Research for Immediate Application: A Quick and Dirty Manual*, New York: Harper & Row, 1975.
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Expected Learning Competencies

Before putting Shell Six down, you should ask yourself the following questions. Am I able to explain:

1. The issues involved in designing a demand information system. What are the tradeoffs
2. Which business processes within the firm rely on the firm's demand forecasting process?
3. Why a manager should suspect a forecasting process with no forecast errors?
4. How forecast errors are used to enhance the forecaster's learning process.
5. What performance metrics make sense when evaluating a firm's forecasting process?
6. What the logic is behind using seasonally adjusted forecasts? How can you tell whether not a seasonal or cyclic factor is stable enough to use in your forecasting process
7. What your instructor added to this shell and why he or she thought that it was important enough to warrant its inclusion?

Frequently Asked Questions

Instructors have been known to ask questions similar to the following:

1. Describe the demand forecasting process that Digital Research used to forecast toy demand?
2. Compare and contrast the internal customers of the HMWW and the DIS forecasting processes.
3. Describe some of the demand management methods that you have experienced in your life.
4. Explain collaborative forecasting and how it can be used to make better inventory stocking decisions within supply chains.
5. When an airline discounts some of its seats on a given flight, they are practicing:
   a. Demand management
   b. Exponential smoothing
   c. Gradient projection
6. When the government announces that consumer sales for the month of December as 2% lower on a seasonally adjusted basis, this means:
   a. Sales are 98% of last years sales
   b. Actual sales declined by 2%
   c. The seasonally adjusted time series for consumer sales declined by 2%
7. Which decision does the HM in the HMWW demand forecasting process support?
   a. Where to build production facilities?
   b. How much additional production capacity will be needed?
   c. What type of work force is necessary?
   d. All of the above What your instructor added to this shell and why he or she thought that it was important enough to warrant its inclusion
8. The MAD statistic generally does a good job measuring a forecast process' ability to predict shifts in demand, such as a business downturn,
9. In general, internal customers closes to the actual making or selling transaction need demand forecasts in greater detail.
10. If sales increase by the same percentage every period, then the sales trend line is linear.

SHELL SEVEN
LONG TERM CAPACITY MANAGEMENT

Sorry----Wrong Number

In January of 2003, the telecommunications industry was stuck in its over-capacity quagmire. WorldCom is in Chapter 11, Michael Armstrong's dream for AT&T is in shambles, and the supplier firms to this industry are deep in debt and short on customers.

Given the talented people working within this industry and the investment community that supplied it with long term funds, the question needs to be asked: How did this happen?

A good start is to review what some of the leading minds in business, government, and the business press were saying before the dot.coms came tumbling down.

- Federal Communications Commission chairman, Reed Hundt reported that "Internet traffic is doubling every three months.
- WorldCom's Max Crankite, was telling people that its traffic was increasing by 85% a month.

Most in the industry had come to believe these numbers. But when Andrew Odlyzko, the director of the University of Minnesota's Digital Technology Center, tried to confirm these growth rates, he keep running into a problem. He commented that

> "every single instance that I tried to investigate, I always ended up with statements by people at WorldCom's UUNet unit----I did not hear of anybody else make authoritative statements that their traffic was growing at this rate."

And in the business world, who is going to predict that their company could not grow as fast as this "Mississippi startup?" AT&T's management would often talk about such growth ratges, but they were always careful to say Internet traffic, not out Internet traffic." But most of us were not listening—carefully.

The end result that the telecommunication industry will not be able to snap out of its doldrums until the massive capacity this wrong number cause is cleaned up—either by growth or by having it rendered obsolete by new product breakthroughs.*

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* It will do no good to sue WorldCom since it has gone bankrupt. It hopes to emerge as MCI and a clean balance sheet but they are not likely to have many friends in the telecommunication industry.

Shell Seven
Long Term Capacity Management

Table of Contents

Learning Objectives for Shell Seven

After reading this shell and thinking about its contents, you should be able to:

1. Understand the importance of long-term capacity decisions to the system design process.
2. Understand the performance characteristics of each of the five process choices. For each process choice, you should be able to describe the business environments each does best.
3. Able to explain the information technology and human resource management needs of each process choice.
4. Understand how one measures capacity and which of the three types is best for operations planning.
5. Explain the three capacity investment timing strategies and how each is used to support the firm's business strategy. Why would a firm purposefully elect not to meet all demand?
6. Understand the economics and the value delivery issues that are involved in the plant location decision. How might the other elements of value be incorporated into the facility location problem?

INTRODUCTION

In Shell 2, we defined capacity *as the ability of an organization's value chain to procure, make, and deliver the desired quantity of desired product in a particular time period.* Here, we deal with the "right stuff" and the "enough stuff" part of capacity management. Specifically:

- *What type* of facilities can best enable the operations management function to contribute to the organizations strategic objectives?
- *How much* capacity does the firm need to support the firm's strategic plan?
- *When* should capacity be added or removed?
- *Where* should capacity be placed?

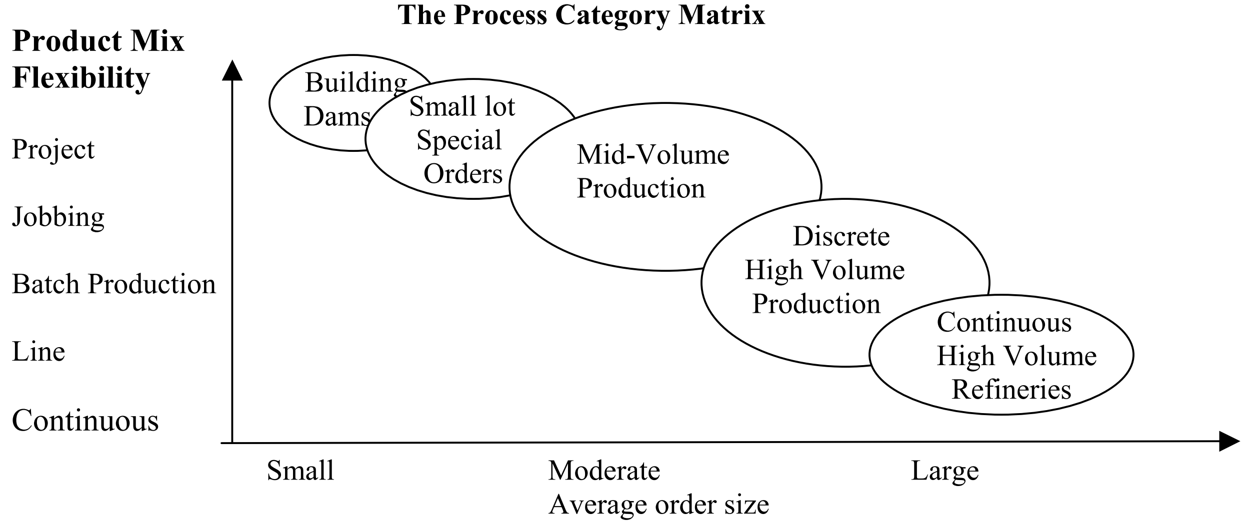
In the following sections, we will provide an overview of the issues and a brief introduction to some of the analytical tools that have proven helpful in dealing with these issues.

WHAT TYPE OF CAPACITY?

The *what-type capacity issue* has two basic dimensions: *market orientation* and *process choice*. In Shell 2, we introduce four basic types of market orientations: MTS, ATO, MTO, and ETO. If customers are unwilling to wait, then the make-to-stock market orientation is appropriate. If, however, the customer demands a wider product mix than the firm is able to stock, then the ATO or MTO market orientations must be considered. Lastly, if the customer's need is truly unique, then it may be necessary to utilize the ETO--quite possibly with the customer being actively engaged in the product innovation process. The last three market orientations involve strategic *postponement* as a means to enhance value creation. *

The second dimension of the "what type" capacity issue relates to the process choices the firm elects to use to transform factors of production into products valued by customers. While no two systems fit any category in exactly the same way, certain similarities make it possible to categorize operations systems as being one of five classical forms. The criteria used to classify the systems are the average order size and the range of product mix capabilities as is shown in Exhibit 1.

Exhibit 1
The Process Category Matrix



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* In multi-stage manufacturing systems, the customer may be the next stage and the way it orders goods can vary from MTS to ETO i.e., stage 3 may expect stage 2 to stock the needed goods or its needs may vary sufficiently to require one of the build to order market orientations.

The larger ellipse for mid-volume production signifies that batch production is the predominant process choice in manufacturing. The zones along the diagonal overlap to demonstrate zones of indifference, i.e., sections along the continuum where either process choice would be appropriate.

The characteristics of each manufacturing system can be classified further by three traits:

- the typical business setting,
- a profile of the physical and human resources, and
- the nature of its typical management control systems.

In the following sections, we discuss how each process choice differs with regard to these traits.

Projects often are one-time endeavors, such as building a dam, or they can be significant production orders, such as an order for a 747 aircraft. Projects can also be significant organization development programs, such as designing and developing a new product. In each case, the importance of the project is such that normal management control systems are insufficient. More intense coordination activities are needed if the factors of production reside in different parts of the organization or the supply chain. The interconnected nature of project activities requires an overall understanding of who will do what, how, and by when.

Projects invariably are "make to" endeavors. ETO projects require engineering departments to work closely with the customer to ensure the product meets functional, cost, and delivery requirements. Once a project starts, it is not uncommon for the project's size to be so large that the productive resources must go to the site. If such is the case, the nature of the equipment and the human resources must be mobile and the management system must be tailored to get each resource to commit to project objectives—including getting each task done right and on time.

In-house projects, such as building an aircraft or developing a new product, often require a management system that can motivate and coordinate disparate factors of production. Each of the key activities must be organized and their work sequenced in a manner that results in a plan that is doable and consistent with what has been promised to the customer. In-house project management is further complicated by the fact that the resources involved may be working on more than one project at a time. Thus, project managers must plan the timing of resource use to minimize having a resource scheduled at the same time doing two projects.

Most equipment used in a project tends to be general purpose because it pays to maintain functional flexibility so the equipment can be used on subsequent jobs. Most of the equipment used to build Denver's Mile High Stadium was used on a prior project and will be used on future projects. On the other hand, the creeper cranes used to build the Gateway Arch in Saint Louis had little use on other projects.

Project management systems have evolved from solving the minimum elapsed time problem into modern project management software that enables operations managers to:

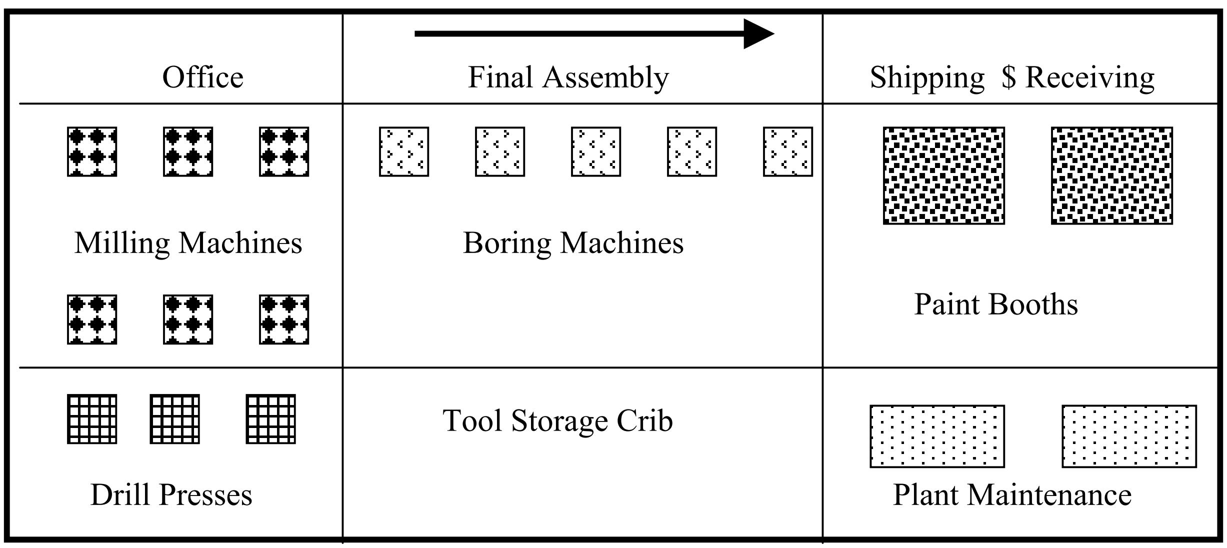
- break down the elements of a project into appropriately detailed work activities.
- predict where bottlenecks are likely to occur.
- rearrange work to meet targeted project completion dates, and then be able to
- keep track of progress made on each activity and expenditures incurred as the project develops.

When managed correctly, the project process choice provides the capabilities to design and make products that are tailored to meet the unique needs of customers. When done within a manufacturing environment, project management enables operations managers to maintain sufficient control to ensure that the project is done right, on time, and under budget. The only downside is if a firm tries to do too many orders as projects, the resulting multi-project management system may become unwieldy.

Jobbing is the second manufacturing process choice. Jobbing is often used when the system must process a large number of orders and the volume associated with each order is small. If the number of orders is also small, then this work is best done in a garage. But if the number of orders is large, the firm ought to consider a job shop. Because the nature of the work in a job shop varies, the equipment used are often general purpose machines. This is so because the firm does not know exactly what it will be asked to do. Hence it opts for process flexibility.

Job shops use a *process layout* in order to maximize system flexibility. In a process layout, manufacturing resources are physically laid out by function, i.e., all of the lathes are in one department.

Exhibit 2
Job Shop with a Process Layout



Job shop workers must be skilled so that they can read drawings in order to know how to set up and do many types or jobs. Its style of management should empower the skilled workers to get the job done. Operational decision-making occurs at two levels within a job shop. At the workstation level, the sequence in which jobs are done is usually performed by an operator using order information, i.e., how much time is it going to take to complete the order, when the order is due, etc. Prioritizing which job is processed next is done on a decentralized basis.

At the supervisor level, managers allocate resources to ensure that operators will have the factors of production needed to get the orders out on time. In some job shops, the number of machines or work centers is greater than the number of machine operators. These are called *labor-limited job shops.* In a labor-limited job shop, operations managers reassign workers to the work centers where they are needed. If there is more work than can be handled by the existing work force, this may necessitate either: hiring more workers, scheduling overtime, or farming out some of the work.

The focus of the control system used in job shops differs from that of a project-oriented shop. With a project, the number of jobs is small and the task is that of coordinating work to get the tasks done. In job shops, the challenge is to manage the flow of work to ensure that the orders get done on time in an efficient manner. Most job shops do this by providing the workstations with information that enables the operators to prioritize their work. Given sufficient resources and lead times, job shops often work smoothly without having to be micro-managed by plant supervisors.

In many job shops, the number of activities being managed is large and the workflow pattern for each job is not the same. This makes keeping track of the location and status of orders a major task. The advent of bar coding and shop floor level computer systems makes this possible, provided that each worker understands the need to document completed activities so that when the work has been done, it can be transferred to the next workstation. It is interesting to speculate what impact wireless communications will play in future shop floor control systems.

Effectively run job shops allow firms to respond to the wide variety of customer needs. Most orders in a job shop are do-to-order jobs. MTS orders may also exist as reorders for stocked items are released to job shops. For example, during the Christmas 2000 season, demand for Gateway computers was lower than forecasted. This MTO operation found it necessary to deviate from its normal build to order practice because it feared that last-minute shoppers would buy its competitors' products if asked to wait for Gateway to build and ship one. The result was unsold finished goods inventory at Gateway Country Stores, a new experience for Gateway.

While job shops offer the ability to have a high degree of product mix flexibility, this process choice does so at the expense of production lead times. When tracking an order as it progresses through a job shop, one would observe it spending most of its time waiting to be serviced at a workstation. As a result, job shops have the reputation of having rather long manufacturing lead times and high work-in-process inventory.

Dialogue Driver: Some have likened what a student experiences within a university as being similar to what happens in a job shop. Do you think the analogy fits your experiences?

Line Production usually comes to mind when people think of manufacturing even though this process choice is not used as often as many think. It is only applicable to production situations in which the demand for a product is sufficiently large to warrant designing a process capable of achieving manufacturing economies of scale. In most other situations we must use either the batch or jobbing process choice. There is nothing more uneconomical than a high volume line creeping at a pace that underutilizes its capacity.

The line production process choice includes three variants.

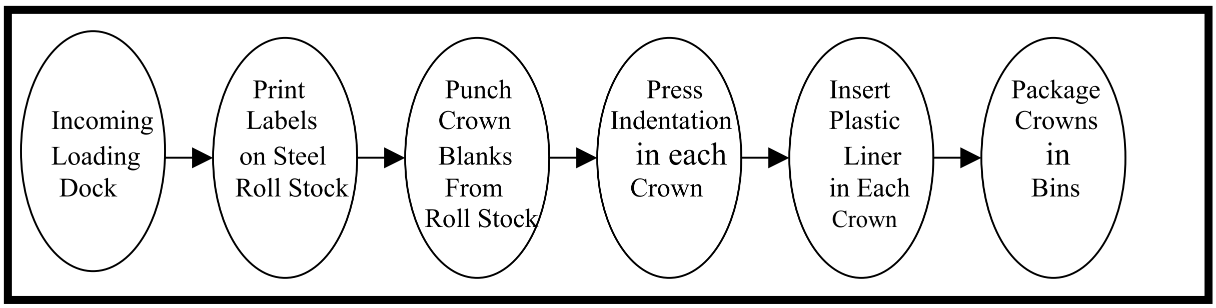
1. *Single model lines* make one product type at a time. Henry Ford loved this mode so much that he offered to paint a Model T any color the customer wanted, as long as it was black.
2. *Mixed-model* lines can produce more than one model of a set of products that require similar work performed. If we use letters to denote products, the sequence of products on a mixed model line might look like, ABCAECAABD and so forth.

3. *Batch mode lines* make multiple products one product at a time in batches, i.e., for a certain period of time, one product is made. Then a product changeover is made and then the line commences production of a second product. Usually all product types fall within a family of similar products.

Although most people tend to think of assembly lines, the category also includes *fabrication* lines. Such a line might start with a hard-boiled egg at one end and pass it down a line where a series of semiskilled artisans paint portions of a design. After the last workstation, a customer can buy a hand-painted egg. Many Chinese "works of art" were handcrafted on assembly lines. At the other extreme, an automobile engine starts as a steel casting that travels down a line where a sequence of special purpose equipment transforms it into a machined engine block. Highly automated machining lines are called *transfer lines*.

The layout of a production line usually arranges machines and people into workstations in the order in which the tasks are to be performed. This arrangement is called a *product or process oriented layout*.

Exhibit 3
Bottle Crown Cap Assembly Line using A Product/Process Layout



The factors of production used to perform tasks on lines can range from unskilled humans who are trained to do simple, repetitive tasks to highly automated machines that perform complex tasks. Material handling activities within assembly lines can range from humans pushing racks of products between workstations to automated guided vehicles that transport partially completed product from one area to another. Simple conveyor systems provide fixed paths, which may severely limit the flexibility of the factory. Increasingly "smart" conveyor systems read destination codes off the product and route it to the desired workstation.

When high volume demand exists, the argument for using line production is strong because economies of scale are possible. Division of labor possibilities permits the use of unskilled workers to perform simple, repetitive tasks. The repetitiveness of the work enables the system to invest in other labor saving system support automation, such as robots, to do some of the work.

While lines are often the most efficient way to assemble or fabricate products, they do pose certain other problems. Asking humans to do repetitive tasks can result in labor unions, which in turn limits flexibility. The old adage that "bad labor management begets bad unions," has certainly been true in the automotive industry where the major auto companies have spent much of the last decade trying to overcome the mistrust they earned in earlier times.

Dissatisfied workers can have a major impact on product quality. Perhaps the best example of what disenchanted workers can do to a company is Brian Bosworth, the Oklahoma football star who worked on an assembly line during a summer. He proudly admitted that when he worked one summer on an automobile assembly line, he purposefully put ball bearings in car dashboards to create nuisance rattles. He thought that this was funny. A major challenge is to develop work environments capable of aligning the interests of a unionized workforce with that of the company.

A second major task of line operations managers is to ensure that the needed raw materials arrive on time and in conformance with quality standards. Managing the flow of materials to a line is critical. Unreliable supply can adversely affect delivery, product quality, and cost performance. Unreliable suppliers cause the system to carry "just-in-case" inventory or expend time expediting work to avoid late deliveries.

<u>*Batch Production*</u> is used when the number of items ordered in orders is sufficiently large to make it worthwhile to try to capture economies of scale. A batch may be the result of one customer ordering a large number or the result of combining orders from many customers wanting the same item. With the latter case, since all customers are unlikely to want delivery at the same time, some finished goods inventory occurs.

There are two variants of batch production. In some instances where the product flow varies too much, batch production exists within a job-shop like setting, i.e., batches of combined orders flow through the shop as if they were single orders. The second form of batch production is the batch line mode described above.

The advantage of batch production is that if the product mix and volumes permit, plants are able to achieve some of the economies of scale associated with line production while capturing some of the product mix flexibility of job shop production. Equipment can be more special purpose and have at the same time some of the productivity associated with line production. Operators may not need to be as proficient in doing a wide number of tasks because most of the time they will be running one type of machine. Work in process inventory is low since units do not spend much time within the system. Finished goods inventory may be higher since the plant must make sufficient stock of each item to tide them over until the next production run.

The plant layout used for batch production will depend on its type, i.e., a process layout for job shop batch production environments and a product layout for line batch production. The more that batches can be produced in a "line-like" setting, the greater the opportunity to realize line manufacturing economies.

Batch is the most popular process choice since most production is done in batches of 50 or less. Batch production is able to achieve economies of scale through one or more of the following streamlining measures:

1. Reductions in setup times: Batch production runs fewer, larger orders than jobbing, spreading the costs of preparing the operator, the machine, and its fixtures over larger numbers of units.
2. Reducing production startups costs: These costs include lower levels of productivity or higher levels of scrap that commonly occur at the start of a new production run.
3. Cost benefits of designing and/or acquiring special-purpose equipment: Production at moderate volume often justifies the cost of machines, tools, or fixtures that increase output rates and efficiency.
4. Labor-rate savings: Specialized equipment for batch production reduces labor intensity, allowing the firm to replace skilled job-shop workers with less-skilled production line workers who command lower wages.
5. Lower production overhead for preparing bids and supporting new job releases: This cost benefit comes from bidding and tracking fewer, larger jobs than a job shop typically must accommodate.

Batch production effectively manufactures standardized products, usually to fill recurring orders.

Continuous-Flow Processes offer the opportunity to use efficient continuous-flow equipment to make a continuous-flow of undifferentiated liquids, gases, and mineral products. Whereas operations managers typically view a production line as a string of connected workstations, they think of continuous processes as a single entity. Some processes start out continuous flows but at some point switch to high volume discrete production. A good example is sugar refining where the end product is packages in boxes or bags.

Continuous-flow processes normally make standardized goods, which compete on price. Such a process might transform one input flow into a series of output flows. Crude oil is refined into oil products using a distillation process. Other continuous-flow processes transform a blend of input streams into an end product. However, the firm with the lowest processing cost usually prospers most in such a market.

Continuous-flow processes are capital intensive. They use specialized processing equipment designed to achieve carefully balanced throughput rates from specified inputs to fill specified storage capacities. An oil refinery design seeks to efficiently process a specific type of crude oil into a blend of outputs. The same process may fail to efficiently process crude from a different source. If refinery inputs are changed, the resulting capability mismatch often diminishes system performance.

Continuous-flow processes need employees well trained to manage their particular technologies. Most rely on process automation, so they need fewer workers but those who have specialized product and process knowledge to keep things running smoothly and to react when things don't go as planned. The environment usually results in a centralized organization structure with a bureaucratic management style. When your plant costs $200 million, you don't want your employees winging it as they manage your facilities.

Continuous-flow processes use product layouts that arrange equipment to facilitate the flow of materials through processing steps into the finished product or products. The locations of continuous-flow processes often depend on the locations of raw materials sources, transportation economics, or environmental issues. Continuous-flow processes cannot tolerate much variance. They perform limited, specialized functions to produce standardized products. To recover the investment in expensive equipment, they generally try to operate at close to capacity at all times.

Dialogue Driver: If the manufacturing process consists of a sequence of manufacturing steps, what needs to be placed in between the steps if the process choices are not the same?

HOW MUCH CAPACITY?

Operations managers face at least three capacity sizing issues. The first is deciding how quickly the firm must respond to a request for a good or service. To a time sensitive business, such as The New York Stock Exchange, this challenge is influenced by external developments. In the past, when stock tickers ran late, this was a sign of a busy trading day. Stock market brokers modulated transaction demand since they could only answer their telephones at a certain rate. Customers did not like being placed on hold, but they understood the limitation. Today, IT advances occur at a rapid rate but NYSE customers' expectations are rising at an even faster rate. There are many more investors, some who actively check stock prices online during the day. Each expects that *his* market orders will be executed immediately. As a result, the NYSE must anticipate not only the average rate of demand for its services, but also the highest conceivable rate. When capacity sizing, the NYSE cannot risk capacity short falls since they have dire consequences on market liquidity.

Some firms selling commodities feel no need to meet all demand. “Sold out” and “No Vacancy” signs tell potential motel customers to go elsewhere. This is not necessarily bad because such a strategy can allow firms to fully utilize capacity, thereby supporting a low cost business strategy. The risk is that the customer that goes elsewhere might not be back. With commodity businesses, shortages of this kind can be the norm.

The second issue influencing the capacity sizing issue relates to the extent customers’ demand patterns can be managed. In the prior shell, we introduced the concept of demand management, i.e., the process by which a firm tries to shift demand to alternative products and/or time slots to the mutual satisfaction of the firms and its customers.

The third capacity sizing issue relates to the extent to which the firm can use inventory and backlog to decouple order requests and the production of a good. When firms use the MTS market orientation, it can manufacture goods during slow periods to cover demand in periods where demand exceeds capacity. This works well when demand patterns are seasonal and predictable. The risks associated with placing standard goods in inventory is minimum, but not without costs.

Backlogs occur when a firm is able to get a customer to wait for the good or service. In many systems, backlogging demand for a product is a symptom of a capacity or a demand-forecasting problem. But there are other situations where the customer expects to wait. Getting customers to wait may enable a firm to utilize its plant capacity at a higher rate. In an earlier time, cotton producers had to have sufficient gin capacity to process cotton as it was harvested. Today, if you fly over cotton fields, you see “loaves” of picked cotton stored on the ground under plastic tarps. The cotton is only brought to the gin immediately prior to it being processed. This allows the firms to invest in a smaller number of modern gins and be able to operate them long after the cotton picking season ends.

The backlogging of an order often occurs when a firm uses a build-to-order market orientation. In these situations, firms can smooth demand patterns by shortening and lengthening product delivery dates. When business is good, firms extend the time it takes to get the merchandise. This is nice so long as a customer is willing to wait—but not all do. When a backlog increases beyond a point, firms will take steps to increase its capacity. When times are slow, short-term resource level adjustments can “right-size” capacity. In an earlier time, these were called layoffs. The output of the capacity sizing decision is a planned capacity profile that will enable the firm to satisfy a certain amount of demand in a specific manner.

d

Dialogue Driver:

Where do you, as a consumer, experience having your purchase requests backlogged? To what extent does each experience lower your estimation of the value of the product being sold?

Can you think of a firm that combines delivery reliability to enhance the value of their products that they back order?

d

Measuring Capacity

There is no universally accepted way to measure capacity. Most systems measure it in terms of their outputs, but there are situations where the input measurements provide better description of the capacity of a system. The unit of measure also varies from situation to situation. John Deere's cotton picker plant measures manufacturing output in terms of tons shipped. They could have just as easily measured output by the number of cotton pickers shipped, but this measure might not include important spare parts shipments. Other firms use dollar amounts but these pose a problem when the prices of product have materially changed.

To illustrate the capacity definition problem, we need only to look at a college. What is college capacity? Is it defined by: the number of instructors, classroom space, or the demand for courses? Assume its faculty agree to teach anywhere any time. Then we can define capacity by the number of class times, classrooms, and sizes of the classrooms.

In 1999, the California State University System (CSU) announced that it would not build any new classroom space to meet the projected student enrollment surge. Its proposed solution was to make better use of “underutilized” classroom space. It correctly identified that many classrooms are not be used:

- Before 7:30 AM each morning and after 9:30 PM in the evening
- Between 4:30 and 6:00 PM each day
- On Fridays, Saturdays, and Sundays
- During the summer months and during holidays

CSU’s top mucky-mucks have correctly identified empty seats, but have they identified useful capacity? Probably not since it is unlikely that students would want to take courses in these periods. There are a number of other reasons why capacity is not fully utilized. These include:

- Students often drop a course after the start of a course.
- Individual faculty may not always welcome late arriving students even when space is available.
- The mix of courses taught does not always match what the students want to take.
- Inflexible resources, i.e., Fine Arts instructors are unwilling to teach MIS courses.

The task of education system managers is to find ways to reduce these loss-of-capacity factors. As a classroom exercise, you might build a cause and effect diagram for each of these factors.

Lastly, the time period used to define capacity matters. With purchasers of stock in a rapidly changing market, what mattered most was the ability of the NYSE to meet peak demand rates, not the total daily demand. Peak period capacity is especially important in many service situations when demand cannot be postponed. When the stock market is rapidly changing, a delay in executing a stock transaction can amount to major losses. Such also is the case with the generation of electricity since it cannot be stored. In both situations, the way one measures capacity must be internally consistent with your strategy's definition of the way the firm plans to serve customers.

Three Definitions of Capacity

Some mismatches between demand and capacity result from frustrating gaps between the output rates that operations managers assume in planning and the rates that their plants actually generate. Such a gap often seems to infer some problem with management methods, but it may actually indicate an incomplete understanding of capacity. When operations managers state process capacities, they must clearly indicate which of three types of capacity they intend to specify:

- *Maximum capacity defines the highest rate of output a process or activity can achieve*. It specifies a theoretical upper limit above the usual rate for routine operations. Operations managers calculate the maximum or design capacity of a process based on the number and duration of available shifts, the number of available machines and employees per shift, and the working days in the period of the calculation. This calculation requires some very important simplifying assumptions:
- Equally skilled workers: This assumption eliminates the need to account for differences in efficiency due to individual worker's training or abilities.
- No loss of time to product changeovers or differences in products.
- No loss of capacity due to machine breakdowns, worker problems, scrap, and salvage. This eliminates real-work disruptions like employees asking for time to rest or eat.
- No loss of capacity due to preventive maintenance or planned downtime.
- No overtime work or heroic efforts by employees.

  These impractical assumptions make maximum capacity an upper limit for the regular output rate of a process.

- *Effective capacity identifies the output rate that managers expect for a given activity or process*. They base production plans and schedules on this measure of output. Effective capacity normally falls short of maximum capacity by some amount.
  - Operations managers often plan to operate their systems at less than 100 percent of maximum capacity for several good reasons:
    - Accommodate unexpected demand: No realistic shop-floor scheduler expects to receive all orders with normal lead times. Important customers submit rush orders that require rapid responses. Firms have found that a little free capacity can add value.
  - Allow time for preventive maintenance and other activities that support capacity: Preventive maintenance reduces the chances of disruptions due to unplanned breakdowns. Scheduling downtime for this purpose can reduce system variance.
  - Correct unexpected breakdowns: Despite maintenance, breakdowns reduce effective capacity.
  - Employ capacity efficiently: Running at maximum capacity can severely strain equipment and people. Operations managers often consciously run their plants at lower capacity levels to avoid stressing people and equipment.
- *Demonstrated capacity deals with actual rather than planned production*, i.e., *it measures the actual level of output for a process or activity over a period of time.* Planners calculate theoretical values for maximum and effective capacity to guide their arrangements for production. Operations managers calculate demonstrated capacity simply by averaging recorded figures for actual output over a period of time. Exhibit 4 shows this calculation for a work center that performs some process operation. Over a 5-week period, this work center produced output for an average of 591 hours per week, ranging from a high of 635 hours in Week 3 to a low of 550 hours in Week 5.

Exhibit 4
Averaging Observed Results to Find Demonstrated Capacity

Work Center 123	Observation Period: 5 weeks beginning July 12, 1999
Week	Observed Output
1 (beginning July 12)	620 hrs.
2 (beginning July 19)	580
3 (beginning July 26)	635
4 (beginning August 2)	570
5 (beginning August 9)	550
Total hours (capacity)	2,955 hrs.

To calculate the demonstrate capacity, managers often use the average experienced over a period of time. In this case, the demonstrated capacity would be: Average hours = 2955/5 = 591 hrs/ week

Demonstrated capacity may differ from both maximum and effective capacity for many reasons.

- Product Mix: The number of different products that a process must generate affects its demonstrated capacity through requirements for setup times. Whenever a process switches production from one product to another, it must set up equipment for the new output. Setups may make changes to equipment (new tools or layouts), and they may require operators to relearn methods for making the new product. A diverse product mix requires many such changes, and these setups reduce demonstrated capacity.
- Operator Skill and Experience: Operator skill differs from operator experience in important ways. Operator skill refers to abilities of individual workers. Some people naturally excel at work that requires great precision; the natural abilities of others suit them to physically demanding work. Excellent vision gives a person one essential requirement for work as a test pilot. Physical or natural attributes like these may help an individual to develop certain skills.

  In contrast, experience comes from learning, training, and executing tasks. If an instructor shows someone how to do a task, then the trainee gains experience. Someone who makes something every day accumulates more experience than someone who has never made that product. In general, skill and experience both increase the efficiency of a worker and the demonstrated capacity of a process.
- Condition of Equipment: The abilities of equipment also affect demonstrated capacity. Improving the capabilities or condition of equipment and tools raises demonstrated capacity. The condition of equipment and tools depends on operation, storage, and maintenance practices.
- Types of Jobs: Important differences between the work required for specific jobs often affect processing methods and efficiency. In particular, production of prototypes must proceed without guidance from established production standards or requirements. A process may turn out prototypes and other demanding jobs less efficiently than routine production, reducing demonstrated capacity, if workers have to spend more time doing each job.
- Inaccurate Production Standards: Demonstrated capacity may differ from effective capacity not because of inefficiencies in actual processing, but because of poor standards for process performance.
- Quality of Materials: Demonstrated capacity also depends on the quality of the materials that a process handles. Poor-quality materials inhibit efficiency because the process must either work around defects or spend time inspecting finished products to ensure quality compliance.
- Other Factors: Several additional causes can contribute to differences between demonstrated capacity and maximum or effective capacity for a process:
  - *Starvation*: Capacity may disappear between two or more linked activities. If one work station sits idle waiting for inputs from internal or external suppliers, then demonstrated capacity falls.
  - *Blockage*: Like starvation problems, blockage problems inhibit efficiency when a downstream activity fails to keep pace with upstream activities.
  - *Production yield problems*: Effective capacity plans for production of acceptable units of output. Demonstrated capacity does not count defective units, so scrap, rework, and salvage all reduce it.
  - *Time spent on training*: Any unplanned training for employees can reduce demonstrated capacity by reducing either utilization or efficiency rates.

Demonstrated capacity may fall for other reasons like power failures and seasonal drops in efficiency.

Operations managers can increase a maximum capacity within a period only by increasing physical resources. They can do this over the long term by building new facilities, adding better equipment, or hiring more workers. They can increase maximum capacity over the short term or intermediate periods by adding a second or third shift. Overtime work provides a strictly short-term boost. Most of these options take time to implement, except simply scheduling overtime shifts.

Alternatively, managers can increase capacity by farming out certain process activities. Outsourcing provides an increasingly popular way to do this. It is covered in the supply chain management shell. Since effective capacity represents the output rate that a planner should realistically expect, the methods for developing this measure of capacity become important. Some of the ways operations managers use to express effective capacity are:

- Top-down measures: These express effective capacity as a percentage of maximum capacity. If a process has a maximum capacity of 840 hours per week and management wants to maintain a 20 percent cushion, then effective capacity equals 840 hours times 0.80, or 672 hours.
- Another method calculates effective capacity as a function of maximum capacity, efficiency, and utilization.

If one defines these terms as:

Maximum capacity = Hours/Week * Planned overtime percentage * Output/Hour

Efficiency = Standard time/Actual time

Utilization = Actual hours possible /Scheduled available hours

Then effective capacity is the product of these three terms.

Effective Capacity = Maximum Capacity x Efficiency x Utilization

Guidelines for Calculating Capacity

Operations managers need a methodology for evaluating capacity and the activities that determine it in specific situations. The steps in this analysis form a process for calculating capacity.

Step 1: Describe the General Flow of Activities within the Process: Operations begin evaluating the capacity of a process by identifying and describing the activities involved in the process and the organization of those activities. In particular, they want to assess the sequential or parallel organization scheme of process activities. As we will discuss later, this difference influences methods for calculating the overall capacity of a process.

Step 2: Establish the Time Period: Since capacity is a flow rate per period of time, to be consistent, it should measure the capacity of each activity in the process on the same basis.

Step 3: Establish a Common Unit: After choosing a time period, operations managers have to identify a common unit of measurement for the entire process.

Step 4: Identify the Maximum Capacity for the Overall Process: Managers determine the overall maximum capacity for the entire process in two steps. First, they determine the maximum capacity for every individual activity, and then they combine this information to identify the overall capacity of the process. The first step is relatively straightforward, but the second requires careful study.

Step 5: Identify the Effective Capacity for the Overall Process: After calculating the maximum capacity, operations managers determine the effective capacity, as described earlier in the chapter. Top managers can set this value by a top-down mandate, or operations managers can calculate it based on utilization and efficiency rates, as previously discussed. Organizing activities either sequentially or in parallel has the same effects on the effective capacity of a process as they have on its maximum capacity.

Step 6: Determine the Demonstrated Capacity. Operations managers calculate the demonstrated capacity for the entire process based on observed results over time.

Step 7: Compare the Demonstrated, Effective, and Maximum Capacities and Take the Appropriate Actions: In the final step of the capacity-calculation process, operations managers compare the three different measures of capacity and decide how to respond. They may choose to:

- Reduce the input rate
- Increase the upper limit on process capacity by adding resources
- Evaluate the current uses of capacity
- Do nothing

By applying this seven-step process, managers can assess the causes and scope of any capacity problem. In We now will discuss possible applications of these concepts to support capacity management decisions.

The effective capacity calculation should be done for each stage of the operations processes. These can then be placed as the capacities in the network flow problem (revisit Shell 4) to see which operations are likely to limit production. Once the bottleneck operations have been identified, the firm may either: live with this network capacity, adjust short-term resource allocations, or initiate investment in additional equipment.

Planning Effects of Capacity Types

By comparing maximum, effective, and demonstrated capacity, operations managers can identify potential improvements and decide how to implement them. This helps clarify the following capacity problems:

- *Insufficient Capacity*: Some physical obstacle such as lack of adequate machines, facilities, or tools may keep the capacity of a process below the level that the firm needs to satisfy demand. Capacity managers can overcome this obstacle only by adding new physical capacity. They can construct new facilities, buy more equipment, draw more heavily on the capacity of suppliers, or hire more employees. Each of these actions raises the maximum capacity of the process.
- *Excess Capacity*: A firm that can produce more output with existing resources than customers demand finds its OM process underutilized. The cost of maintaining this excess capacity forces the firm to spend more than necessary to produce its desired output. A manufacturer may incur costs for idle personnel or machines. A service organization incurs costs for idle personnel, and it risks loss of product appeal if customers sense that few people share their enthusiasm for the service. Restaurant customers may begin to doubt their choice for dinner if they notice that no one else has joined them in the dining room. Both manufacturers and service organizations experience large gaps between their effective and demonstrated capacities if they maintain excess capacities.
- *Uses of Existing Capacity*: A capacity problem may result from the current organization of productive resources rather than a mismatch between demand and the amount of capacity. Such a problem may result from unnecessary tasks in the current process or from equipment breakdowns, poor-quality inputs from suppliers, late deliveries, employee absenteeism, or inferior process design. Operations managers could increase the amount of capacity available to process activities without additional investments in resources by identifying and eliminating the impediments to current capacity.

To solve a capacity problem, managers must first diagnose its cause as either a mismatch between demand and capacity or simply a misuse of existing capacity. They do this by comparing planned levels of capacity with the actual level of output from the system (i.e., demonstrated capacity). Gaps among these three types of capacity often help operations managers to evaluate capacity problems.

TIMING CAPACITY INVESTMENTS AND DIVESTMENTS

The manner in which a firm makes long-term capacity decisions is a function of the following factors:

- The lead time required to make and implement the decision: In some bureaucratic organizations, it just takes longer to get capital expenditure decisions made. In other situations, external regulatory institutions, such as community zoning agency, add to the length of time it takes to get approval to proceed with an investment.
- The capacity addition lead-time: The time it takes to design, construct and bring a facility up to speed. Many heavy equipment makers that sell ETO products have this trait, such as the manufacturer of electric generators for a utility's power plants. This might take as long as ten years.
- The capacity increment alternatives: In some cases, the only economic choice is to make sizeable increases in capacity. One cannot economically build a small, corrugated linerboard plant. In other situations, it is possible to build small plants or make small capacity additions to existing facilities.

Consider how the clockspeed influences how capacity planners perform in these industries. Slow clockspeed firms have sufficient notice of new demand conditions to adjust capacity. Firms with Lexus-lane clockspeeds have greater needs for timely demand information and an ability to adjust capacity quickly as needed. Firms that succeed without these two capabilities are called lucky.

Fortunately, the same management practices that enabled firms to rapidly design and develop new products also support rapid adjustments of process capacities. These include:

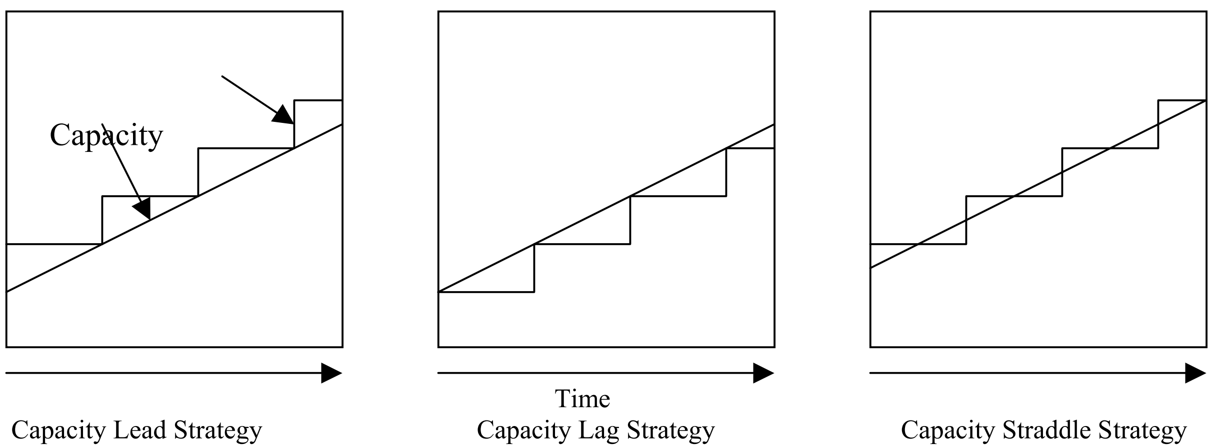
- Computer-assisted plant design enables engineers to conceive facility designs rapidly.
- Early suppliers involvement in product and process innovation processes.
- A trend away from vertical integration, thereby simplifying supply chain system design.

Dialogue Driver: Does the fact that your firm is outsourcing much of what it previously did really reduce the capacity expansion/contraction challenge – or just make the problem less visible?

Three Capacity-Expansion Timing Strategies

In an expanding market, each competing firm either implicitly or explicitly adopts one of three basic capacity-expansion strategies, as shown in Exhibit 5. A firm chooses the tradeoffs associated with each strategy based on the needs of the firm's customers and the business's strategy for meeting those needs.

Exhibit 5
Three Pure Capacity Expansion Strategies



The exhibit simplifies the behavior of real-world markets, which often diverge from the linear pattern of capacity expansion. Market demand for mature products may exhibit a linear growth trend, but newer products often grow in rising and falling patterns driven by the product life cycle. Actual expansion decisions depend on product differences, which may create steady, rapid growth, as for audio CD-ROM players, or spurts in demand followed by rapid declines, as for CB radios. Technological innovations can influence capacity-expansion plans as well.

A firm employs a *capacity lead strategy* when it intentionally invests in capacity in advance of demand to eliminate the chance of losing sales to competitors. The economic tradeoff requires incremental profits from making those sales to exceed the incremental costs of operating below full capacity. As an alternative, the firm may value its current customers so highly that it invests in the extra capacity despite the cost to protect its customer-service reputation.

A *capacity lag strategy* calls for expansion investments only after confirmation of rises in demand in order to maintain a high utilization rate. If a plant produces either a homogeneous commodity or a standard product that appeals to customers based primarily on cost, then this strategy will maximize profits by minimizing operating costs. This choice makes the important assumption that customers will return after buying from competitors when the firm cannot fill their needs. This assumption may be valid in markets for commodity products and those dominated by cost-driven managers, as seems to be the case at the Mars candy company.

A *capacity straddle strategy* tries to keep abreast of growing demand by matching average capacity to average demand. It calls for expansion only when managers expect that they can sell at least some of the additional output, but before they know that they can sell it all. Clearly, this strategy has some of the advantages and disadvantages of the two extreme choices. Success depends on the critical choice of how long to wait before building capacity.

Many operations managers rely on total cost analysis methods to balance the extra cost of operating below maximum capacity against the risk of stock outs and disappointing customers by keeping capacity below demand. To solve more complex problems over multiple time periods, they often formulate mixed-integer programming models with algorithms that indicate both the timing and sizes of any expansions. These techniques give valuable quantitative information, but managers must carefully evaluate the tradeoffs of every decision and its contributions to the firm's strategic objectives.

This discussion has assumed that every firm times its investments in capacity based on internal investments. In some business situations, however, *collaborative* arrangements with suppliers or even competitors can help to solve capacity-timing problems. Cooperation with competitors becomes particularly attractive for commodity products manufactured in capital-intensive facilities. For example, a manufacturer of corrugated containers would have to spend \$250 million to \$300 million to expand its process capacity to manufacture linerboard, and the resulting increase in capacity would far exceed the firm's internal need. It might build the plant and hope to sell the excess output in the spot market. At the same time, a competitor might make the same plans, leaving both firms with expensive capacity to produce much more liner board than either needs. To avoid this problem, the competitors could forge a long-term product swapping agreement in which Company A would build the plant first and sell linerboard to Company B at the posted market price. Company B would then time its next plant expansion for a time when the combined needs of the both companies would warrant additional capacity. Clearly, this strategy would work only in commodity markets where the firms could exchange essentially identical products.

Dialogue Driver:
In the wake of Enron-era financial shenanigans, how can we explain why the aforementioned capacity swaps are different from say, the broadband capacity swaps made by Global Crossings and Quest?

Hint: The apparent motive behind the broadband capacity swaps was to inflate both firms' revenue, while the motives for swapping linerboard capacity was to make capacity investments more efficient.

Flexible outsourcing provides a similar solution that adjusts the flow of a company's work by mixing in some inputs from suppliers. When capacity becomes scarce, a firm may divert some of its internal work to the external factory rather than building new internal capacity. When it does expand capacity, it can take some of this work back within the internal factory. This would raise the firm's capacity utilization rate over a period of years while controlling the threat of stock outs and poor fill rates. This practice would require careful planning and implementation to avoid alienating the firm's relationships with its suppliers.

Capacity Sizing Tools

OM applies analytical tools to help them determine the right sizes of physical facilities. By measuring maximum, effective, and demonstrated capacity, operations managers can realistically project the likely output rates of proposed configurations of productive resources. Based on these output rates, they can then estimate the impact of the utilization rate on the cost component of the value equation. The total cost per unit of production in some proposed system equals:

$$C = V + F/R \qquad (1)$$

where

F = Fixed costs of the system
V = Variable production cost
R = Planned capacity rate

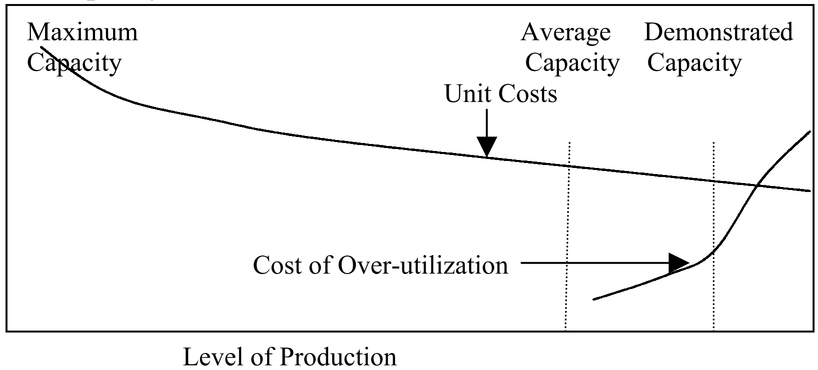
Actually, this simple analysis needs some adjustment for the cost of operating a system without a sufficient cushion of excess capacity. As a plant's utilization rate increases, output rises beyond demonstrated capacity. This has some good effects and some bad ones. The benefits of high utilization include intensive scheduling that draws high returns from investments in facilities and equipment. A tight schedule creates a compelling need to prevent starvation and blockages as well as breakdowns and absenteeism; a small problem due to any of these causes can seriously disrupt the workflow throughout a shop. If human resources constrain output, increasing attention on motivating workers can coax additional output out of a tightly stretched system. Like students during finals week, operating employees can perform above theoretical standards over the short term.

Over-utilization of plant resources has some undesirable longer-term consequences, such as:

- Premium labor costs, including expenses for overtime or temporary help
- Costs to rush production, including expenses for expediting orders
- Threats to customer service, including incomplete and backlogged orders
- Excessive wear, including overtaxed workers and machines that suffer from infrequent maintenance
- Limits on time for management initiatives, including continuous improvement

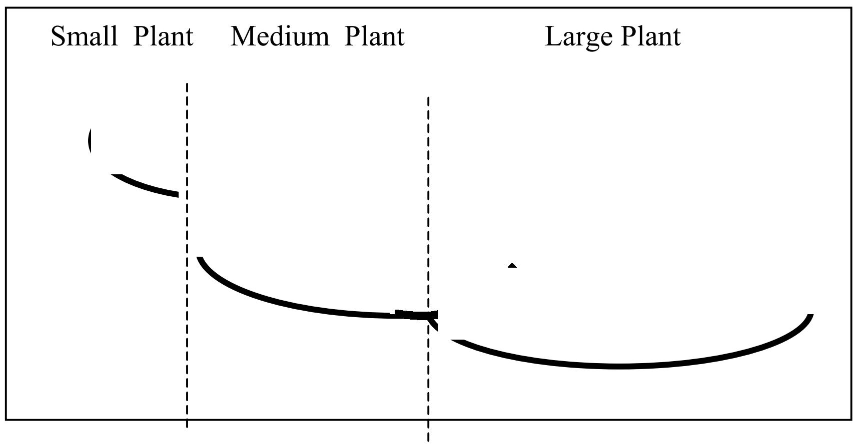
Equation 1 focuses only on costs, so it allows operations managers to ignore the other three elements of the value equation. To supplement their cost analysis, they need some means to approximate the impact of overextended production on their system's ability to provide the quality, speed, and product variety that delight its customers. Equation 1 quantifies the effect on a firm's average unit cost of a particular plant utilization rate, but estimating the costs of over-utilization is more difficult. Experienced plant managers recognize some diseconomies of scale, but they seldom can give precise cost estimates.

Exhibit 6
Capacity-Related Production Tradeoff Costs



Operations managers might compare a number of feasible plant-size alternatives with a sketch.

Exhibit 7
Economics of Plant-Size Alternatives Costs



The curves present the general effects on average total costs of three potential plant sizes. Each shows a declining average total cost as the utilization rate increases until the process reaches its demonstrated capacity. Beyond the optimal point, diseconomies of scale due to overextended resources drive up costs, offsetting the incremental benefits of additional production.

The plant size choice depends on its expected demand over time. If operations managers expect orders in Range 1, they should establish the smallest plant. They should plan for the medium-sized or large plant to handle volume in Ranges 2 or 3, respectively. If they expect growing or declining demand, a complete analysis would project production volume and costs for multiple time periods.

If operations managers have enough reliable information, they may construct a mathematical model of the effect of production volume on plant size. The lack of precise input data may cast doubt on the reliability of the conclusions. In practice, a spreadsheet based on the judgments of personnel should usually is sufficient.

WHERE TO LOCATE CAPACITY?

Once the best size of a plant has been determined, the long-term capacity-planning task becomes that of finding the best locations for the facilities. Facility location decisions are important for three reasons:

- They often involve making long-term commitments that can not easily be changed.
- They often determine the cost and service characteristics of the value chain.
- This in turn can influence the market size and your firm's market share.

The last two points are particularly important in services since their competitive advantage often depends on a facility being located near customers. While you might have a preference for a Big Mac, it is unlikely that you would drive twelve miles to the closest McDonald's when a Burger King is next door. We shall leave the retail facility location decision to your marketing course given the importance of consumer behavior considerations. But not all services are proximity driven. A service can rely on telephones, computer networks, and overnight parcel services to provide needed customer service.

As one move back through the value chain, the facility location decision becomes less of a marketing driven decision to one of making cost and service tradeoffs. Firms locate facilities using a number of factors:

- The locations of customers
- Customers' expectations and value-equation priorities
- Competitors' locations and operating methods
- Projections of service levels and appeals to the latent demands of existing and potential customers
- Actual or estimated relevant costs as determined through total cost analysis
- Feasible alternatives for capacity adjustments
- Effect on the firm's long-term objectives
- Effect on the firm's profitability
- Life style considerations of key stakeholders

Like many other decisions in operations management, location choices have shown the effects of powerful changes. In the past, firms treated plants and equipment as completely stationary resources. In capital-intensive industries, this remains true. But increased mobility has become common in service, distribution, and high-technology manufacturing businesses.

The general procedure for location facilities within your value chain is usually a multi-stage decision making process. The following four-step process can be used to address the facilities location problem:

Step 1: Determine if the decision-making process is largely going to be cost driven or market driven. If the decision being made here has material consequences on the ability of the firm to compete for customers, then the model must be market driven. If however, the major impact of facility location decisions is on the cost effectiveness of the system, then a cost minimization model often will be suffice.

Step 2: Determine which decision variables are most important. Starting with the point of origin for each key raw material, build a total cost model that incorporates each key decision variable.

Step 3: Study the industry manufacturing and distribution patterns and ask, "Why do we and/or our competitors structure their value chains in this fashion?" Then ask what condition would have to exist before existing value chain structures would no longer be valid.

Step 4: Develop a finite set of "plausible location alternatives," based on your analysis of existing value chain systems. This may be a two-stage process. In the first stage, the purpose may be to locate general regions in which it makes sense to place facilities. In the simpler cases, it just may make sense to locate facilities near markets because of outbound freight costs or as customer service requirements dictate. For example, Coca Cola decided early on that since most of Coke was water, it made little sense to bottle it at a central location. Likewise, the demand for quick service forces distributors to locate their facilities close to their customers.

In a more elaborate case, it may not be apparent how many and where facilities should be placed. In the past, much time was spent on the so-called warehouse location problem. In this problem, a model is constructed to minimize the total freight and warehouse operating costs for a set of customers.

Mathematically, it was formulated as:

$$\text{Minimize } z = \sum\sum a_{ij}x_{ij} + \sum\sum(w_j y_{jk}) + \sum K_j (\delta_j) + \sum\sum b_{jk}y_{jk} \qquad [2]$$

Subject to: $\sum\sum x_{ij} <= P_i$ which says that you cannot exceed plant i's capacity.

$\sum\sum x_{ij} <= W_j$ which says that you cannot exceed warehouse j's capacity.

$\sum\sum y_{jk} = C_k$ which says that you must satisfy the demand at customer k.

$\sum x_{ij} = \sum y_{jk}$ for j = 1,2,…,n which says that the amount shipped into warehouse j must equal the amount shipped out warehouse j.

where a_{ij} is the unit cost of shipping one unit from plant i to warehouse j
x_{ij} is the number of units shipped from plant i to warehouse j
P_i is the capacity of plant i
w_j is the unit cost of processing one unit through warehouse j
K_j is the fixed cost of processing one or more units through warehouse j
δ_j is a zero-one variable that is zero when no units are shipped through warehouse j
b_{jk} is the unit cost of shipping one unit from warehouse j to customer k
y_{jk} is the number of units shipped from warehouse j to customer k
W_j is warehouse j's capacity (this constraint may be inactive)
C_k is the demand of customer k

SUMMARY

This shell provides a conceptual framework for the long term capacity management. Long term capacity management involves four businesses processes that must answer the questions:

- What type of facilities should the firm have in order to enable its operations function provide the services needed if to achieve its strategic objectives? The two facets of the “what type” question relate to the firm’s market orientation and its process choices.
- How much capacity does a firm need to satisfy its market strategy goals? The capacity measurement challenge is discussed and three concepts of capacity are introduced. A set of guidelines for aiding the operations managers calculate capacity are given.
- When should a firm invest in plant capacity? Three pure investment timing strategies were discussed.
- Where should the firm build capacity? A total cost model is introduced.

References

1. Blackstone, J. H. , *Capacity Management*. Cincinnati, Ohio: South-Western, 1989.
2. Burbidge, J., *Production Flow Analysis for Planning Group Technology*, Oxford: Clarendon Press, 1989.
3. Hayes, R. H., and S. C. Wheelwright, *Restoring Our Competitive Edge: Competing through Manufacturing*, New York: John Wiley & Sons, 1984.

Expected Learning Competencies for Shell 7

Before putting Shell Seven down, you should ask yourself the following questions. Am I able to explain:

1. What long term capacity decisions this shell addresses.
2. How process choice influences the value of the good or service the firm is selling? Specifically indicate how each element of the value equation will change.
3. How a process choice impacts the resources used within the firm. I.e., what type of people, material resources, capital, and managerial software.
4. The three definitions of capacity and how they are influenced by utilization and efficiency rates.
5. The different types of capacity addition/subtraction strategies
6. The economic and value tradeoff issues involved in facility location decisions
7. What your instructor added to this shell and why he or she thought that is important enough to warrant its inclusion.

Frequently Asked Questions

Instructors have been known to ask questions similar to the following:

1. Explain how process choice decisions impact the elements of the value equation.
2. Provide and example of each of the five process choices that you have experienced as a consumer.
3. Explain how process choice decisions and the human resource management function are related.
4. Explain how process choice decisions and the management information system function are related.
5. Which of the following process choices is most likely to require skilled labor?
   a. A job shop
   b. Assembly line workers
   c. A project
6. Which of the following process choices is most likely to the most work in progree inventory
   d. A job shop
   e. Assembly line workers
   f. A project
8. Which of the following process choices is most likely to have the shortest manufacturing lead time?
   a. A job shop
   b. Assembly line workers
   c. A project
9. Job shops invariable cost more than batch or assembly line process choices.
10. The where to locate retail facilities is a cost minimization problem.

SHELL EIGHT
PRODUCT DESIGN AND PROCESS SELECTION—SERVICES

The Seat of Power

One goal of service systems is to make every customer feel that he or she is being treated regally. Delighting the customer has almost become a cliché but when something goes wrong in your household's plumbing system, your latent need becomes an immediate need. "Honey, the toilet is backing up—what should I do?"

In Fresno California, the answer to that question is well known because one plumbing company has transformed itself into a well-known world-class plumbing service. View of local TV can not avoid noticing DeMar Plumbing's funny commercials that show a chorus line of male plumbers performing a song and dance routines with toilet plungers. Brand matters, but what matters even more is their reputation for providing reliable, service at a reasonable price.

How did this plumbing company accomplish this? DeMar did much more that wait for customers to call. It did what today is called superior customer relations management (CRM). It systematically collected information on its customer, such as the type, brand, age, and conditions of the water heaters observed on a service transaction. Each customer's service history is recorded. And yes, it even uses direct telephone marketing to try to ferret out latent demand within the community. Does your household having a annoying problem that awaits your home based handyman's attention?

Another attribute of DeMar's service system is its people. World-class services provide more than just competent people. Initial touch points are must help the customer feel that the person receiving the service request call understands and empathizes with your problem and that they will send s service repair person that you will feel comfortable letting in your house. DeMar servicemen receive Dale Carnegie courses to enhance their people skills. They arrive in the distinctive yellow vans observed in the TV commercials. Each wears a crisp, clean uniform and a smile. For repeat customers, it most likely is the same person. And when he leaves, the job is done right and at the price agreed upon at the start of the service transaction.

After the transaction has been completed, the service person immediately updates the CRM system because he knows that it will help him in future transactions. Customers like it when you know who they are and remember the nature of past calls. It also helps your telemarketing processes. They systematically make follow up calls to ensure that your remain a satisfied customers. And they don't make cold calls to you shortly after the transaction. As a domestic throne sitter, you deserve more respect.

Source: Tom Peters video, Service with a Soul

Shell Eight
Product Design and Process Selection--Services

Table of Contents

Learning Objectives for Shell Eight

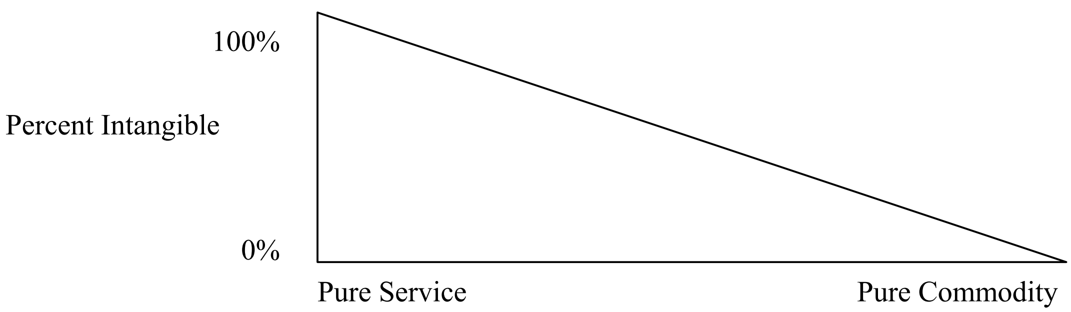
After reading this shell and thinking about its contents, you should be able to:

1. Understand the varied nature of services and service delivery systems. Be able to cite and illustrate how attributes can be used to categorize services. Be prepared to give an example of each.
2. Explain the emerging roles of information technologies to enhance service delivery systems.
3. Albeit flawed, be able to cite the three classic forms of service delivery systems. Why is it that these forms are an inadequate role model for service system designers/
4. Explain how performance metrics can be used in service system design.
5. Explain how process mapping is used in competitive analysis.
6. Give an example of service blueprinting.
7. Discuss the future challenges facing service system designers.

INTRODUCTION

In this shell, we explore how a firm goes about creating services and service delivery systems that are capable of delivering value that exceeds the expectations of targeted customers. To a certain extent, it may not be possible to completely separate our treatment of service system design from that of manufacturing system design because many products are a bundle of tangibles and intangibles. In this shell, *a service is defined as a transaction in which the customer largely perceives the dominant value-adding component as being the intangible part of the product bundle*. When the product bundle is expressed as a spectrum, the types of product delivery systems covered in this shell lie in the left-most zone of Exhibit 1. We have also included some examples of some service deliver systems along this spectrum.

Exhibit 1
The Product Bundle Spectrum



Institution Class	Intangible Provided	Tangible Component
Restaurant	Food preparation and ambiance	Food
Telephone utility	Message transmission	Phones
Movie theater	Visual experience/enjoyment	Popcorn
Auto Repair	Knowledge based corrective action	New parts
Software	Symbol and word arrangements	CD-ROM

Each total product experience has a tangible component but their dominant component is intangible.

A customer's total product experience with a service organization over time may involve a *sequence of transactions*. The degree of tangibility of each transaction within this sequence will vary. Consider the case in which a customer buys a Mini-Cooper. Initially, a potential buyer experiences mostly intangible inputs to the purchase process. These include: the reputation of the original Mini-Cooper, car magazine hype, and a few sightings of Mini-Coopers about town. An image is formed. Once the potential buyer advances to the purchase stage, one might expect this transaction to be dominated by the tangible entity being procured. A tradeoff exists between getting a car at the lowest possible price against getting the Mini-Cooper at the earliest possible date. The buyer's value setting process will influence this decision. But once the purchase has been made and the vehicle delivered, the owner will once again focus on the quality of the sequence of service transactions experienced during the post-sale period. How the buyer is treated during this sequence of transactions defines the *total product experience.*

This example illustrates another trait that complicates the use of the value driven approach to the product innovation process—namely that the value evaluating process is both *individual and situation specific*. When buying the car, a buyer's behavior may have seemed to an observer as being that of a cost conscious person.

But once the car has been purchased, the way the individual values the service component of future transactions with the car dealer may be indicative of a person who wants the car service quickly and by competent mechanics. Because the customer subjectively determines value, one cannot assume that an individual will use the same value-setting criteria within the sequence of service transactions.

And just because a customer exhibits one set of traits in one service setting, this does not mean that the same value-setting behavior will occur in other product acquisition endeavors. If we follow the car purchaser as she drives from the dealer, we might see her travel to an upscale clothing store to buy designer jeans and then drive to a discount store to buy paper towels. In each situation, the nature of the product and the type of the transaction influences the customer's value-assessing processes.

Even though your customer exhibits different behavior in different settings, the service design process need not be complicated because you only need to focus on the behavior exhibited in your setting. But some customers are inconsistent within a setting. For example, the same person might be a style-conscious, spendthrift buyer of golfing attire but an economizer price when buying branded golf balls since the local discount sporting goods stores routinely advertise them at lower prices. Your course's golf shop needs to accept lower margins on branded balls in order to maintain an image that its goods are reasonably priced.

What this means to designers of services and service delivery systems is that the behavioral assumptions about your targeted customers may be more complex than might appear at first glance. In the following sections we provide a framework to help system designers understand the idiosyncrasies of services, service systems, and the value-assessing processes of their customers.

Attributes of the Service Component

The varied nature of services makes precise classification systems difficult. Rather than trying to do the impossible, we define and discuss the attributes of services. As we proceed, you will find opportunities to cite counter examples. This is exactly why categorizing services is so difficult. So in each of the following cases, assume that we have added the caveat, "in general", since iron clad statements are not possible. *In general*, the following attributes can be used to describe the *service component* of a product bundle:

- Services are Intangible. The intangible component has no physical form. While you cannot lift it or bite into it, one or more of your other senses may experience it. You detect the scent of steaks being cooked at a restaurant. When you receive a dozen roses, their scent is an integral part of the total product experience. Knowing the name of the person who sent the roses is another intangible that might influence the value of the total product experience.
- Services cannot be inventoried. Given their intangible nature, most services cannot be stored. The implication of this attribute on service system designers is obvious—the system must either have customers that will wait or have a service delivery system that is fast-to market, fast-to-product, or both.
- The nature of service demand is often heterogeneous. The demands customers place on the server often are dissimilar and/or difficult to anticipate. The customers' ability to create seemingly unique needs means that service system designers must develop a service delivery system that can accommodate diverse service requests or redirect customers in a people-pleasing way.
- Services are labor intensive. Many services use the flexibility of well-trained humans to respond to heterogeneous service demand. The advent of flexible automation, especially in the information technology area, may make this trait less necessary. One only has to experience a telephone triage process to understand how it feels when serviced by computer-assisted processes. God help us if we need to talk to a person and we don't know how to spell the person's name.

- o <u>Service transactions are repetitive</u>. Often, service needs are continuous, as is the case with your need for electricity, or frequent, as is the case with the need for food and gasoline.
- o <u>The arrival rate of service requests is random</u>. Knowing the rate at which customers decides they need service is a key input to the service system design process. The rate is partly a function of the quality of the product, the nature of the customers' needs, and the promises made at the time of the purchase. Some firms transform random rates to known fixed intervals, as is the case with service appointments. Others offer customers products that rarely need to be serviced, as is the case with Maytag washing machines.
- o <u>Services involve extensive customer contact</u>. Many services involve contact between the service requester and the service system. Often this contact is of a personal nature. Two important system design questions need to be asked. First, how important is customer contact to the marketing of this service? There are some medical procedures that most humans will not normally initiate by themselves. In such cases, personal contact with a medical practitioner is an important part of medical delivery systems. In other business situations, an opportunity to transact more sales is lost if the helpful presence of a sales person is not built into the service transaction. The second question is, "how much contact do targeted customers want to have?" While I don't mind being known by my banker, the convenience of a nearby ATM window is what is needed for many transactions. In book retailing, the question has become, "Do I want a learned book sales person to help define my needs or will Barnes and Noble's Internet system provide me with a sufficient level of service?" This depends on the customer, the type of book needed, and perhaps the season of the year. Barnes and Noble's dual service system provides the capabilities to serve both types of customer needs.
- o <u>Service quality is difficult to assess</u>. Measuring service quality is often subjective and the people making the subjective assessments often disappear before you have an opportunity to get their assessment. Bad service quality often results in loss of future sales. How then do you know if the tight-lipped customer who says that the service was "okay" actually disliked the experience and is quietly exploring alternative service providers? Designers need to build service quality metrics into the performance evaluation systems—even if it seems that you are "imposing" with your question. Customers would rather have you err on the over-caring side than think that you don't care if they were pleased.

A second way to categorize the service itself is by the degrees of freedom it offers the customer. A customer's attitude toward service providers often depends on the options offered. The number of the choices wanted by the targeted customers helps both the service system designers and marketers identify potential order winners as the starting point for their own product innovation programs. Existing services fit into the following categories:

- o <u>Zero-say services</u>: In these transactions, the customer must accept the product as offered by the service provider. This need not be bad. For example, residential consumers must accept electricity as it is offered by the local utility. Your water service treats its product with chlorine and in most cities, fluoridate it for your child's dental health. Some customers strongly resent having to pay for governmental services that they don't use, such as the San Jose State professor who refused to pay for the local garbage collection service because he recycled *all* of his household waste. He lost in court.
- o <u>Minimum-say services</u>: These services give the customer the single option of buying the product or refraining from the transaction. Many customers elect not to buy cable TV service. Other couch-potato customers use their remote control devices to avoid the joy of television commercials. Caller ID allows the telephone recipient to screen telephone calls. This too would be a minimum say service.
- o <u>Mandated Services with Options</u>: Government or other social institutions mandate purchase of minimum levels of some services, such as automobile insurance. Customers can chose among vendors, however, such as State Farm or Farmers Insurance, and perhaps select other service features. In the commercial market, firms make choices to suit mandatory fire insurance, workers compensation, employee health-care plans, and annual boiler inspections to their particular needs.
- o <u>Elective Services</u>: These common services include tasks that people could do themselves, but they find that others can do the jobs more cheaply or more effectively. Services in this category include: getting a haircut, mowing your lawn, preparing your tax returns, or even the company's product design function.

Increasingly, companies are electing to outsource business activities that in an earlier time would have been done by staff personnel.

- Luxury Services: Most customers admit that they really don't need these services but they enjoy the treat. Like the area of product design, this category is dynamic. Many people once considered trips to their hair stylist as luxuries, but now many view them as elective necessities. Hiring a personal bodyguard may have seemed like luxuries reserved for movie stars and mob associates, but in some parts of the world, businesses feel the need to protect key personnel.

Designers of services and service delivery systems need to thoroughly understand what core benefits their targeted customers want. The service transaction dimension provides the system designer a better view of the options of these customers.

Dialogue Driver: Have you ever experienced a zero-say service and liked the experience?

Additional attributes of the service itself could be listed, but the above are sufficient given our learning objectives. The point is that a system designer must perform attribute audits to map the company's perception of how well its system will deliver service that is consistent with the firm's strategic initiatives. If your firm's response to attribute audit questions is "I really don't know," then you and the folks in marketing need to do the field work to learn more about your system and your targeted customers' perception of its performance.

Attributes of Service Customers

A second way to categorize services is by customer attributes. Recall the discussion of the Mini-Cooper purchase. It illustrates that customers wear many hats, i.e., a person might be quite frugal when buying one type of product and seem inconsistently extravagant when buying another. Even within the same product category, the *ultimate consumer* of the item may influence a customer's values. For example, the values that a father might bring to buying an automobile for his youngest daughter might be different from that for his eldest daughter who happens to be a mechanic.

If each customer is truly a unique character with attributes quite different from any other customer, then the task of the service system designer is to create a system with the capabilities to effectively respond to each customer's desires. Such systems can be created, *but at a cost* that often delivers the service at a price offering that is perceived as being too high, i.e., the costs associated with providing the services are too high for the level of performance received.

Thus service system designers seek to identify clusters of customers with like value-assessing processes. In our discussion about the Mini-Cooper customer, we noted that the customer often wore different hats as she dealt with the dealer. We therefore find it useful to categorize the types of hats people wear when approaching a service transaction. Some hats commonly seen on customers are:

- The Economizer: These customers want to minimize the cost for products that meet their order qualifying standards. Jiffy-Lube's product strategy is tailored for oil change seeking customers wearing Economizer hats. Some even call these people cheap.
- Personalized care seekers: These seek interpersonal gratification from the service transaction. The value is being greeted in a friendly way and by name. "Ms. Peaker, your *regular table* is ready."

- Convenience seekers: Those that value delivery speed and/or products customized to fit their particular needs. Service systems that can tailor their services to meet their specific needs will have a competitive advantage. Location and short lead times usually are important to this class of customer.
- Ethical/Loyalists: These customers' value non-product attributes of the service based on some moral, ethical, or social reason. A customer might patronize a fellow Rotarian or a person known through a religious organization. Some children prefer McDonald's because they relate to the franchise clown.

If one were designing a specific service delivery system, it would pay to develop customer profiles suitable for each transaction within the service system. It may be that the mix of your customers' value profiles is too diverse to be categorized. This too is useful information because it means that your delivery system will have to have the capabilities to respond to heterogeneous requests. It might lead to a marketing decision not to pursue certain types of customers—or do things that discourage their entering your service delivery system.

Dialogue Driver: Where would you place brand loyalty within this framework?

Attributes of Service Transactions

The third way to categorize services is the structure of the *service transaction*, i.e., the proximity and form of the contact between the server and the customer. The proximity attribute provides a meaningful input to the service system design process in that it specifies where the service response capabilities are needed and how fast it must respond to satisfy customers. In most instances, it does this by describing the spatial relationship existing between the customer, the service, and the service provider. The three types are:

- The customer is the consumer. In this case, the person initiating the service transaction personally uses the service. Two possible situations exist here. The first is on-site consumption, which may provide the service provider instantaneous feedback as to whether or not a need was satisfied. In other instances, the customer consumes the service at a later time and at a remote location. With take-out services, it is difficult to assess customer satisfaction.
- The customer and the consumer are not the same. The customer seeks the service for another person who is the consumer. An example of this is when a husband buys a dress for his wife. Measuring service satisfaction in this case is more difficult since the buyer and the end user may not value the product bundle the same. As is the case above, the actual consumption may take place at the site of the sales transaction or at another time and place.
- The customer seeks to have an entity serviced. In some situations, an entity, such as a lawn mower, is being serviced for the customer. One dimension of customer satisfaction is how well the serviced item works subsequent to the transaction. Other elements of value include the price, swiftness, and the convenience the service provider extends to the customer. Lexus dealers probably don't repair their cars any better than other dealers, but the manner in which they extend their service has contributed mightily to this car's J.D. Powers' customer satisfaction scores.

In most instances, the customer and the entity can be separated, but the customer may not want a separation to occur. "I would just as soon watch you work on my car." In other situations, the entity being serviced is inseparable from the customer, such as inserting a new battery in a patient's heart pacemaker. The entity being serviced may even be intangible, such as the case when a firm provides informational advertising to create a more informed customer. The perceived quality of a product can be increased by effective marketing services.

Understanding the *spatial relationships* existing between the customer and the service system provides meaningful inputs to the service systems design process. One immediate observation is that when the customer does not immediately "consume" the service, this may create an opportunity to provide a buffer between the server and the consumer. For example, when servicing lawn mowers, the customer may accept *service postponement* since most people recognize that the service center is likely to have a backlog of work.

The second term used to define this categorization is the *form of customer contact*. The following represent system ranging from little or no human-to-human contact to systems in which empowered, face-to-face interactions are the norm.

- *One-way downward communications:* Here, information is transmitted to the customer, often by mail or voice mail. The customer has little opportunity to respond and in many cases, there is no need to. Receiving a confirmation of your hotel reservations would fall in this category.
- <u>On-site technology</u>: Here, the customer experiences an interaction with an inanimate system that offers a limited number of choices. Examples of this type of transaction includes: a soft drink vending machine, a bank ATM machine, and perhaps your professor's home page. In each case, the number of options open to the user is limited by the choices offered. Try getting $11.43 from your ATM machine. Some computer-assisted telephone call management systems also would fall into this category.
- <u>Human voice telephone contact</u>: This is an efficient, albeit often annoying, way to initiate communications between a server and a customer. When initiated by a customer, it can range from an efficient call screening system to a pleasant, helpful voice. In the other direction, firms initiate calls to provide information and/or a sales pitch designed to create customer satisfaction. From the customers' perspective, the value of these calls is quite low. Why is it that banks cease serving customers at 5 PM but allow their telemarketers to call them during dinnertime?
- <u>Face-to-face customer interaction</u>: Three types of face-to-face interactions exist. They are
- <u>Tight specification interactions</u>: Here the human presenting the service has a limited authority to flexibly respond to customer requests. McDonald's used to served hamburger *their* way. Some restaurants don't allow substitutes, even though you hate peas. What we offer is what you can get.
- <u>Loose specification interactions</u>: Here, human servers are given the resources and the authority to perform limited product customization activities to please customers. Yes, we can alter that suit Mr. Melnyk to fit your leaner body now that you have lost 40 pounds.
- <u>Total customization</u>: In these transactions, human servers are empowered to do whatever it takes to please or placate a customer. Nordstroms department stores are often cited to illustrate a firm using the total customization approach.

Increased sales opportunity associated with face-to-face interactions may come at the expense of system efficiency. Being efficient only makes sense when it matches the customer's needs and expectations.

Matching a customer's service expectations is an equally important facet when designing the service transaction. The above classification is mostly from the service provider's point of view. Customers' expectations of a service relationship range from an *encounter to a full-blown relationship*. For example, when a customer needs to withdraw cash from a bank account, a convenient ATM machine provides an encounter that meets the customer's need. That same person might object to a robot-like bureaucrat impersonally asking an endless series of questions when applying for a car loan from her bank--the same bank that the customer has been doing business with for seven years. If the loan officer cannot treat this customer like a preferred customer, you would think that the bank's database could recall prior transactions and not ask for information that *it* already possesses.

When seeking a car loan, customers often seek a transaction cloaked with the personal care that we normally associate with small-town America. But e-commerce may be changing our expectations here.

The third dimension of the service transaction relates to the complexity of the customer-server interaction. As we have seen with the PT Cruiser customer example, there often are a number of stages of service that a customer can experience. The customer or its entity may travel through a network of servers, the route being a function of the customer's needs or the servicing requirements. The service transaction sequence can be categorized as is shown in Exhibit 2.

Exhibit 2
A Service Transaction Sequence Taxonomy

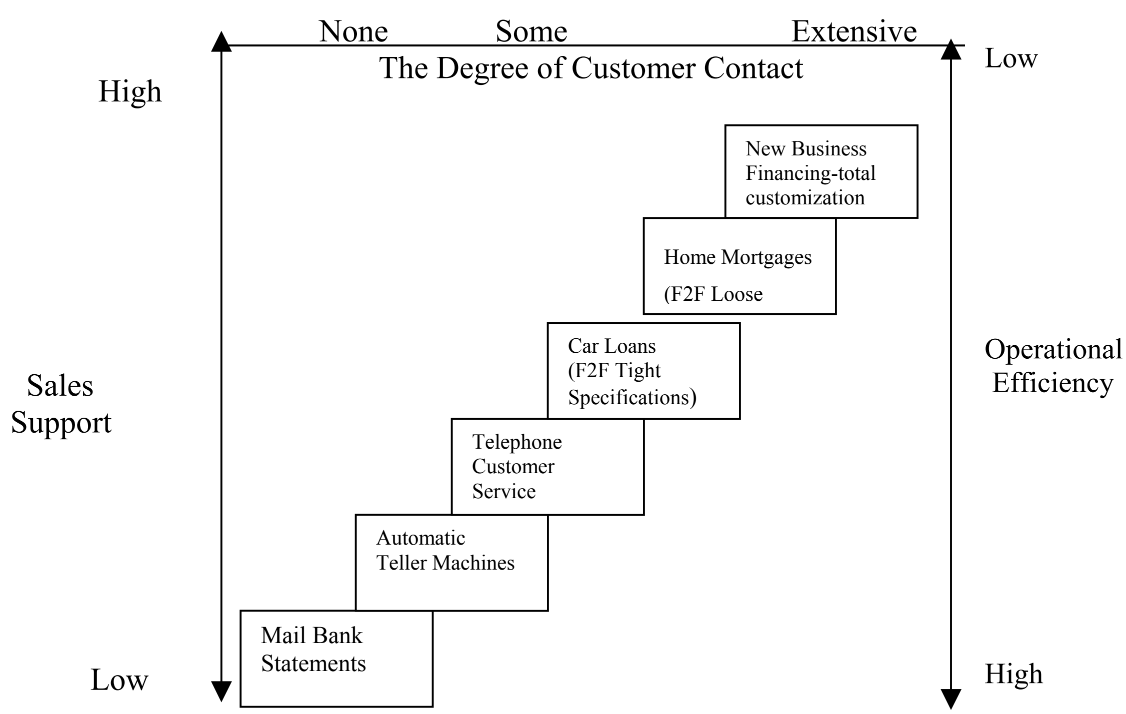
	Fixed Routing	Flexible Routing
Single Stage	Purchasing Popcorn	Bank teller routing
Multiple Stage	Purchasing a car	Hospital care

In some situations, the statistical description of the customer routings and the service times required at each stage may provide a meaningful input to the service system design process. When these are important, the system designer will often be found using either queuing theory or simulation models to determine which structure and resource allocations decision will best provide the firm with a service system capable of meeting the performance goals stated in its strategic initiative.

An Illustration of Attribute-Driven System Design

The following section is included to illustrate how transactions with each of these attributes can exist within one service. To see this, we use the service system design matrix shown in Exhibit 3. In this illustration, we see that this bank uses just about every type of service transactions. It uses a postal service to inform the customer of the status of the account and provide a record of all account transactions. This is an activity that has not changed much over the last ten years.

Exhibit 3
The Service System Design Matrix



The second activity, the ATM machine represents a revolution that took place in the banking industry. It enabled banks to improve transaction efficiency while providing enhanced service to its customers. Customers no longer need to enter the bank for routine transactions—in fact, with some banks, one doesn't even need to go to a bank since ATM machines are widely situated at sites that are convenient to customers. One can even travel to many parts of the world and still conveniently retrieve funds, but often at a cost. If you need a non-routine transaction, this will require that you call customer service or go into the bank.

Telephone service has been enhanced by information technology. The human on the other end often has immediate access to the status of your account and other pertinent data. The bank may often have the ability to download this data to a form that you may need for a subsequent loan application. For example, if you are making an appointment for a car loan, the bank can partially fill the application based on what it already knows about you. It can then electronically submit this partially completed form to you so that you can check your records to verify it and make any changes to reflect your current financial condition. It might even refer you to a web site to help you understand the likely monthly payments, the current value of your existing car, and value-ratings of the vehicle that you intend to purchase.

When the customer engages the bank's personnel on a face-to-face basis, the nature of the transaction will be greatly influenced by the degrees of freedom the bank provides its service representative. Retail banks are like fast food franchisers in that the product being offered is highly standardized with little customization. When you move up the service matrix diagonal, the nature of the transaction changes in that the person facing the customer is empowered to customize the service. This makes economic sense when the customer has sufficient clout to warrant increased levels of personal service and product customization.

b

Dialogue Driver: Can you think of a service that does not fall along the diagonal shown the Exhibit 3?

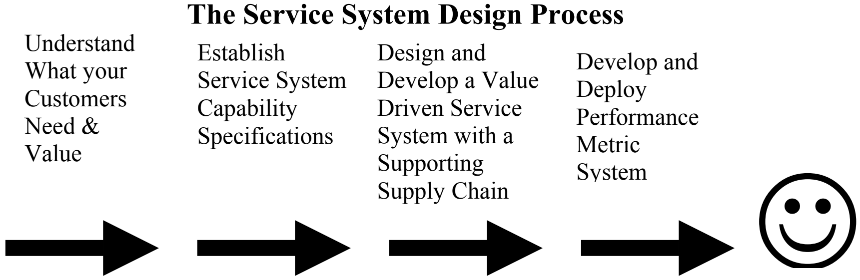
b

THE SERVICE SYSTEM DESIGN PROCESS

Earlier, we saw the system design process shown in Exhibit 4. This model is applicable to the service innovation process because it asks system designers to focus on those businesses processes needed to deliver the product that targeted customers demand of their service vendors.

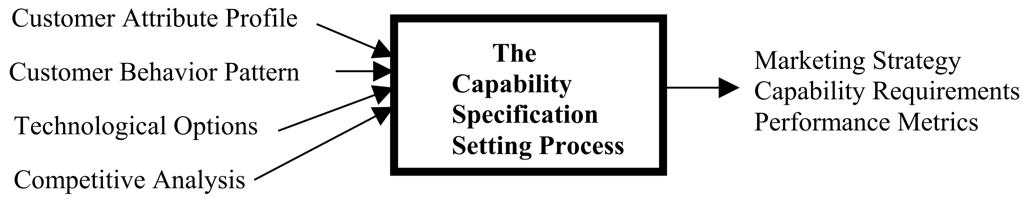
Exhibit 4

The Service System Design Process



When we have a thorough understanding of the targeted customers, the competition, and the technologies available, we can then develop capability specifications that define what the designed service system must do. Schematically, this process is shown in Exhibit 5.

Exhibit 5
Developing Capability Specifications



The inputs to this process help define the target customers and how the firm intends to bring them in as satisfied customers. The outputs of this process will enable:

- Marketing to develop a functional strategy that is internally consistent with the strategic plan.
- Operations Management and Marketing jointly define a set of capabilities that will be needed to accomplish the stated strategic goals.
- To establish performance metrics that will serve to orient the organization toward achieving the stated goals and to monitor performance to support the planning and control functions.

While we have said much about the customers' value setting process, we need now to explain further the three other inputs to the Capacity Specification Process.

Customer Behavior Patterns

In our earlier discussion of order winners, order qualifiers, and order losers, we applied these concepts to something that we just called a product. Life is not quite that simple because the customer may value each component of the product bundle differently, as we saw with the car-buying example. Since services often consist of a sequence of transactions, one must try to understand the customer's behavior at each stage.

One of the things we know about people is that complexity and uncertainty is the norm. We should not expect that target customers use the same value setting process either within the product bundle or throughout the sequence of service transactions. Thus the service system designer must understand how the target customer will "behave" throughout the total product experience. Three types of customer profiles are:

- Customers with like-but-not identical behavior patterns—these are sometimes called *customer families*. In marketing, these are often called market segments.
- Customers with less-than-consistent within-in total product experience behavior.
- Customers who aren't always consistent! In effect, we are asking the designers to build systems capable of hitting moving targets. While it would be foolhardy to provide you with a list of all of the things a systems designer needs to do to accomplish this quasi-impossible task, there are a number of behavioral patterns experienced service system operators have learned along the way.

When building a service delivery system, designers should be cautioned that:

- Customers often do not rate each segment of the sequence of service-delivery process as being of equal importance. Some segments of the service process are order winners and hence must be done extremely well. Others are just order qualifiers. These must be done well so as not to turn them into order losers. To rephrase George Orwell, "All segments are equal but some are more equal than others."
- A customer's impression of the total product experience often is most influenced by the first and last stage of the service. This is called the *Mount and Dismount Effect*. Lower than expected service in any one segment of the service process may negate acceptable performances elsewhere in the entire total product experience. In effect, we have floating order losers.

- The customer is not always consistent—but is always right. We should add three caveats:
  - *Not every customer should be your customer!* Customers with value setting processes significantly different than that which your organization is designed to deliver may be too costly to satisfy. Striving to satisfy these customers will cause your organization to divert itself away from its goals.
  - *Customers do not have the right to abuse humans within the organization*. World-class organizations defend their people. Not to do so may be illegal but it certainly is counterproductive since service organizations rely of their human resources to get the job done. To quote Intel's Andrew Grove, "World class companies should have world class customers."
  - *What the customers say they want and what they will actually purchase may be two different things*. In business, the saying, "Beware what you wish for, because you might get it," gets transformed into "Beware what they say that they want because you might end up with either the wrong capacity profile and/or unwanted inventory."

We don't have the answers for this thorny task. We just know that the more the designers understand about the idiosyncrasies of the targeted customers, the better the service and service delivery system is likely to be.

TECHNOLOGY IN THE SERVICES

In services, the number of technological options has never been greater. Advances in the information technology area permit system designers to introduce flexible automation to perform many of the repetitive and quasi-repetitive tasks that were previously done by humans. Robots are able to replace humans in tasks ranging from delivery mail within an office to being the eyes and hands of medical surgeons. Telecommunications technology advances has made communicating with the customer, between service providers, and within the supply chain easy. Customer credit checks can be done in an instant. Correcting incorrect information in your credit files still takes a tad longer. The age of miniaturization has impacted both information technology and entity transformation processes.

The challenge to designers of service systems is to be able to address the following issues:

- What new technology can assist us in performing a task that currently needs to be done?
- Which tasks might be performed for the customers?
- Which of the product enhancements or product augmentations will be of value to our customers or to those that we want as our customers? Specifically, we need to know:
  - Which of the elements of the value equation will it enhance?
  - Will the enhancement be valued by the target customer?
  - What might the unforeseen consequences be to each change?

The desire to achieve cost minimization increases the urge within firms to automate when engaged in the service system design process. But before a firm elects to go down the people-free route to service delivery, one should be sure that hidden customer relationships are not harmed.*

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* As powerful as computers have become thy often fail to see hidden connections that exist between customers. This point was best made by the Anne-Marie story Karl Albrecht, *The Only Thing That Matters*. A highly automated bank lost one of its major customers because its computerized system sent a five year old daughter a letter informing her that her personal saving account was being reduced by a $5 low activity charge. Shortly thereafter, her father moved a rather large account to a competitor's bank.

CLASSIC FORMS OF SERVICE-DELIVERY SYSTEMS

Service system designers can often simplify the work of process by duplicating or adapting types of systems that have succeeded in the past. In manufacturing, such familiar models result from the requirements of equipment layouts and work flowing between stations. Besides moving the capability specification process forward quickly, these models simplify communications; operations managers understand immediately that specifications for a paced assembly line will define a system that delivers components to workers in some regulated fashion, usually via a conveyor system of some kind.

The varied nature of service processes complicates the effort to identify such representative models of delivery systems. First, service systems often perform less visible work than manufacturing systems, and the tasks and their patterns may vary much more than in manufacturing systems. Service managers often resist having their systems described as being representative of a classic service system model by saying that their processes are different. Despite these difficulties, the typical persistence of operations managers has led to the development of some representative forms of service-delivery systems. These classic service forms are:

- *The Production Line Approach*: This seeks to develop efficiency by standardizing service procedures. The most commonly cited example of this has been McDonald's, which creates standardized products, cooked and served using standardized service delivery procedures.
- *The Customer Involvement Approach*: This approach involves customers in one or more significant stages of the service delivery process. It may be something as simple as using an open salad bar in which a customer makes his own servings. Or it may even involve the customer in the product design stage, as is currently being done by Dell Computer.
- The *Personal Attention Approach:* In this system, the customer receives copious quantities of service from competent, caring personnel. An example of this approach is Nordstroms. The key is to provide customized service so effectively that the customer truly feels pampered.

USING PERFORMANCE METRICS TO SUPPORT SERVICE SYSTEM DESIGN

In Exhibit 4, we defined a four-stage service system design process that asks the designer to:

1. Develop an understanding of what your customers need and value.
2. Establish service system capability specifications.
3. Design and develop a value driven supporting system within a supporting supply chain.
4. Develop and deploy a performance metrics system.

The work that needs to be done in Stage 4 will be relatively straight forward if the service system designers have done the job in the first two stages.

A key output of the first stage should be a clear statement of exactly what subset of the population the firm intends to declare as its target customer group. This should result in a set of assumed values. For example, if one were designing a new dry cleaning establishment to serve an upscale neighborhood, the stated customers profile might be: Professional workers who expect that their garments will be professionally cleaned and returned with a nearly new look. (Quality is the order winner). The capabilities specifications for a successful dry cleaning establishment serving these customers might include:

- The cost of garment cleaning should be no more that 10% higher than the competitions' prices.
- The time required to perform the service should be, flexible
- A wide range of special services offered should be high, e.g., minor tailoring, spot removal expertise, knowing how to handle lace and leather goods, etc.
- To treat regular customer in a friendly, Nordstroms-like manner.

Each of these is an order-qualifier that can be translated into an order-loser if done badly.

Since this firm's corporate strategy is to develop a chain of 200 dry cleaning outlets throughout Manhattan, it will need to develop a number of distinctly different capabilities. A partial list would include:

Exhibit 6
Linking Performance Metrics to Value and Capabilities

Value	Capability	Performance Metric
External Customer Needs		
Quality	Dry cleaning expertise	Customer complaints
	At cleaning center	Customer lawsuits
	At retail outlets	% of retail clerks trained
Competitive	High cleaning center utilization	% plant utilization
Price		Average cost/garment
Delivery Speed	Quick response for rush jobs	% rush jobs done on time
Delivery Reliably	Flexible plant capacity	On time % for 3-day jobs
Internal Customer Needs		
First class sites	Site location decision making	Sales per retail outlet
		# stores closed/year
First class retail clerks	Employee selection and training	Customer complaints
		Employee turnover
Effective pickup	Effective entry job paper work	# of lost/missing items
		# of mis-processed job

Even for a 200-outlet chain, this process can get fairly complicated. But good things just don't happen. Systems need to be well planned, well executed, and then monitored to assure that all is going as planned.

Best Practices

When designing or redesigning a service system, there is no need to reinvent the wheel. Thus before we proceed, it is useful to cite some of the best practices that world-class services use. These include:

- Having strategic initiatives that clearly define the type of customer the firm is going after and a good understanding of what these customers' value. While saying this may seem to be repetitious, *it is fundamental*. If you don't know who you are trying to please and what it takes to please them, then you are striving for success in the dark. You may win customers, but only because you are lucky.
- Having good, well-understood performance metrics to assess how well the existing system is doing in meeting the core needs of customers. Since the way your existing customers value your product is dynamic and subject to influence by your competitors' actions, a firm can never assume that it has a lock on its existing customers. World-class service providers continually seek out their customers to assess how they are currently doing and to help anticipate what additional features they will want in the future.
- Obtaining good, timely external feedback of evolving market condition. This involves knowing which consumer need is not being adequately met. To grow, a firm must do at least one of three things:
  - Increase sales from existing customers by selling them more products.
  - Win existing product sales from your competitors.
  - Seek out customers who are not currently participating in the market. Retailers have discovered a "new" market—the inner cities. Home improvement and supermarket chains are discovering that rising income levels and population density make older urban markets attractive.
- A fervent desire to eliminate waste, both from the customers' and service-provider's perspective. As a consumer, you no doubt can cite many instances of waste. Some call this poor service. But in a value-driven system, it is viewed as waste because it lowers the value the consumer assigns to the total product experience. Instances of customer-side waste are:
  - long queues of customers waiting to be serviced,
  - unnecessary delays while the server looks for your file, and
  - being asked to enter information that you have previously provided the service firm.

Waste on the service firm side includes practices that are unseen by the customer but degrade one or more of the elements of value offered to the customer.

- A superior understanding of the costs associated with delivering world class service. Good activity based cost systems allow the firm to evaluate the profitability or the costs associated with each type of service transactions. Knowing the profitability of customers provides the service system designer with the option of providing different levels of service to the different groups of customers.
- A fundamental understanding of emerging telecommunications and information technologies. World-class service providers make sure that any investment in new technology is done to enhance customer value—not strictly the service provider's costs. Here the product innovation process must make use of the tools of market research to understand what feature additions and deletions the customer will value.

SERVICE SYSTEM PROCESS DESIGN TOOLS

In Shell 5, we introduced tools for documenting, analyzing, and understanding existing business processes. These tools can be applied to the service system design process. Some common tools are:

***Competitive Analysis*:** This is input to the capability specification process. It seeks to avoid reinventing the wheel by learning from what other successful firms have done. But as we learned in our discussion of benchmarking, merely looking at other systems is not enough. It must be done in a systematic, purposeful way. The watchwords are: "Think process and stay focused."

Process mapping can be used to help document the service attributes that your design team thinks are important for your system design problem. Often, one starts off with a survey of existing service firms. Exhibit 7 illustrates the use of this tool for fast food operations. In this case, we compare the service attributes of McDonald's, Burger King, vending machines, and an upscale restaurant, Reynaldo's. We selected ten attributes, some rely on subjective inputs, while others attempt to capture numerical data.

Exhibit 7
Attribute Map for Food Service Systems

Nature of Interaction
Personal ... Impersonal
R ... B M ... V

Labor Intensity
High ... Low
R ... B M ... V

Customization
Customized Service ... Standardized Service
R ... B ... M ... V

Method of Payment
Credit Only ... Cash Only
R ... B M ... V

Simultaneity of Consumption
Immediate ... Mostly Immediate ... Much Later
R ... B M V

Number of Customers
Few ... Many
R ... B ... M ... V

Number of Service Dispenser Locations
Few ... Many
R ... V ... B ... M

Number of Transactions/Location
Few ... Many
R ... V ... B ... M

Comments: The ambiance matters at Reynaldo's. Reynaldo's customers savor their food; others just eat.
V = Vending machine; M = McDonald's; B = Burger King; R = Reynaldo.

Attribute maps can be used either to assist the designers of new service systems or to evaluate the performance of an existing system. Their use in the new service system design process provides a systematic way. It starts with a statement of a number of key service attributes. Then perceived or measured performance of comparable businesses within the target markets is recorded. Knowledgeable persons are used to score each firm being studied. Each firm is assigned a symbol.

Attribute mapping can also be used to highlight how a service has changed over time. This system redesign procedure starts by asking, "What was the service system profile at the time it either was built or when the last major system design change was made?" It then asks, "What is the service system profile now?" Any significant deviations should evoke a third question, namely "Do these changes indicate a need or an opportunity to change the system to serve our customers better?"

Before we apply attribute mapping to compare the performance and structure of existing business, we should remind the reader that in our discussion of benchmarking, we cautioned that one must take care not to define the process too narrowly. If we are considering going into the home pizza delivery business, we should define the task broadly, i.e., the task of delivering a perishable consumer item to residential locations. This allows us to study existing services that provide home delivery of pizza also. Limiting a search to operating pizza delivery services assumes that the Pizza Huts of the world have captured all the worthwhile product delivery ideas.

For example, White Castle, a Mid-western hamburger chain, will deliver its popular "sliders" anywhere via Federal Express. While this solution may seem a bit extreme, it brings forth one new fact: that most product delivery services were created prior to the advent of fast, relatively low-cost services such as FedEx. Service system designers may find valuable solutions two or three standard deviations away from the norm. [2]

***The Service Guarantee*:** The service guarantee is a customer-oriented statement that clearly defines what an organization will do for the customer if it fails to deliver one or more of the things it has promised the customer. Some common examples are:

- Domino's Pizza offers its product free if not delivered within 30 minutes.
- Caterpillar offers tractor replacement parts free if not delivered within two business days.
- Federal Express, defined itself with its "Positively, absolutely, overnight" advertisements.

While service guarantees are primarily marketing tools, the implications on the service system designer are obvious in that they serve as publicly stated performance metrics.

The structure of a guarantee must be written in the language of the customer—not the language of lawyers. It has been argued that an effective unconditional service guarantee should include: [3]

1. Customers should be able to know precisely what the guarantee promises in measurable terms.
2. The company response should be meaningful to the customer both in financial and service terms.
3. The company should be capable of "paying off" quickly and in a manner that stresses sincere regret.
4. From the customer's perspective, the payoff should be easy to collect.
5. It should be unconditional. Issues in dispute should be decided in favor of the customer.

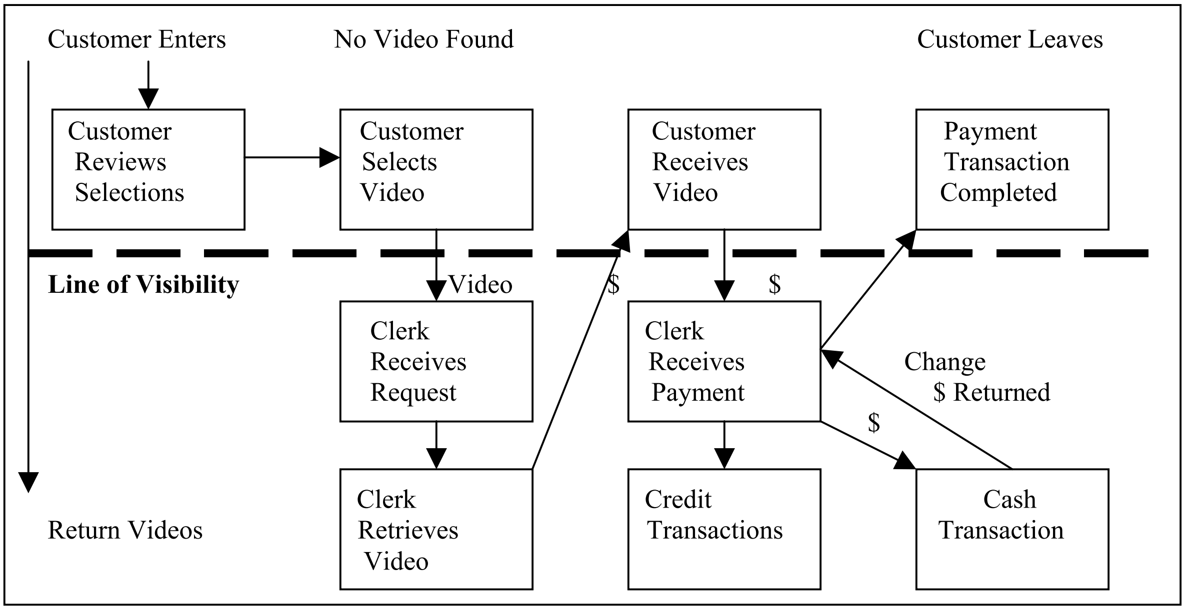
Service guarantees support effective service system design by forcing them to focus on meeting the needs of the customer. They also force the designers to define key performance metrics in a customer-oriented fashion. When the late Michael Walsh took over as the CEO of Union Pacific, he found that the railroad defined on time delivery in terms of point-to-point elapsed time within its network. He changed these to reflect how long it took to reach the customer. Service guarantees promote effective feedback within the system. While it may save the company some money, it does more harm if a dissatisfied customer quietly leaves your customer base. Remember, dissatisfied customers talk.

Dialogue Driver: What service guarantees have you encountered. How have they influenced how you value the product?

Service Blueprinting: Service blueprinting is a process-flow-like tool that is used both to design service systems and to better understand the operations of a service delivery systems.[4] A major contribution of service blueprinting is that it allows the system analyst to distinguish between those parts of the service system that are clearly visible to the customer and those that are beyond the sight of the typical customer. Within service blueprinting this line of visual demarcation is called *the line of visibility*. We know these in the real world as "Employees Only" signs.

Exhibit 8 presents a sketch of the customer's interactions with the process activities of the store. The solid lines represent physical movements, and the dotted lines indicate communication flows.

Exhibit 8
Service Blueprinting of a Video Rental Business



This procedure involves four steps:

- *Identify processes*. Map all business processes that perform essential roles in delivering the service.
- *Isolated potential or known fail points*. Scrutinize the process flow diagrams and identify points at which the system can fail to meet or exceed the expectations of customers, then design fail-safe procedures to eliminate these potential defects. Since service quality often depends on employees, training may be more important than designing Poka-Yoke mechanisms like those in manufacturing systems.
- *Establish a time frame*. Since time is an essential part of a service's value package, the system designer should establish standard execution times. This also helps to control costs since the labor component of the total execution time determines much about the cost equation.
- *Analyze profitability*. Compute a pro forma income statement early in the system design phase to serve as a reality check throughout the system design process. This step requires realistic estimates of what customers will pay for the planned service, how many customers will it serve, and what patterns of arrival are expected.

The *line of visibility* also allows a second interpretation of the service-delivery process by focusing attention on customer interactions with employees. This line could mark a point of physical separation in the system; perhaps a new system could save customers the trouble of completing the activities above the line, primarily selecting videos and paying the rental fees. Clearly, a new system could not complete these activities in a less costly way by assigning store personnel to verbally describe available titles over a telephone. However, a printed catalog could provide this information, but many customers want the most recent releases. Emerging telecommunications technologies can enable, the store to offer a current video catalog on line. Customers could dial up on their home computers to survey the available offerings and then make selections; store workers would then charge the rental fees to customer' accounts and hold the videos for pickup, or perhaps deliver them at an additional cost.

This example illustrates an important advantage of service blueprinting. It forces service system designers to describe an existing or proposed system and then encourages them to rethink activities to discover potential improvements. For each envisioned system, it also presents a framework for estimating both the cost to the organization and the value received by customers.

FUTURE CHALLEGES FOR SERVICE SYSTEM DESIGNERS

The future portends great challenges to service oriented companies. It will be an era of paradoxes. In many instances size will matter, i.e., the fruits of product innovation will go to those that establish major beachheads in new service areas. We need only cite Amazon.com to illustrate that today's giant was yesterday's concept. But while size matters, future customers often will not tolerate standardized, impersonal transactions unless they want them that way. They expect the vendor to know who they are, what their tastes are, and to stop asking them to answer the same damn questions over and over. In the following section, we discuss some of the challenges we think future service system designers must meet:

- The Challenge of Market Segmentation: Ease of market entry means that customers are going to have many more choices. Brand loyalty may remain strong, but technology will make it easy for a customer to consider what your competitors offer. The implication is that firms are going to have to work hard to reinforce their ties with their customers and that they must be prepared to modify their product bundle to cater to their unmet needs. This will lead to dramatic changes in the service delivery system—the most important is being able to get close to the customer. Fewer standard service products will work.
- The Challenge of Speed: Service providers will be expected to enhance their capabilities as they relate to the second element in the value equation, speed. Customer impatience has become common, and if your firm doesn't rise to this challenge, some other firm will. Delivery speed often will be accomplished in new ways. This Christmas, millions of e-commerce customers will be placing their orders online and sending their gifts by FedEx. If only we could automate Boxing Day. We did—its called eBay.
- The Challenge of Service Quality: Customers expect increased service quality. It is downright contagious. If we can get world-class quality in the goods we buy, why should we settle for any less from service component of the product bundle?
- The Challenge to Create Customer-Oriented Employees: Even with the emerging service-system support technologies, people will remain a key element in service systems. The human resource management task is compounded by the fact that many service businesses have low entry-level pay scales for jobs that involve high degrees of customer contact. These people who fill these jobs, e.g., hotel desk clerks, retail sales person, your office's receptionist, often will need considerable training to elevate their people-pleasing skills. Retraining of even your skilled work force will be an ongoing endeavor. The fact that industry recognizes this is evidence by the fact that 70% of all training occurs outside of academia.

  Lastly, the behavior of large companies and the job-hopping patterns of young skilled employees do not mitigate for a large gold watch market. Few of you will work for one company throughout your career and if you do it most likely will be in two or more functional areas. This may be good.

Unfortunately, many think that most of these problems will be solved through the extensive application of information technology. While many routine tasks can be automated, consumers increasingly are raising the bar by making increasingly heterogeneous demands on the system. People still count and will continue to do so throughout the twenty-first century.

WORLD-CLASS SERVICE ENABLERS

These challenges are being overcome through the use of good management practices and the judicious uses of technology. The key to success is to understand who your customers are, what they value, and thjen to build a service delivery system capabilities needed to satisfy their needs. Some means to this end are:.

Capability-Focused Human Resource Management. One often sees signs in the window of retailers saying, "Friendly Sales Persons Wanted." While this creates a favorable first impression, *smiles, by themselves, are not enough*. The task confronting the human resource function will be a function of:

- The degree of heterogeneity within the business processes. The more that the service demands are alike, the greater the opportunity to have people to deliver standardized services. Business processes that have higher degrees of uncertainty will require the use of personnel who can adapt to changing requirements.

- The amount of human skill upgrading it must provide its human applicants. If the humans being hired come from different cultures, then both training and low level supervision must use communication means that reach the target audience.
- The organization design must be able to motivate and reward employees performing at or above the desired levels sufficiently well to keep them as your key resource. High employee turnover normally is a sign of waste—but not always.
- If your organization envisions increased reliance on certain technologies, it must either hire or train existing employees to rise to this challenge. An educated work force will adapt to technological change better, especially if they are involved in new system designs and implementations.

  Implicit in many of these points is the judicious use of empowerment. Organization designers must understand where "creativity" works and where it may work against the firm's business strategy. When you stop at the "Golden Arches," few customers do so in search of a surprise, such as a Big Mac taco.

Effective Customer Service: The primary purpose of customer service is to provide customers with post-sale support and/or to resolve complaints a customer might have as a result of the total customer experience. Secondary purposes include: listening to and observing the consumer in pursuit of potential enhancements to the product and/or product delivery experience, indirectly monitoring competitor actions, and observing your organization through perspective of the customer.

Effective Within-Firm Communications: A judicious use of beepers, cellular telephone, and radio technologies allows firms to achieve effective communication within the organization and with its customers. Many stores equip their staff with portable devices for within-store two-way communications. Some allow remote access to computer databases. Sears uses 1-800 numbers to provide product information that a customer requests, such as: "Is this paint thinner safe for use in our son's nursery?"

The use of emerging technologies often violates traditional management practices, such as chain of command. But the need to provide timely customer service should transcend management dogma. If managers are uncomfortable with being bypassed, that's another job for human resource management.

Effective Use of Bar Coding to Support the Transaction: We all are familiar with of bar coding within grocery stores. Advances in bar coding and other information technologies can enable service systems to:

- Bring more information to and from service transactions: Three ways to do this are by using:
  - Two dimensional bar coding (they no longer are bars) to include much more information about either the product or the customer.
  - WORM (Write Once Read Many) cards that contain up-date information.
  - Access to Internet or Intranet files that relate to either the product or the person.

The bearers of this information can be the customer, the service organization, or both.

The value of information increases when we are able to link information from different files. Today, many systems use the data only to facilitate a service transaction, i.e., by quickly entering price information to a cash register or to quickly process a check or credit card. But when the information from this transaction can be placed in the context of overall buyer behavior or your own personal behavior, then we start to get more meaningful inputs to the process of learning what is working and not working at the sales level.

To either de-skill jobs or instill better customer satisfaction. Suppose a person walks into an auto parts store with a fuzzy need, e.g., need a spark plug for my car. The store person might ask, "What kind of car is it for?" The response, "It's a 1985 Ford Taurus. "What size engine does it have?" The customer responds, "I don't know-but it is the front."

- Consider a different scenario. That same customer enters the store bearing a card that Ford placed in the glove compartment of each new car. This card is an advance bar coded card that describes engine size and all of the options the car had as it came off the assembly line. The customer then hands this card to the auto parts store clerk and says, "I need spark plugs for this car." The clerk enters the card into a device to read the part needed, whether or not the store has that part in stock, and where it is located within the store. He responds, "You need six A4556 spark plugs and they can be found on aisle 8. Just look for the blinking light." You might ask, "What blinking light?" Well, the same system that provided that information can activate a light just above the A4556 spark plugs and leave it on for five minutes. Of course, once the sale has been made, the same in-store computer adjusts inventory, quite possibly reorders more spark plugs and provides information to the store's demand forecasting system. If the sales transaction had captured the person's name and address or even just the owner's zip code, this information could also be placed into the store's demand forecasting database.

Let's review what happened here. This system relieved the firm of having to train an individual with product knowledge and the schematic of where items can be found within the store. It quickly told the customer that she needed six spark plugs, the store had them in stock, and it directed her to aisle 8. Finally, the checkout process automatically updated the store's information base.

- It facilitates customer-involvement in the service delivery process. Suppose in the auto parts store example, it had a customer service kiosk near its entryway. The customer places the car card into a slot and indicates the type of part needed, which in this case is a spark plug. After clicking on "spark plug" the kiosk display indicates that you need six A4556 spark plugs, they are in stock, and can be found on aisle 8. It asks, "Do you want them?" If you answer yes, it says "Is there anything else that you need today?" After fulfilling your part needs, it turns on the lights above the appropriate aisle stocking points.

Not all customers will want this type of service, but if you think about it for a moment, service system designers have already done this to/for you in many instances. Your ATM machine has you doing the work that was previous done by a bank clerk. But before investing in humanoid-free systems, two basic question need to be asked: "Does your target customer want it?", and " Is it in your firm's best interest to lose direct/intimate contact with your customers?" Many a sales person would argue that their role in the customer service transaction involves more than handling routine, repetitive requests for information. After all, they are called *sales* persons. What can be done is not always what should be done

Extensive use of Internet and Intranets: The evolution of customer-vendor interactions that started with bar coding has advanced far beyond with the advent of e-commerce. Amazon.com is a perfect example of customer involvement on the Internet. But the impact of evolving network technologies extends far beyond e-commerce. The areas impacted include:

- Residential and business telecommunications networks increasingly are switching from line-to-line connections to the information packet transmission systems of the networks. Broader bandwidth capacity will enable the transmission of voice, data, and video through these systems.
- New technologies will make less expensive to extend communications throughout the world.
- The combined effect of deregulation of businesses, such as cable companies, and the merging of voice, video, and data transmission technologies will give customers a wider range of choices.
- Customers will have access to greater amounts of product information in a timely manner. As more companies sell the same products on the net, it becomes easy to compare the prices of like goods. Indeed, software exists to search the net for the best prices. Today, our focus is on price, but the information base can quickly be extended to the other elements of the value equation. Wouldn't you want the ability to report the poor customer service that you experienced?

These are but a few of the changes the Internet will bring to service systems.

Extensive use of premium delivery services to support fast to market to product services: The advent of FedEx makes it almost routine to get high valued goods quickly to the customer. Not only are customers receiving goods faster, but the entire nature of the supply chain has been changed. Industrial firms, such as National Semiconductor, ship all of their products directly from one warehouse via FedEx to their customers.

Extensive use of distributors to provide wider product variety: Many of the features being demanded by customers can be done at facilities closer to the customer. Distributors and certain retailers have assumed certain tasks previously done upstream within the supply chain.

Creative use of information technology to support customer-friendly system: The challenge of IT is to create systems that blend what needs to be done in a manner that mutually serves the service provider and the service recipient

Each provides designers with options heretofore considered unrealistic or unnecessary. But has what is possible and what is desired changed? The challenge to the service system designer is to figure out what is wanted by the target customer today—and what they will likely demand in the future. This is not an easy task but normally it does not always have to be done at one time. Experimentation and prototyping still provide designers a way to explore what works and what it wanted.

SUMMARY

In this shell, we provided a framework for thinking about and classifying services and their service delivery system. No two services are exactly alike, but understanding the similarity among service systems enables service system designers to avoid reinventing all of the wheels it will need in a new service delivery system. Once again, thinking about the firm as being comprised of a set of business processes facilitates an ability to analyze the role and performance of the parts that contribute to the makeup of the whole. We then introduced a framework for describing the service system design process and some of the tools commonly used in this endeavor. While much of what we discuss is focused on the design and development of new service systems, they are, in most cases, applicable when studying how to enhance the performance of an existing system. Finally, we focused on the evolving challenges future service system designers will face. We then described some of the means system designers should consider using when developing systems capable of responding to new product challenges.

End Notes

1. Barbara Gutek, *The Dynamics of Service: Reflections on the Changing Nature of Customer/Provider Interactions*. Jossey-Bass, San Francisco, 1996, p. 7.
2. C. W. L. Hart, "The Power of Unconditional Service Guarantees," *HBR*, July-August, 1988.
3. G. Lynn Shostack, "Designing Services that Deliver," *HBR*, January-February 1984.

References

1. Bethune, G. (with Scott Huler, *From Worst to First*, J. Wiley, N.Y., 1998.
2. Connellan, T.K. and R. Zemke, *Sustaining Knock Your Socks Off Service*, amacom, N.Y., 1993.
3. Fitzsimmons, J.A. and M.J.Fitzsimmons, *Service Management: Operations, Strategy, and Information Technology*, McGraw-Hill, N.Y. 1997.

Expected Learning Competencies

Before putting Shell Eight down, you should ask yourself the following questions. Am I able to explain:

1. What a service is and how service relates to the product bundle.
2. Some of the ways service systems are categorized and why doing this might be useful to both the OM manager and service system designers.
3. How information technologies have changed the services are delivered today and how these developments have changed the value equation.
4. What some of the future impacts emerging technologies might have on service systems.
5. The roles of performance metrics play both in service system management and service system design. How do these tie in with the value equation?
6. How each of the process improvement tools introduced works and be prepared to give an illustration of each being used.
7. What your instructor added to this shell and why he or she thought that it was important enough to warrant its inclusion.

Frequently Asked Questions

Instructors have been known to ask questions similar to the following:

1. What are some of the things that distinguish a product that is mostly a service from a product that is mostly a good? What might their similarities be?
2. Prepare a list of five services that you buy and then classify them using the categorization presented in the text.
3. Identify ten technologies that you experience in the services that you buy.
4. Service blueprinting is most similar to:
    a. Process flow analysis
    b. Check sheets
    c. Time and motion study
    d. Histograms
5. Which of the following is not usually an attribute of a service?
    a. Tangible
    b. Heterogeneous
    c. Random or uneven arrival rates
    d. Extensive customer contact
6. Which of the following businesses has a line of visibility closest to the customer?
    a. In and Out Burger
    b. McDonald's
    c. Fry's
    d. An ATM window at your local bank
7. When McDonald's says that it is trying to introduce a credit sales process in which the transaction takes no more than five seconds, this would be an example of a firm trying to compete with a better:
    a. Product capability
    b. Process capability
    c. Knowledge capability
    d. It is both a and b

SHELL NINE

DESIGNING PRODUCTS & PRODUCT DELIVERY SYSTEMS—GOODS

Fast to Copy Winner

When it comes to athletic shoes, no firm makes and markets product better than Nike. Its core competencies lie in product design, celebrity-based marketing, and an ability to have product well made in low cost factories throughout the Far East. Many consumers willingly pay $100 for a pair of Air Jordans to get performance in an athletic shoe. Other customers want "to be like Mike." It is important to be seen wearing cool gear even if you don't do much more than hang around. If you have the cash, Air Jordans will fill this need. But some consumers are unwilling or unable the price and are moving to Skechers—an upstart that expects to earn $70 million on sales of $960 million in 2001.

Forbes recently noted that Skechers "invents nothing, but makes a lot of money on other people's ideas." Their forte is that they closely study the shoe market hoping to spot the latest fashion trend so that they can pounce on it quickly and then out just as quickly as the fad tires. Their shoes must "spark me-too purchases but not be so ubiquitous that fickle kids reject the brand as "over." It is insightful to note that the company's name came from a street slang term for "a person who can't sit still."

Serving this market presents a major challenge. Skechers tracks the hundreds of new product offering of sneakers, sandals, and loafers as they appear in the world's fashion centers. Their challenge is to spot the winners and then quickly have its product designers "approximate" these styles with shoes that can be made at a lower cost. It then relies on its supply chain, all of which are offshore suppliers, to make and distribute new products to the market one month faster than the major companies can.

One recent shoe illustrates their capabilities. In 1999, they saw a bowling style shoe made by a small Spanish company called Camper. Thinking that it was a winner, it had its designers come up with a $55 version which was on the market before upscale companies had their versions selling for $100.

Skechers' products can be made for less because their designers understand the target market segment and manufacturing economies of scale. Recognizing that its customers value fashion most, its shoes aren't designed for performance. Its ad program feature "young, cute people sitting around. No one jogs or skateboards. No one even breaks a sweat. Even the $55 Energy 'jogger' is pretty much just for hanging out and looking hip." This permits its designers to use a common sole in its Energy sneaker line that has 100 different uppers and colors. Hanging around shoes can use lower cost raw material costs such as less expensive leather. This product architecture permits Skechers' supply chain to achieve economies of scale at its low cost offshore plants.

The trick in fast to copy businesses is to be right, quick, and a tad lucky. So far, Skechers has been.

Source: Melanie Wells, "Sole Survivors," *Forbes,* August 6, 2001

Shell Nine
Product Design and Process Selection--Goods

Table of Contents

Learning Objectives for Shell Nine

After reading this shell and thinking about its content, you should be able to:

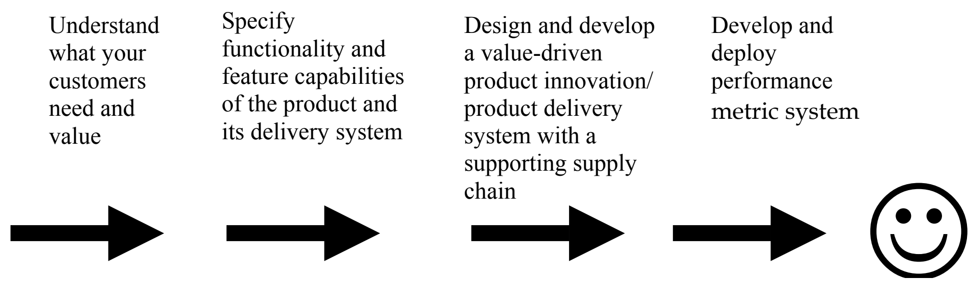
1. Understand the role product innovation can play in helping a manufacturer of goods gain a competitive advantage
2. Explain what is meant by product architecture. Then be able to explain how it can enhance elements of the value equation.
3. Understand the issues that relate to a decision to standardize products and/or the parts that go into making it.
4. Understand the pros and cons associated with the decision to modify the organization structure to permit concurrent engineering.
5. Able to explain and give examples of each of the tools discussed in this shell.
6. Discuss how a learning organization supports the product innovation process.

INTRODUCTION

Never before has the need been greater for a firm to produce products that offer compelling value for its customers. Most observers agree that a major reason for the 2001 slowdown is that American industries' product offerings offer no compelling reason to buy cars, personal computers, and other big-ticket items. In this shell, we study the product innovation process for manufactured goods. History shows us that some companies clearly are consistently better at it than others, while some occasionally get lucky. Some never even seem to understand what it takes to create customer-pleasing products.

The logic used to design manufactured goods is the same as was presented in the previous shell.

Exhibit 1
The Manufactured Goods Design Process



Designing this customer-fulfillment process normally includes personnel from marketing, design engineering, and operations management. Individuals participating in this process may pursue conflicting goals. Engineers often seem more determined to express their creative urges and solve intricate problems than to address customers' needs. Both engineers and operations management personnel often resent the perceived willingness of marketing to respond to every real and imagined whim of any customer, regardless of the demands of the resulting product variety. Operations management personnel often seem overly devoted to building a stable, well-organized environment in their pursuit of higher efficiency. *Well-managed product innovation processes effectively deal with conflict by issuing guidelines for resolving disputes*. Those that don't often create products that are "off-the-mark" and organizations that are frustrated. Good products just don't happen—they are the result of effective product innovation processes.

Manufactured goods differ from services in three ways. The first is that a good can be inventoried, thereby giving system designers additional degrees of freedom. The second difference relates to risk. More so than for services, the design of manufactured products and their supporting delivery systems requires substantial up-front financial commitments. The product innovation process for manufactured goods must be market-driven and supported by realistic estimates of the size of the likely market. Simply believing that "the market will come" is risky business. Business history is littered with projects that failed because firms did not fully understand the needs and foibles of customers.

The third difference is that the product innovation process for goods are often supply chain-wide endeavors where the players often come from outside your firm. Developing next-generation micro-processor chips requires Intel to coordinate its efforts with Microsoft, other software players, and the makers of chip manufacturing equipment. Those firms that try to go it alone often experience dire consequences. As Tom Friedman said: "In the Lexus lane, it often is more important whom you know than what you know." [1]

PRODUCT ARCHITECTURE

The first step in any product innovation process is to fully understand who the target customers are, what they value, and the likely size of the market. As we saw with Skechers, product designers use these key inputs to make product architecture decisions. *Product architecture* establishes three things:

- o It specifies the functional capabilities of the product, its features, and post-sale servicing needs.
- o It specifies the capabilities of the product delivery system and post-sale support that the customer expects.
- o It specifies the roles and risks each player within the supply chain will assume.

The business process that develops a product's architecture is driven by the firm's corporate strategy. It must deal with a number of design issues, such as:

- o How well can a standard product meet the core needs of target customers?
- o How well can a standard product with a flexible set of optional functional modules satisfy the product mix variety demanded by buyers who want customized products?
- o How effectively can product designers divide the functions of the product among separate modules?
- o How should these modules interface with each other?
- o How much *technical risk* should the design of each module take?
- o How much *reserve capacity* should the designs of the overall product and each module include?
- o Which of these modules should designers develop in-house and which should they contract out?

Most of these decisions are not evident to the product's customer. In a sense, these are product design decisions that fall beyond what was called a *line of visibility* in the service area. But within the firm, they have important effects, not only on product quality, but also on the resources needed to effectively perform the product-innovation process. *Good product architecture can help designers to develop products capable of providing the firm with a competitive advantage. If being fast to market or fast to product is a strategic goal, then the ability to achieve these ends starts with good product architecture.*

End Product and Parts Standardization

The desire to make and use standardized parts has its roots in the American industrial revolution. It was Eli Whitney's use of standard parts that enabled his firm to gain a competitive advantage in its bid for an army rifle contract. Henry Ford's assembly lines were made possible by improved manufacturing processes that allowed unskilled workers to quickly affix standard parts to standard cars. Standard end products enable manufacturers to use make-to-stock market orientations, thereby decoupling manufacturing decisions from market transactions. So it is quite understandable that many operations managers prefer to make standard products using standard parts. However, the decision to produce standard goods and/or to use standard parts is a strategic issue.

This may sound like a bunch of olive tree lovers trying to justify resistance to change. None-the-less, before we dismiss product/part standardization as "old fashioned," let's review some of the arguments for making or using them. Standardization of products and manufacturing inputs can help a firm achieve:

- o <u>Lower Product-Design Costs</u>: Economies of scale that occur when product design costs are spread over a large number of copies of the same product. This is possible only if the standard product can satisfy a significant number of customers with its common design.

- Lower Component-Design Costs: Using standardized components in a product allow the firm to provide product features without paying for new engineering work. Apple Computer lowered the costs of its product by using components parts that were designed for Wintel machines.

  The disadvantage may be a less distinctive end product. The key question is: Do the customers care?
- Lower Production Costs: Standardized products can be made using less costly manufacturing processes. Large runs spread setup costs over more units. In addition, batches of standardized products often justify investments in more efficient production processes. Higher volume production systems often allow the process to use less skilled employees.

  A disadvantage is that product and manufacturing flexibility often is lost when high-volume processes, such as an assembly line, are used. When Lee Iacocca wanted Chrysler to reintroduce convertibles, its assembly lines were too inflexible so cars with roofs were made and then cut off later.
- Quicker Product Design through Standardized Product Interfaces: A product interface is the place where functional capabilities of the components meet. Personal computer design has benefited by industry standards that define the protocol that must exist between each module.

  The downside may be a loss of design creativity. Why must each kitchen appliance use 110 volts?
- Enhanced Product Flexibility Capabilities: Standardized features that use standard interfaces permit a firm to engage in assemble-to-order manufacturing, which permits its designers to enhance its offerings without risking incompatibility as long as they stay within the parameters specified by the standards. \
- Lower Delivery Costs: Being able to inventory standard products may create economies of scale in transportation. Shipments of goods from the factory to warehouses or retail outlets can take advantage of economies of scale in transportation. This creates an incentive to sell the goods you have on hand.
- Faster Product Deliveries: A firm can also move its inventories of standard products to sites near customers. This facilitates a rapid response to any order, helping to delight a time-conscious customer. This decision must balance the higher cost of deploying stocks across larger distances due to requirements for physical storage facilities and human resources to staff themEnhanced Product Recognition: Known products assure consumers that their purchases will meet their expectations. "Intel Inside" stickers reassure customer considering a PC with little brand recognition.
- Simplified Value Comparisons: Standardized goods help consumers to shop for the best price or product performance. People can easily compare Wal-Mart's price for a certain grade of Quaker State motor oil with the price of the same product at Kmart.
- Consumer Protection: Regulations assure McDonalds' customers that its Quarter-Pounder will contain ¼ pounds of approved meat. Unfortunately, in a litigious society, a standard offers a well-defined target for bottom-fishing lawyers and consumer protection agencies.
- Enhanced Communication Capabilities: At a coffee shop, you might make a request like, "I'll have a large cup of fresh-brewed, French roast coffee, please." You have just defined the product you want using three well-understood terms. Each term reduces the communication effort.

The key to successful product innovation is to know what features or parts of the end product need to be customized to meet the expectations of the target customers. A customized Steinway piano probably is driven by aesthetics, such as the finish of the piano, but the functional part of the product can be standardized. But that too might be changing. Recently, a pianist with small hands demanded a keyboard with narrower keys so that she could perform some of the more challenging pieces. When will it end? Never!

Dialogue Driver:

Environmentalists often are concerned with how a product will be disposed of once its useful life is over. To what extent does the use of standard parts contribute to their goals? How might the use of standard parts hurt the environmental movement?

Product Flexibility Via Standardization

The following are some of the approaches that have used to design customer-pleasing products:

Mass Customization: This is a product-development strategy that seeks to satisfy a market's desire for a customized product while retaining the economies of scale of mass production. Mass customization enables a firm to achieve this goal by several fundamental methods or combinations of them: [2]

- Customize services offered with standard basic packages of goods and services.
- Create customized goods and services.
- Customize standard goods and services at the point of delivery.
- Organize the customer-fulfillment process to provide quick responses.
- Assemble standard, modular components to customize final goods and services.

Each of these techniques work to achieve low-cost, individualized products.

Modular Product Design: Modular design can be used either in a make-to-stock or one of the variations of make-to-order market orientations. It enables product designers to refine products rather than reinventing them to meet evolving market opportunities. The modular approach to should be considered when:

- The technologies of the different modules are changing at uneven rates.
- The product-functionality needs of target customers vary too much for a one-size-fits-all approach.

The microcomputer market is a good example of this. Within a microcomputer, the central processing unit and the hard drive modules become obsolete rapidly. A well-designed product allows PC makers (or PC owners) to upgrade one or both of these modules to gain a state-of-the-art machine relatively cheaply.

Modular architecture also offers valuable benefits if the demands on one function cause its components to wear out faster than the other components. How many times have you thrown out a product that is perfectly good except for one part. As environmental consciousness increases, this will be considered wasteful. Batteries provide a good example of this. Flashlights with replaceable batteries allow users to keep part of their equipment while replacing only the worn out components. In other situations, designing replaceable parts into a product can provide it with enhanced market features, such as lower initial cost, lighter weight, or varying functionality. It can also provide the designing firm with great post-sale marketing opportunities.

The product architect must fully understand the tradeoffs associated with each of these issues and then try to find the best set of compromises between their demands. This decision must allow for the possibility that the set of compromises will turn out to be a null set, that is, the situation may dictate that the compromises aren't acceptable to the targeted market. Effective product innovation requires designers to take as much time and make the necessary effort to build a product in the right way for a particular situation.

Within a modular product, designers must weigh the benefits of an open architecture. Along with the other benefits of standard interfaces, they open the opportunity to supply components that perform the stated missions of the modules to many vendors. In its mainframe hey day, IBM periodically changed the interfaces between functional modules of its mainframe systems to foil competitors. When Memorex started to make substantial inroads into its disk-drive business, IBM changed the interface on its next model to render its competitor's products unusable. While this tactic may secure customers' expenditures, those people may resent paying more for products as a result. A similar battle is now raging between HP and the small independent firms that refill printer cartridges.

Technical Risk in Product Architecture

Deciding how much risk a firm should assume within its product innovation process can spark controversy in high-technology firms. Designers often express frustration over the unwillingness by some to limit technological innovation. If customers do not want or need these innovations, they may have a valid argument to justify their go-slow strategy. But as Deming noted, "No customer ever asked for the light bulb." A risk-averse firm may start losing customers to competitors that offer innovations. *The amount of risk assumed within a firm's product innovation process is a strategic decision--not an engineering decision*.

In the past, some market leaders have prospered by following risk-adverse product-innovation strategies. Caterpillar let other firms take the lead in new products, believing that its strong market position would allow it to successfully introduce new ideas that proved viable. Komatsu's rapid rise caused it to review strategy.

Another type of risk that often exists in the Lexus lane is the risk of being outmaneuvered in the battle to decide industry standards. Early in the VCR's product life cycle, Sony's Betamax was considered to be superior to Panasonic's VHS tape standard. But Panasonic's marketing muscle outmaneuvered Sony. In a more recent era, software makers who compete with Microsoft point out that this industry giant has gained enormous competitive advantage by controlling product interface standards. In its anti-trust trial, it was revealed that even Intel was coerced not to engage in certain software development areas. Developers of applications software want industry-wide control over the interface between its Windows operating system and other software. Microsoft has refused to yield that control. Microsoft claimed that "it is playing fair."

Product Reserve Capacity Considerations

The designers of a product and its product delivery system must size the capacity in a manner consistent with the corporate strategy. The first challenge is called the *product capacity issue* and the second is the *production process capacity issue*. Both issues interpret the challenge using the broad definition of capacity, i.e., the right stuff and the enough stuff perspectives.

Cost-driven manufacturers often emphasize the need to have their products rated and their product delivery systems operated at the highest possible level. This is appropriate when making commodities. With commodities, there isn't much of a product design capacity issue since most have well-defined standards. The challenge is how to meet these standards without unduly exceeding them. The need for reserve capacity for commodity delivery systems is less since buyers do not expect guaranteed availability.

However, when one is dealing with customers with high expectations, the reserve capacity decisions require product architects to have a better understanding of the impact shortfalls have on the firm's competitive well being. In the product area, shortfalls often reflect on the design quality of the firm's outputs--even when the user may be using the product incorrectly. Delayed deliveries and off-spec goods are perceived as a failure of the firm's product delivery system. From the customers' perspective, it matters little what the cause is. Customers tend to "shoot the messenger," i.e., they blame the party that they deal with.

V

Dialogue Driver: How might the practice of building reserve capacity into a product be justified as being environmentally sound? Or can't it?

f

Outsourcing All or Part of the Product Innovation Process

In the past, operations managers often faced *make or buy* decisions when it came to procuring parts. Today, this issue has expanded to include:

- *To what extent should we have the customer participate in the product innovation process*? One upscale playhouse company now has the children of its clients specify what they want. At the other extreme, purchasers of standard products have no say in the product innovation process.
- *Should we make the end product or have a supply chain third party make/assemble it*? Contract manufacturers, such as Solectron, started out stuffing components into printed circuit boards but the scope of their services now range from product design to final assembly.
- *To what extent should we own the parts of the supply chain*? As this is written, we see the Ford Motor company trying to spin off its parts manufacturing operations at the same time it is trying to integrate forward by buying auto dealers.
- *Should we engage in internal product design*? Volvo used an outside design studio to create a less boxy, more exciting car. Cisco Systems admits that it cannot fully understand which new technologies will thrive in its industry. So it routinely buys business startups with promising new products. Its product architecture exists at the macro-level and it has developed an organizational capability to buy and integrate promising high-tech startups into the Cisco family.

It is in this area that the differences between the Lexus lane and the Olive tree-shaded lane is greatest. The more you travel in the Lexus lane, the more likely you are to believe that a firm should make and design *only those components for which it has a strategic advantage*. The need for state of the art technology and the need to be fast to market clearly are driving Cisco's actions. In 1999, Intel recognized that it lacked certain technologies if it was to expand its core business beyond microprocessor CPUs into the broader Internet communications equipment market. As a result, Intel started buying firms to acquire these capabilities.

For firms competing at the Olive-tree clock speeds, they may need to engage in vertical integration to achieve low cost competitive strategy. If your firm is trying to avoid attracting new entrants to your market, this may work to your advantage. Within the past decade, both Coca Cola and Pepsi have restructured their supply chain to give them greater control over their products' bottlers and distributors. But in high clock speed industries, firms such as IBM, Unisys, and Tandem have failed dismally trying to compete with closed product architectures, vertical integrated business strategies.

ORGANIZATION DESIGN FOR PRODUCT INNOVATION PROCESSES

In the past, most American firms used *sequential product design and development processes*. The tasks assigned to each stage were completed and then "thrown over the wall" to the next stage. In a slow pace business environment, this practice worked as long as there was no competitive need to be fast to market.

While sequentially organized product innovation processes may have worked in the mass-manufacturing era, its flaws showed up during the Japanese onslaught of the US markets during the 1970s. In industry after industry, American producers found themselves competing with products of higher quality, more features, and with lower costs. What had gone wrong?

To understand what often goes wrong in sequentially designed products, consider the stages a new product goes through at an automobile firm. The following steps are:

1. Executives meet and approve a bold proposal to develop a new automobile model called a mini-van. This new vehicle looks like a small van, drives like a car, and fits in a standard garage.
2. Before this project can start, the design process must establish certain key parameters to guide later decisions. A target price will dictate a *target cost* for the vehicle. A prospective launch date governs

schedules of all phases of the project. Extensive initial market research can help to focus the design and development process on the features that customers want.

3. The styling department then builds clay models to refine the image of the product. Engineering then takes over and starts to define required parts for a vehicle with the intended capabilities and features. Representatives of the styling and engineering departments meet to work out any problems that emerge. Sometimes higher-level managers must step in to reconcile differences.
4. Suppliers and process engineers then receive the component designs with instructions to figure out how to make and assemble the parts. More problems emerge. More meetings follow to continue the search for parts and processes capable of producing a vehicle that fulfills the initial vision within targeted costs.
5. Finally, manufacturing begins the task of making a few test units of the new model. More problems arise and department representatives hammer them out in more meetings. As the model launch date nears, manufacturing schedules production of the mini-van. Marketing requests high initial production rates to support its new model introduction program and the dealers have placed firm orders.

This example illustrates some of the problems that arise in a sequential-innovation process. First, it often took too much time—usually about five years. Long product design lead time means that the firm must forecast what its target customers will want at least five years from now—actually longer since auto firms like to run a specific model for at least four years. Do you know what you will want in 2010?

Sequential product development costs too much. Japanese carmakers invest substantially less to create new car models than its American or European rivals. Conventional wisdom argues that rushing projects cost more--an assumption that pervades many project-planning programs. For example, the critical path method normally assigns a higher cost to tasks that are done on a rush basis. But based on what we have learned from studying the ways Japanese car companies design and develop their end products, it can be argued that sequential product design achieves the worst of both worlds--it takes too long and it costs too much.

Sequential product development also inhibits proactive quality management. The design quality produced by an innovation process reflects the inherent value that customers place on product features. One measure of design quality is the number and timing of engineering changes needed to refine the product. As compared to Japanese firms, the product development processes of American firms tend to make about the same number of engineering changes, but those changes tend to occur later in the design process when they cost more. Worse yet, engineering changes after the product launch are quite common. The resulting product recalls amount to unpaid advertisements heralding a product's poor quality.

A major organizational problem associated with sequential product development is that it permits people to work comfortably within the confines of their specialty areas. Engineers spend most of their time with like-trained engineers and they expect performance evaluations as engineers by other engineers. To allow necessary exchanges between departments, meetings are commonplace.

Sequential product development creates larger problems than ineffective communication--it creates a problem of perspective. People responsible for product development need to know more than what the next internal customer needs. They need to understand the needs of ultimate customers and how they will use the product. Lacking this perspective often leads to flawed product designs, such as the infamous Chevy Monza goof, where they built a car that required owners to lift the engine from its mounts simply to change its spark plugs. Chevy engineers missed this design flaw because they lacked the ultimate user's perspective.

Engineers began to learn less about practical information in school as many colleges dropped practical courses in machine shop, metal-fabrication, and foundry techniques in favor of more theoretical material. At the same time, decay in the nation's system of vocational training schools widened the knowledge gap between production workers and designers. The success of unions contributed to a communications gap between knowledgeable workers and product designers.

Mass producers like the automobile makers could tolerate these conditions throughout the years after World War II because no competitors offered any better deals. The then Big Three prospered making standardized cars each year and making major model changeovers every 3 to 5 years. This permitted them to spread the high cost of new product designs over several years' production. This made economic sense to the number-crunchers in Detroit. But their customers became dissatisfied, especially when GM surprised them by putting Chevy engines in Oldsmobiles. Olds buyers, who grew up hearing about the superiority of the division's "Rocket" engines, complained loudly. The automakers thought they wouldn't care. This is but another symptom of top management lacking a basic understanding of its customers' values.

The plight of American automobile manufacturers illustrates the shortcomings of sequential product design. Similar problems appear in most organizations that have failed to make a needed adjustment away from rigidly segmented mass manufacturing/mass marketing strategies to more flexible methods designed to better serve fragmented markets. Not all firms need to make this adjustment, however; some stable markets, such as table salt and corn flakes, still permit deliberate, sequential processes for product innovation.

Nothing New

American manufacturers did not start off using tunnel vision. During the early stages of the U.S. industrial revolution, product innovators like Thomas Edison succeeded, in part, because they maintained cross-functional perspectives. Edison created his "innovation factory," joining engineers with other workers in multidisciplinary teams. Today, we seek similar cross-functional thinking in product design shops, such as IDEO.

An unfortunate bi-product of Henry Ford's success was that it led him to expand the division of labor concept to the organization as a whole. Ford tried to copy his principles of interchangeable, unskilled workers assembling standardized parts, and apply it to most functions of management. Industrial engineers specialized in narrow aspects of products and processes, limiting careers within narrow boundaries and eliminating the cross-functional thinking that existed in Edison's innovation factory. As the product became more complicated, the areas of specialization narrowed further and management hierarchies became steeper. Communications among product design participants disintegrated.

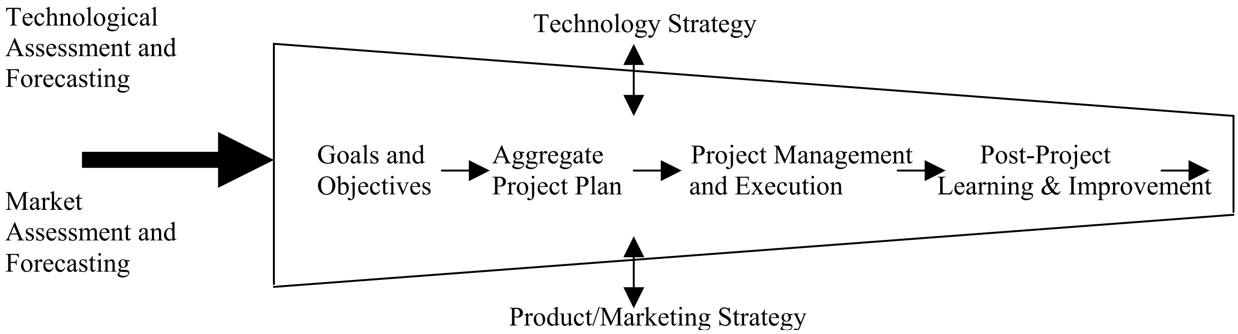
Source: Tracy Seipel, "Design Firm Focuses on Humanizing Technology," San Jose Mercury News, 7/21/01

Rediscovery of Concurrent Engineering

One way to reduce the duration of a project is to have certain tasks done simultaneously. This is easier said than done, but it can be done if the organization fully utilizes the benefits of cross-functional thinking. The advent of cultures that foster teamwork and fully utilize the capabilities of information technology makes this possible. The need to be fast when competing in the Lexus lane makes this an absolute necessity.

Wheelwright and Clark argue that firms should develop explicit product-development strategies to coordinate all of the major business processes that contribute to product innovation.[3] They suggest that this process be shaped like a funnel.

Exhibit 2
The Product Development Screening Process



Source S.G. Wheelwright and K.B. Clark, *Revolutionizing Product Development*, Free Press, 1992, p. 35

Exhibit 2 illustrates the way candidate projects are reviewed. At the front end of the funnel, two ongoing business processes occur. The first is *Technology Assessment and Forecasting,* which strives to evaluate new process technologies that will emerge from research and development endeavors to find practical applications in the marketplace. It also assesses the extent to which the firm will benefit from these developments. Boeing would want to know when composite fiber will be a practical replacement of metals in airplane frames.

The technology assessment process weighs the benefits of acquiring capabilities from external sources against developing these capabilities internally. The strategy business process needs to ensure that these issues are addressed in an unbiased manner. The second front-end task is a *Market Assessment and Forecasting Process*. This business process forecasts both the demand and product capabilities demanded in current markets *and those that it would like to enter.* This analysis should go beyond merely forecasting unit sales or their dollar value by product and region. It should seek to form the basis for understanding and managing customers' expectations, i.e., the things we need to know in the first stage of Exhibit 2.

Assessments of both the marketing and technology situations can come either from organization-wide business processes or from more external sources. That decision should reflect the organization architect's assessment of the best resources to assign to the work. In the past, firms tended to complete these activities as corporate functions. More recent trends have led toward smaller corporate headquarters and more resources deployed among divisions or even product lines.

These front end processes help define the direction and rates for product and process innovations. The *Technology Strategy* determines whether the company will introduce new technology in small increments or whether the nature of the technology warrants a major breakthrough strategy. Of course, these decisions depend on the firm's overall willingness to take risks. Similarly, the *Marketing Strategy* determines whether the firm introduces large-scale, blockbuster innovations or sequences of incrementally enhanced models. The technology and product/market strategies must also create internal consistency with the firm's strategy.

This formal process cannot produce anything on its own. Into the funnel flow a stream of new product and new process ideas. Listening to customers provides essential clues to their desires, but this free advice requires deft handling. Processing of such an idea should include a review by an attorney to advise about ownership rights to resulting new products. Legal can flare up over valuable product ideas. Recently, an inventor successfully sued the major automobile manufacturers claiming that they had "improperly used" his invention of the multi-speed windshield wiper. Some firms take the extraordinary step of certifying someone as out of the loop by routinely returning all unsolicited product ideas to guard against later claims for compensation. Now there's a dead end job!

New product ideas pass through a funnel that serves as a screening process to identify and target resources on those with the most commercial promise. Two additional parts of the product-development strategy process affect this screening process. First, an input to the product innovation process must be a clear statement of the firm's strategic goals. Strategic guidance over the product design and development process coordinates the overall investment pattern to ensure internal consistency. Hence, a statement of goals of the product-development strategy should guide its activities.

At the aggregate level, goals need to be made explicit and then juxtapositioned to examine their compatibility. The purpose of this process is to provide integration both in the aggregate and at the level of the individual projects. Typically, the goals range from market share to profit, and from dates for platform generation introductions and technology achievement to new product/process performance directors.

Performance measurement must be an integral part of this planning process. Beyond the routine sales and profit objectives, the product and process innovations should be evaluated based on three additional criteria: cost, time to market, and quality. Exhibit 3 lists some typical performance metrics for each criterion.

Exhibit 3
Performance Metrics for Product Innovation

Cost:	Actual versus plan	Total number of engineering hours Outside service expenditures
Time to market:	Actual versus plan	Elapsed time from conception to launch Time required to recover investment
Quality Design:	Actual versus plan	Design-measured customer satisfaction Conformance: actual results versus specs
General:		Number started versus number completed Number started versus number successful Production yields: actual versus plan Percentage of sales from new products Market share: actual versus plan

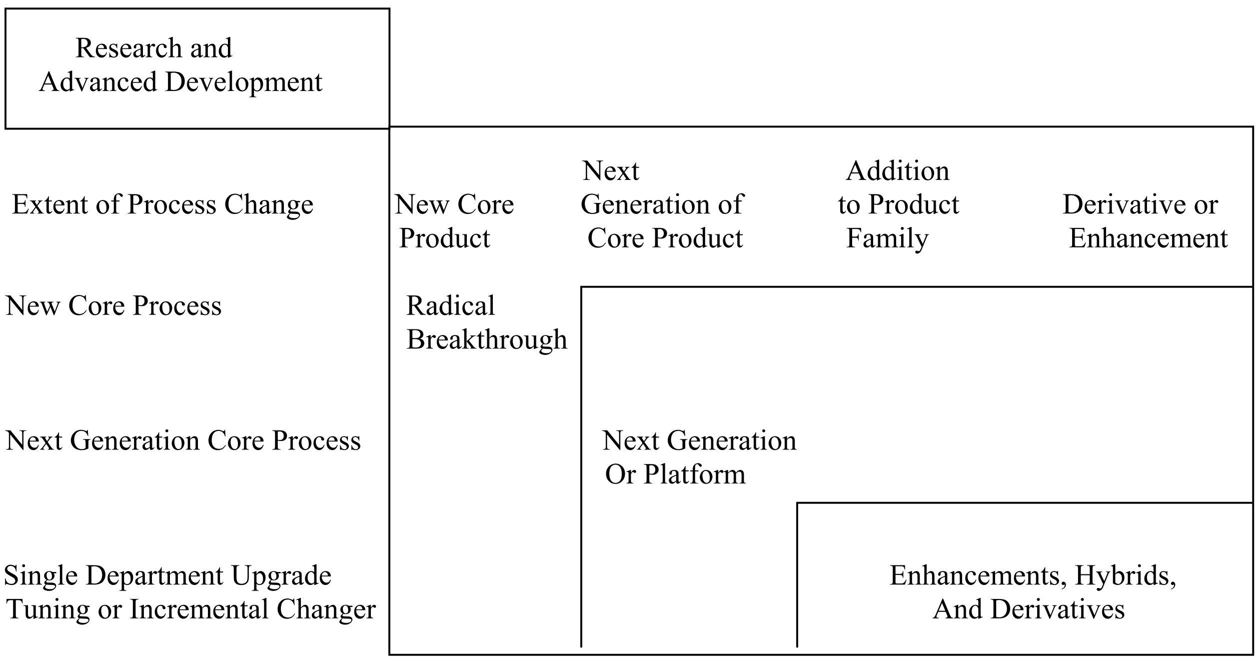
After setting and quantifying goals, the innovation infrastructure proceeds by developing an *aggregate project plan*. This critical reality check ensures that proposed projects described in the statement of goals and objectives are resource feasible. It helps the firm to plan its deployment of resources to direct the right amount of resources of the right type to each project at the right time to maximize the likelihood of its success.

To create an aggregate project plan, even the most modern product-development process needs to complete some old-fashioned project planning. This activity begins by breaking down the project into specific tasks. It then estimates the type and the amount of resources that each task requires. Although this estimate is subject to considerable uncertainty, failure to quantify, at least approximately, the distribution of resources and risk allowing the project to run out of control. In a sequential product-development system, this planning produces a sequence of tasks that form the project network.

Based on more general project planning as input, commercial project-management software can help determine the likely length of a project, its critical path (i.e., the sequence of tasks that cannot suffer delay without delaying the entire project), and the timing of resource needs. Resource planning must consider the needs of other projects. Unless the project can rely on resources dedicated exclusively to its activities, it may seem feasible by itself while other projects plan to use the same resources, leading the organization as a whole to take on many more projects than it can complete. Unfortunately, similar situations arise quite regularly.

Every project proposal must state what resources it will need, when, and for how long. These are difficult questions. No two projects seem alike, so past experience may not help much with an estimate of current needs. Some involve extensive technical support while others need mostly marketing resources

Exhibit 4
Primary Types of Developmental Projects



Source: S.G. Wheelwright and K.B. Clark, *Revolutionizing Product Development*, Free Press, 1992, p. 49

The labels along the left side and top of Exhibit 4 suggest strategic implications of this classification scheme. Clearly, a sweeping project to develop a new core process or product or both requires more resources and more organizational flexibility. In particular, participants must expect to engage more vigorously in Senge's systems thinking perspective than participants in a project to build a derivative of some successful current product or process. Small projects with limited scopes in the lower right corner of Exhibit 4 probably do not require cross-functional product-innovation teams.

Dialogue Driver:
During your college days, you often are asked to work together in teams. Can you use the above exhibit to explain why some team experiences are worthwhile and other a total waste of time?

Wheelwright and Clark use four types of developmental projects to define resource needs for projects.

- Research and Advanced Development Projects are ambitious projects to find new core products or processes, for example, a project by General Motors to develop an electric car. Such a complex task requires an advanced mix of skills, perhaps provided by people without experience with past products or processes to encumber their progress. A firm needs a special type of organization to nurture such a team and to protect it somewhat from the realities of the marketplace. Schedules are important, but project managers must not try to force such basic innovation to occur on their schedule.
- Breakthrough Development Projects seek to develop products or processes that will employ some entirely new technology, itself perhaps developed through an advanced development project. Ford based some breakthrough projects on its V8 engine. GM developed its Corvair around a rear-drive, aluminum, air-cooled engine. Some breakthroughs succeed, some don't. Sony developed its Betamax video recorder based on both new core products and new core processes. Breakthrough products often become beachheads in their markets for entire families of products.
- Platform or Generational Development Projects develop platforms from which the firm can launch later, derivative products. Apple Computer's development of its iMac computer is a good example of such projects. If successful, these new products provide a starting point for entire sequences of related products. This type of new product endeavor does not represent a breakthrough that deploys formerly unknown products or processes. That is, unless you don't consider colored computers a true innovation.
- Derivative Development Projects refine and improve selected features of existing products. Adding a CD-ROM drive to an existing computer or adding an M&M with a crispy crust would amount to derivative projects, as would a sequel to a successful motion picture. The scope of such a project is much narrower than the other, more ambitious innovations.

Project Management –A Concurrent Engineering Tool

Concurrent engineering carries out product-innovation projects through cross-functional teams that complete the multistage process detailed in Exhibit 5. This process relieves the engineering department of sole responsibility for the design stage, instead spreading the work among many departments. Senge's book has provided valuable help for practitioners of concurrent engineering.

Exhibit 5
Activities and Responsibilities in Concurrent Engineering

Conceptual Design	
Marketing:	Proposes and investigates product concepts
Engineering:	Proposes new technologies and simulates performances
Operations:	Proposes and investigates manufacturing/delivery processes
Product Design	
Marketing:	Defines markets and specifies objectives
Engineering:	Chooses components and key suppliers
Operations:	Defines process architecture and estimates costs
Product and Process Engineering	
Marketing:	Conducts customer tests on prototypes
Engineering:	Builds full-scale prototypes for evaluation and refinement
Operations:	Builds prototypes, plans full-scale system, tests tooling and new procedures
Pilot Development and Testing	
Marketing:	Prepares for market roll out, trains sales force
Engineering:	Evaluates and tests pilot unit
Operations:	Builds pilot units in commercial processes, system, trains personnel, checks suppliers
Volume Production and Launch	
Marketing:	Fills distribution channel, sells and promotes, gains feedback from target customers
Engineering:	Evaluates customers' experience with product
Operations:	Builds up plant to volume targets, refines quality, yield, and cost performance
Post-Sale Service	
Marketing:	Gains customer feedback
Engineering & Operations:	Study warranty data

Concurrent engineering permits a single team to start working on each stage before finishing work on the earlier stage. This overlap both relies on and reinforces the broad perspective that members bring to cross-functional teams. A core group of key team members stay with the team throughout all stages of product innovation, joined periodically by new members with specific skills who act more or less as consultants. In this way, the team can expand and contract its skill base, making it both efficient and flexible. The core team members provide critical leadership, commitment, and perspective to a project.

Success Record of Concurrent Engineering

The Clark and Fujimoto study used three performance metrics to evaluate product-development activities: cost, quality, and time-to-market.

- Cost: This performance metric evaluated the funds that firms spent to develop products from idea inception to market launch, with adjustments for differences in the car models. American car companies, with their sequential methods, used about 3.0 million engineering hours to produce a new model, whereas Japanese companies required 1.7 million hours to complete the same activities concurrently.
- Quality: This performance metric indicated how well developed products met the expectations of target customers. Practitioners of concurrent engineering implemented programs such as quality function deployment and design for manufacture, discussed later in this chapter, to ensure that their product designs accurately reflected the needs of both internal and external customers.
- Time to Market: This metric evaluated the elapsed times of various product-development efforts from idea inception to product launch. They found that Japanese firms took 46 months on average while American firms took 60 months.

These findings imply that speedier product development doesn't cost money--defying the conventional wisdom that faster action costs more.

The Womack et al. study confirmed the conclusions of Clark and Fujimoto.[4] Their evaluation of car designs identified four major differences that can partially explain the differences in performance between mass manufacturers and what the study called lean manufacturers. The study found strong project-leadership organization structures in the Japanese lean producers. In the Toyota system, this strong leader is called a shusa. This leader's personal power and organizational skills give the design team the necessary resources to design, develop, justify, and launch newly designed products. Unlike American design teams, the core members of Japanese teams often stay with their projects long after successful launches pursuing the ultimate goal of building a satisfied customer base rather than just a successful product. This person brings many strengths to the product-innovation process, including vision, broad product knowledge, skillful handling of organizational relationships, and an ability to inspire team members with diverse perspectives.

In Western firms, by contrast, product-development leadership brings less organizational esteem. Team members often view their roles as temporary assignments within career paths that depend largely on relations with fellow functional specialists. Leaders must work harder to coordinate weakly committed team members and to gain needed cooperation among functional areas, often in competition with other major responsibilities of team members. Such an assignment often represents a short-term staff outside the organization's prime career-advancement tracks. As launch date approaches, product design and development teams often disband or shrink.

Japanese car manufacturers built their organizations to encourage *active teamwork* among both individuals and the functional departments, and the shusa's role contributes to this strength. While individual employees maintain links to their functional departments, the shusa's evaluation determines the organization's assessment of individual performance and subsequent job assignments. Teamwork can grow as core members remain committed for the entire life of the project.

Most Americans serve on product-development teams as short-term diversions from their primary positions in their functional departments. Their workspace often remains within those departments, reinforcing their identification with their functional areas rather than the new team. Relocation can become important in such a new project, as one successful team at a Mid-western company learned when it lost its perfect off-site location because real-estate experts found it uneconomical. Team members scattered among their individual functional departments and team effectiveness dissipated.

Teamwork influences cost effectiveness, as well. Clark and Fujimoto found that about 900 engineers participated in a typical project at a U.S. firm while the Japanese firms "enlisted about 485." The most committed practitioners of the shusa system reduced team membership to only 333. These lower numbers reflect more efficient organizations and lower turnover within Japanese product design teams. Conversely, U.S. firms often reassign key team members prematurely to new projects.

They also discovered more than just the expected differences in patterns of communication between Japanese and American automakers. Rather than simply communicating through different channels, American firms seemed to fail to communicate effectively. In their sequential process activities, they frequently overlooked critical design issues early in a project's life. Functional specialists seemed to make vague commitments only to rescind them to avoid the real consequences of the projects, perhaps complaining that insufficient access to upstream decision-making prevented them from contributing.

Exhibit 6
Product Development Performance: Japan vs. American Automakers

	Japanese Producers	American Producers
Average engineering hours per new model	1.7 million	3.1 million
Average development time per new model	46.2 months	60.4 months
Number of employees in project team	485	903
Number of body types per new model	2.3	1.7
Average ratio of shared parts	18%	38%
Supplier share of engineering	51%	14%
Engineering change cost as share of total die costs	10-30%	30-50%
Ratio of delayed parts	1 in 6 late	1 in 2 late
Die development time	13.8 months	25.0 months
Prototype lead time	6.2 months	12.4 months
Time from production start to first sale	1 month	4 months
Return to normal production after new model	4 months	5 months
Return to normal quality after new model	1.4 months	11 months

SOURCE: James P. Womack, Daniel T. Jones, and Daniel Roos. *The Machine That Changed the World: The Story of Lean Production*, XXX, 118

In contrast, Japanese teams spend more time early in the process fleshing out design problems and then formally pledging to make agreed upon contributions to the group. Early in a project's life, the shusa involves a wide variety of perspectives to force the team to confront as many foreseeable problems as possible. These initial agreements reduce the need for later communication.

Through vigorous project leadership, committed teamwork, and active early communications, Japanese auto makers and their suppliers complete much of their component and process designs at the same time. The shusa's coordination helps team members to define their tasks and relationships with other members' tasks, encouraging teamwork and communication to help members take shared risks.

An American designer of a stamped, metal part, say a fender, maintains an arm's-length relationship with the die maker. Since this supplier pays severe penalties if the die fails to meet specifications, the firm waits for a final design before starting the job. A Japanese product-development process would invite the die maker to join the team. This early involvement both helps the part designer to plan for the manufacturing process and allows the die maker to start machining work as soon as preliminary specifications become available. More detailed work must wait for later refinements, but the initial operations can carry on without precise dimensions. This early involvement can both improve the product design and save some revisions. Also, the die maker offers expertise without increasing the design team's engineering burden or cost. This win-win situation reduces costs, improves quality, and shortens lead times.

ANALYTICAL TOOLS FOR PRODUCT INNOVATION

The continuing discussion of sequential horror stories and concurrent solutions may seem somewhat theoretical. To anchor the principles of the earlier sections in operations management, in this section we discuss some of the practical analytical tools for product innovation.

Design for Manufacture (DFM) seeks to integrate the activities of product designers with those of the designers of the product delivery processes that make the product. Design for manufacture does not require complete unification of these activities on one team. They must simply coordinate their efforts to produce the cooperation of team members. DFM gives representatives from manufacturing a forum for providing inputs about the strengths and limitations of the process during a product's design phase.

The early development of design for manufacture responded to friction created by product designs that did not fit existing production systems. These responses often implemented systems theory, as when firms created expert systems to constrain engineers' choices early in the design process. These systems essentially codified the insight of shop-floor workers to provide automatic input to designs. Other DFM systems create standards that specify the best manufacturing practices. One firm reduced the number of hole sizes that designers could expect a shop to drill from hundreds down to 27. An engineer could still specify a nonstandard size, but only after filling out a seven-page form to justify the variation.

While changes like these may have simplified life for manufacturing engineers, they ignored the root cause of the problem, poor cooperation between two functional areas. Even when manufacturing representatives joined product-development teams, they often took advantage of the desire for unanimity to seize a sort of veto power. "Since you ask," the argument went, "do it my way." Design engineers responded predictably: "We knew it would not work."

But somehow along the way there emerged a set of best practices that help guide product innovation teams in the design and development of parts and products. Some of the best practices are:

- Minimize the number of parts, including fasteners.
- Minimize the number of fabrication or assembly operations.
- Discover customers' functional requirements and match the design to them.
- Determine process capabilities and design products to match them.
- Specify standard components with proven quality levels whenever possible.
- Design multifunctional modules and combine them.
- Create designs that simplify fabrication, assembly, and servicing.
- Design products to allow one-way assembly with no wasteful backtracking.
- Avoid special-purpose fasteners or those that require special tools.
- Make parts strong enough to withstand inevitable mishandling.
- Anticipate potential misuse by the dumbest possible customer and create a design that prevents it.

Never underestimate the ability of some teams to seize complexity from the jaws of simplicity.

Design for Assembly (DFA) focuses on reducing assembly costs and indirectly increasing the quality of conformance by creating designs that fit well with assembly operations. This simple strategy begins by reducing as much as possible the number of parts needed to assemble the product. It then works to ensure that the remaining parts fit together as easily as possible.

These simple guidelines compare to the advice of a swimming instructor who said to a struggling student, "Don't sink!" These goals are easier to state than to accomplish. To help solve this problem, Geoffrey Boothroyd and Peter Dewhurst, two entrepreneurial engineering professors, created a quantitative scoring method for part features that identifies areas for potential savings. They begin by scoring an initial design, either a prototype design for a new product or the current design for an existing one, assigning penalty points for each feature of the design. The DFA team seeks to redesign the product to improve this design score.

The DFA method provides an excellent example of the benefits of quantification. It forces entrenched organization members to rethink their positions, often with impressive results as the Ford Motor Company, attests. Although no one can accurately measure the relative contribution of DFA, Ford has reportedly achieved a cost advantage over GM in the range of $1,500 per vehicle.

Design for Post-Sale Service requires less explanation, though it is no less important than DFM or DFA. Just about everyone has experienced frustration over poor instructions in a service manual or heard a mechanic mutter, "Who designed this?" Design for service simply requires product designers to incorporate features that help owners and repair technicians to maintain products; designers should serve these people as customers that they hope to see again and again.

Design for Recycling Being environmentally responsible has become an important facet of the product innovation process. There are three facets of this problem. The first is to design processes that use the least amount of resources. The second is to design processes that minimize undesirable outputs—especially substances and emissions that are harmful. The last line of defense is to design products that enhance the likelihood that they or parts of them can be recycled into other useful products. (See Note A: Environmentally Responsible Operations for a framework for understanding how environmentalists are help product designers rethink what they do.)

SUMMARY

Designing products is a business process that must be managed like any other business process. At the start of this shell, we saw how Skechers used its knowledge of its target customers to quickly craft products that are well suited for its customers. This in turn allowed this firm to design a product delivery system that enables it to deliver fad-oriented customers new items faster than Skechers' competition. This example problem also demonstrated some of the advantages associated with product standardization.

Being able to design new product and then deliver them to customers in a timely way is a capability that most world-class companies possess. We then introduced some of the concepts that enhance these firms to rise above the rest. Product architecture provides the strategic framework. For customers wanting greater product design flexibility, mass customization and modular product designed are one possible avenue to achieve this objective. Concurrent engineering provides the means to significantly reduce product design leadtime. And the various design for strategies represent some of the best practices that have evolved over time.

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3. Womack, J. P., et al. *The Machine that Changed the World: The Story of Lean Production*. New York: Harper-Collins, 1990.
4. Abernathy, W.J., K..B. Clark, and A. M. Kantrow. *Industrial Renaissance: Producing a Competitive Future for America*. New York: Basic Books, 1983.
5. Pine, B.J. *Mass Customization: The New Frontiers in Business Competition*. Cambridge, Mass.: Harvard Business School Press, 1993.
6. Smith, P.G., and D.G. Reinertsen, *Developing Products in Half the Time*, New York, Van Nostrand Reinhold, 1991.

Expected Learning Competencies

Before putting Shell Nine down, you should ask yourself the following questions. Am I able to explain:

1. What a good is and how to relates to the product bundle concept.
2. Some of the ways systems that make goods differ from those of service oriented systems.
3. What product architecture is and the role it plays in the product innovation process.
4. The contribution product/part standardization plays in the product innovation process and how it often enables the producer to deliver products of higher value. When might the use of standardize parts or products degrade a product's value as seen by the customer?
5. Why firms often use serial product design and development processes. In what ways does concurrent engineering improve this process? How might it hurt product innovation/
6. What analytical tools are used to enhance the ways firm design or refine its product line.
7. The role of teams in the product innovation process.
8. What your instructor added to this shell and why he or she thought that it was important enough to warrant its inclusion.

Frequently Asked Questions

Instructors have been known to ask questions similar to the following:

1. Identify four firms that you think have superior product innovation capabilities. How has it enabled them to compete more effectively for your purchase dollar?
2. Explain the role of product architecture in a modern electronic product, such as a laptop computer.
3. Select two products that you think offer more value because they are made using standardize components. Identify one product that you think where its value has been diminished.
4. Identify a product that you have purchased where you think its reserve capacity has increased the value of the product.
5. In the IDEO video, the product innovation process observed seemed closest to:
   a. Product documentation
   b. Value engineering
   c. Brainstorming
   d. Benchmarking
6. Which product innovation process do you think McDonough and Braungart would most relate to:
   a. Design for post-sale service
   b. Design for recycling
   c. Design for manufacture
   d. All of the above
7. The seminal studies of the Japanese car industry confirmed that if you reduce product design leadtimes, you invariably increase the cars' unit product costs.
8. The Ingersoll-Rand video was an excellent example of concurrent engineering.

SHELL TEN

DESIGNING SUPPLY CHAIN MANAGEMENT SYSTEMS

[1]

Hey Buddy, Can You Sell Me Some Steel?

Herb Shubert is smiling again. It used to be that Herb spent hours at a time calling steel mills, searching for the small quantities of steel his small steel fabrication shop needed. He could buy steel from steel wholesalers, but he had long achieved a slight competitive advantage by buying direct.

To rephrase George Orwell, Herb's problem was that while "steel mills value all customers equally, *some customers are more equal than others*." The nature of the steel making process is that at the onset of a batch, the yield of on-spec product is uncertain. So steel mills run slightly larger runs than customer orders call for to ensure that they will be able to fulfill known customer orders. What is left over is orphan inventory, i.e., unplanned steel in inventory with no known customer. These small quantities often meet Herb's needs. However, Herb's problem was that the folks selling steel like to sell large orders. No salesman is going to make his sales quota selling orphan inventory. So the Herbs of the world used to spend hours waiting "on hold, while other "equally valued" customers are served.

Herb is smiling today because two e-commerce businesses have started to serve his needs. When a steel mill has unsought inventory, it posts the quantities and specs on the Internet site. When Herb has a need, he posts his inquiry stating the type and quantity of steel needed. When a match occurs, the transaction proceeds with a minimum of human intervention. Both Herb and the steel marketers are happier today.

Note: If you want to visit these sites, their addresses are:
http://www.esteel.com and http://www.metalsite.net
Both sites have demonstration tours for their visitors.

Source: *Forbes*, Special Edition on B2B, July 23, 2000

Shell 10
Designing Supply Chain Management Systems

Table of Contents

Learning Objectives

After reading this shell and thinking about its contents, you should be able to:

1. Understand the critical role supply chain management plays in contributing to the effectiveness of a firm's operations management function and its ability to support the implementation of the firm's business strategy.
2. Understand how the concept of value provides supply chain system designers for building supply chains capable of delivering product in a manner consistent with the firm's strategic objectives.
3. Understand what the major trends are in supply chain management and how they are or may impact how a firm should construct or refine its supply chain and its supply chain management system.
4. Understand and be able top explain:
    a. The role of purchasing within the firm—past and present (including e-purchasing)
    b. The difference between a product buy and a process buy
    c. The advantages and disadvantages of confrontation and supplier partnership
    d. The advantages and disadvantages of vertical integration
    e. The advantages and disadvantages of the outsourcing and how the concept of core competency should influence these decisions.
    f. The rise of contract manufacturing and the logic behind these strategies
5. Understand and be able to explain the following supply chain management process improvement tools
    a. Cost Reduction by Edict
    b. Make-Buy Analysis
    c. Vendor Scheduling
    d. Value engineering
    e. Supplier Certification/Evaluation Programs

INTRODUCTION

The ability to deliver the right product to the right location at the right time defines the capabilities of the seller's supply chain. Failure of any part in the supply chain often results in customer dissatisfaction. In the past, many firms sought to maximize customer satisfaction by stocking the supply chain *with just-in-case inventory*. Wary customers also carried inventories to guard against shortages of critically needed parts. Today, the capabilities of the supply chain are being enhanced by enlightened supply chain management practices and by emerging information technology applications.

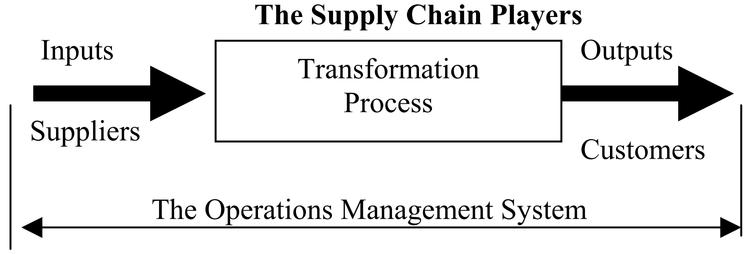
The strategic value of enhanced supply chain management was driven home on October 23, 1999 when it was announced that Dell had replaced Compaq as the leading seller of personal computers in the United States. Dell has a good product and its prices are competitive. But the main reason for Dell's rise to the top of the personal computer sector of the market is that it designed and developed a superior assemble-to customer-order supply chain to serve its target customers.

The major forces driving these changes in supply chain management systems are:

- An expansion of the geographic scope of supply chains--often worldwide.
- Enhanced small quantity delivery service capabilities from firms such as FedEx and Airborne Express.
- A shift in the direction of vertical integration away from upstream processes toward downstream processes. At a time in which firms are withdrawing from owning their suppliers, some industries seem to be bent on owning and/or controlling business units that sell to their customers.
- Information technology based third party providers are redefining how the parties interact.

Every OM system involves a transformation process fueled by the inputs shown in Exhibit 1.

Exhibit 1
The Supply Chain Players



Every operations management process depends on materials, knowledge, and services provided by other organizations—many of which are outside of the legal boundaries of the firm.

Transactions within a supply chain are called business-to-business (B2B). They can be categorized by:

- *The repetitiveness of the transactions*. At one extreme, you have one-time transactions such as the purchase of a burial plot. At the other end, you have buyer-seller transactions that occur hourly.
- *The degree to which the purchase decision and the vendor selection decision is separated*. In a *spot market*, the vendor selected is determined by the deal. In other situations, a vendor selection decision occurs first. When goods or services are needed, the purchase decision defines when, how much, and perhaps at what price. The *Who* component of the decision has already been made.
- *The degree the parties work together to define/design the product*. Three basic types of transaction occur:
  - The item being purchased has been defined by the vendor and is being offered to the buyer on an "as is" basis. Quite often, these are standard products.
  - The buyer specifies the capabilities and features of the purchased item. The buyer knows what it wants and provides prospective vendors with product specifications that must be met.
  - The buyer and seller work together to define the product's design. The buyer defines the need and together they explore how to best develop a product capable of satisfying this need.

- *The point at which ownership of the good is transferred from the buyer to the seller*. In traditional transactions, ownership changes when the good is either shipped or received by the customer. Today, the seller may retain ownership of the good even though it has been transported to the customer. A change in ownership occurs when some future specified act occurs, such as the sale of the product or its use in the next stage of the supply chain. In effect, the seller is placing the good on consignment at the new location.
- *The party responsible for managing the transportation of the good or service to the next stage*. With some transactions, the buyer assumes responsibility for arranging for the product to be picked up and delivered to the next stage of the supply chain. In others, the seller manages shipping.
- *The degree to which humans are immediately involved in the initiation and consummation of the transaction.* At one extreme, humans on both sides are a necessary part of the deal. They may even shake hands. At the other extreme, you have application-to-application systems (A2A), i.e., where software at both ends of the transaction consummates the deal. The extent of decision making done within an A2A system may focus mostly on the *what* and *when* facet of the transaction or it could extend to include the *who* and *at what price* part of the transaction. With repetitive application to application (A2A) transactions, electronic data interchange (EDI) has become commonplace.
- *The degree to which the pricing component of the purchase decision is dynamic*. With dynamic bidding, a customer requests bids for a good or service from a list of approved vendors. The items involved are standard products—such as was described in the orphan steel example. Sun Microsystems is using dynamic bidding to purchase commodity-like goods within its B2B infrastructure.

These are some of the options supply chain system designers must consider when building a system. For existing systems, these reflect the forces of change that designers must consider if the firm is to remain competitive in the marketplace. At one time, Compaq had a world-class supply chain management system. Then Dell introduced a disruptive technology–an internet-based build-to-order system.

The above helps define the buyer-seller relationships. Another way is to describe this relationship using a collaborative scale.

Exhibit 2
Spectrum of Buyer/Supplier Collaboration Benefits

Product/Capacity Buys	**Process/Capability Buys**
Reduced Costs	Access to technical expertise
Flexibility	Market information
Better Quality	Rationalization
Name Recognition	Latest technology/processes
Excess Capacity	

At one end we find *product buys*. In these purchase relationships, the suppliers provide the firm with access to products, but little else. Buyers use product buys to obtain goods at: a lower cost, a higher quality, or a product with brand recognition. In some instances a product buy occurs because a scarcity exists and the buyer is seeking access to the capacity to make that product—hence product buys are sometimes called *capacity buys*. Product buys are often the result of a decision to buy a good rather than make it internally. With product buys, the price component of the value equation often matters the most.

At the other end of the spectrum are *process buys*. The buyers of these goods are seeking other benefits, such as technical expertise, access to latest technology, market information, or market channel access. Here, the relationship with suppliers is far more complex and the need to manage it is greater. We are no longer buying parts, products, or access to capacity. Rather, we are buying access to the knowledge, expertise, and capabilities offered by a supplier. Process buys are sometimes called *capability buys.*

With a product buy, we often have an "arms-length" relationship. Purchasing a good in a spot market illustrates a pure product buy since neither the buyer nor seller has assumed an on-going relationship. The buyer identifies exactly what is needed, as was the case with Herb. There is little need for interaction. The deal may be consummated electronically since the content of the interaction is limited to the placing of an order and acknowledging of its receipt, hence they are well suited for application-to-application buying.

Sometimes, buyers of commodities have vendor preferences. The preference may be based on friendship, proximity to your plant, or favorable past experiences. This type of buyer/seller relation still is essentially a product buy, but no longer at the extreme of the spectrum shown in Exhibit 2.

In contrast, with *pure process buys*, either the buyer or the seller is seeking more from the transaction than just a good. In some cases, both may want to establish a closer relationship. Reasons for wanting to do so might include: a desire to gain access to manufacturing or marketing expertise, a recognition that one party has a cost or location advantage not easily matched, or a desire to minimize business risks.

In defining process buying relationships, it is useful to categorize them by the need being fulfilled. We find it helpful to distinguish between *transaction-driven relationships* and *knowledge-based relationships*. With transaction-driven relationships, the parties seek to become more proficient in making a sales transaction happen. Charles Schwab's pioneering stock trading system is a good example of this since it sought to make the trading of listed stocks an easy, arms-length transaction. Herb's steel buying activities have this trait now.

Knowledge-based relationships occur when one or both parties believe that they can enhance their competitiveness by exchanging knowledge, expertise, or market access. A firm may recognize that another firm has a core competency in a certain area that it cannot match. While Motorola had a fine distribution system for its cellular phones in the domestic markets, Motorola found it useful to rely on third-party service providers to distribute and service its products in China.

It is also useful to categorize product buys by the level of commitment. In some instances, we buy a product because the selling firm or its product has the "right stuff" that we cannot get without engaging in a knowledge sharing relationship. A high-end bicycle maker can secure a high-end running gear from Shimano without sharing its leading edge bicycle frame knowledge. In other instances, a competitive advantage can be gained by entering into a strategic alliance.

Strategic alliances are a means to accomplish one or more facets of a firm's business strategy. In their *Alliance Advantage*, Doz and Hamel argue that one enters into a strategic alliance to achieve: [1]

- Co-option turns a potential competitor into an ally. As was noted by Friedman, in a Lexus-lane world, everyone seems to be engaging in everyone else's business. Business strategy is like a game of chess in that a firm always needs to anticipate the moves of all possible competitors--even among your friends.
- Co-specialization, which is defined as a "synergistic value-creation that results from the combining of previously separate resources, positions, skills and knowledge resources." Obviously, this can be achieved through a merger or a buyout, but the strategic alliance approach ideally gives each party a share of the fruits without the long-term commitment. Ideally, this should be the key objective of strategic alliances.
- Learning and internalizing something that another party possesses that your firm ultimately wants to have in its knowledge base. It is this goal that sometimes gives strategic alliances a bad name since it appears that the motive of one party is to "acquire" the capabilities of the other. Yep, that happens. So it is

imperative that each party enters into the alliance with a wary perspective. Any divorce lawyer will tell you that today's lovers are tomorrow's clients.

While we don't want to turn this into a business strategy course, it is imperative that supply chain system designers understand the strategic implications of their decisions.

At this point, it also helpful to remind the reader of the interactive nature of the product design process and the supply chain design process. One output of product architecture is a decision defining what part of the production process should be done internally, and which should be outsourced. As can be seen from the above, this is not a simple make-or-buy decision.

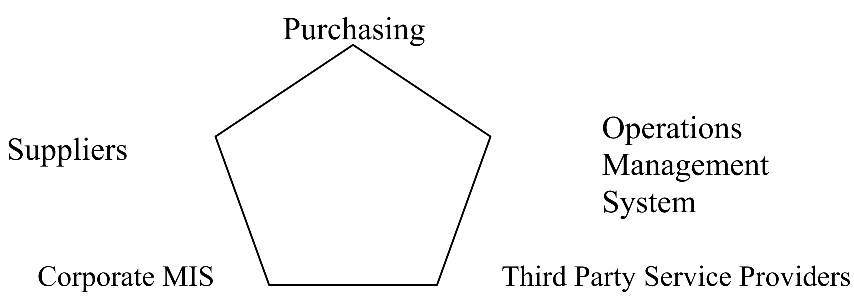
Dialogue Driver:
How would your characterize the historic strategic alliance between Toyota and General Motors which created NUMMI, where they build essentially Japanese designed cars at an old GM plant with former GM autoworkers? The cars and trucks are sold through each companies dealer network.

PURCHASING

The purchasing and the operations functions are closely aligned in their pursuit to support their firm's strategic objectives. *Purchasing is responsible for managing all relationships with suppliers and for placing all buys.* Traditionally defined, it manages what the firm buys, from whom the firm buys, and the terms and conditions of the buys (how much the firm will pay and by when).

Supply chain management systems involves five groups. The role of each within the supply chain is a function defined by the attributes of the purchasing system—including its e-business practices.

Exhibit 3
The Major Players in the Supply Management Process



Purchasing is responsible for representing the firm as the buyer. In many firms, it evolved into a separate corporate function as a result of several factors:

- IT Systems-Dependent: As supply chains become larger in scope and complexity, the need to develop enhanced IT-based systems has also grown.
- Buyer Clout: Clout results from the dollar volume involved. A car company such as General Motors, when negotiating for tires with a company such as Goodyear, has a million dollar deal. The supplier has an incentive to offer a lower price per tire because of the higher profit to be gained on the entire order. This extends to other areas such as terms of payment, quality, warranty, and support.
- Time Orientation: Corporate purchasing often tries to develop long-term relationships with its suppliers. These provide an important vehicle for negotiating lower prices. To the supplier, a long-term relationship means a *reduction in uncertainty.* The supplier knows there is a known demand for a certain amount of its capacity. It can simplify scheduling and production planning since the supplier knows in advance what must be delivered and when. A long-term relationship can lower marketing and overhead costs.

Second, long term relationships indicate commitment. Commitment, in turn, helps ensure a flow of products for the buying firm. After all, the suppliers, when faced by orders from long term customers and customers who are only placing one-time orders, are more likely to meet the needs of their long-term customers. To the purchasing group, ensuring that the firm has a reliable source of supply is the critical task.

Third, long term relationships generate knowledge. The supplier begins to learn more about what the buying organization wants. The supplier begins to understand the type of problems faced by the buying organization. As a result, the supplier can begin to anticipate needs and provide appropriate solutions. Over time, they learn about the capabilities, strengths, and limitations of the organizations. As they learn, this knowledge can be used to enhance the capabilities of each organization.

Performance Metric-Driven: The major role of purchasing is to provide the firm with an assured flow of products. The purchasing department cannot afford to shut down a process because the right items of the right quality were not delivered at the right time to the right place and in the right quantity. Somehow it is difficult to tell an angry operations manager of the great price you paid for an item when that person is faced by a line that is stopped because the item was not there when it was needed. To this end, purchasing tends to be risk adverse when evaluating suppliers.

Dialogue Driver:
Can you think performance metrics that might help the purchasing function to be less risk adverse?

Activities of Purchasing

The major activities of the purchasing functions are:

- Setting the Terms and Conditions Of All Purchases: It is responsible for negotiating the terms of sales, i.e., price per unit, quantity discounts, terms of purchase, warranty policies, return policies, and penalty clauses for late delivery or failure to meet quality or performance standards.
- Supplier Selection: In conjunction with the firm's internal customers, purchasing is involved in identifying and selecting suppliers. This process reflects such factors as supplier capacity, past experience with the supplier, the supplier's eagerness for business, the supplier's specific strengths, limitations, and cost.
- Supplier Scheduling: This responsibility is often shared with the OM system. Purchasing works with the supplier to coordinate the flow so the products arrive at the time when they are needed. This is often achieved through the sharing of information in the form of production schedules.
- Supplier Education: Integrating a supplier requires that the buying firm educate the supplier. The supplier must understand how to read the various pieces of information generated by the buying organization. The supplier must also understand the firm's purchasing policies and procedures.
- Supplier Evaluation and Feedback: A major responsibility is that of providing the suppliers with regular, timely, and meaningful feedback. It must inform suppliers immediately of any problems that have taken place. It should tell the suppliers what they have done well, what areas need improvement, and what actions, if any, the suppliers can take to improve their overall performance.
- Supplier Certification: The purpose of supplier certification is to determine the extent to which the supplier's processes and systems are able to consistently generate quality products in a timely fashion. Once the supplier can prove that they have a controlled system, they can be certified. Ideally, certification allows the firm to simplify the ordering and receipt of jobs from the certified suppliers. Items from certified vendors can now be moved straight from the suppliers' trucks to the areas where they are needed. Wasteful inspection and counting is eliminated.
- Supplier Development: Under certain conditions, the buying organization finds itself faced by the need to develop new sources of supply. The factors which can create the need to develop new suppliers:
  - The product is new and there is no supplier currently providing that product.
  - The buying organization currently is buying the products from a supplier who is located overseas.
  - It has been decided that it would be "better" if there were domestic suppliers for that product.
  - The buying firm may be afraid of being locked into one supplier.
  - Current levels of supplier capacity are inadequate to meet total demand.

- The buying firm may want to work with a supplier who shares its views.
- The buying firm may not be satisfied with the performance of the current set of suppliers and is unable to change their behavior.
  In such cases, purchasing becomes responsible for identifying potential suppliers and convincing them that it would be in their best interest to become suppliers.

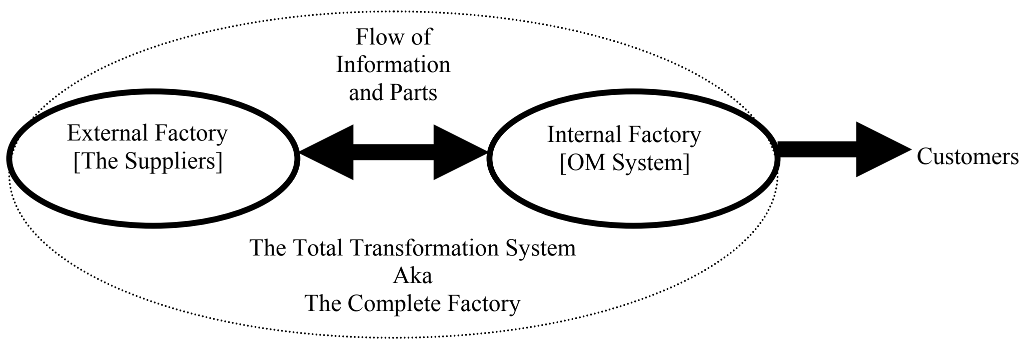
- Supplier Advocacy: Purchasing may need to protect the interests of the supplier from abuse arising within the firm. For example, if production planning frequently changes the schedule, this may make it difficult for suppliers to operate efficiently.

THREE VIEWS OF THE SUPPLY CHAIN

The operations management system is dependent on its supplier for a myriad of things, ranging from paper clips to new ideas and solutions for internal problems. Because of their importance to both the operations management system, three distinct views of the supply chain are used.

Internal versus External Factory: Exhibit Four illustrates this distinction. Thinking of suppliers as an external factory helps operations managers view the suppliers as an extension of their internal operations system.

Exhibit 4
The Total Operations Management System:
The Marriage of the Internal and External Factories



Just as the operations manager must ensure that the transformation process is driven by feasible plans, the purchasing manager and the operations managers must work together to ensure that the production plans of the internal factory mesh with the capabilities of the external factories. This means that we must incorporate into production planning processes information about our suppliers, such as:

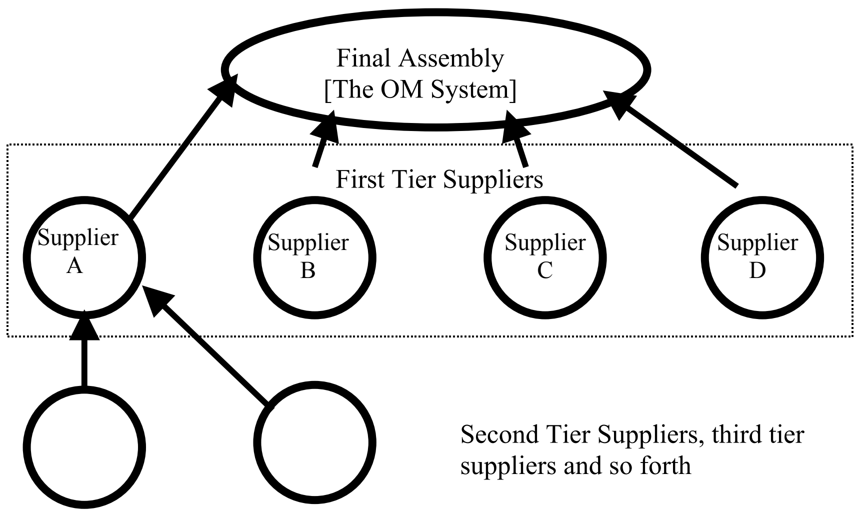
- the levels of capacity available
- your firm's share of that capacity
- likely bottlenecks
- your suppliers' lead-times
- your and their future capacity expansion plans
- any potential threats to production at the supplier's location (e.g., due to strikes)

Increasingly, firms trying to be environmentally friendly are expecting their vendors to be so too.

The Structure of the Supply Chain: When viewing the supply chain, it is sometimes useful to see beyond your firm's direct suppliers by taking a multi-tiered perspective. This perspective sees a supply chain as consisting of all the stages that exist between the ultimate raw material and the ultimate consumer. Direct suppliers are first tier or tier players as is shown in Exhibit 5. Each stage in the supply chain is influenced by actions taken elsewhere within the chain. As a result, effective supply chain management must coordinate capacity not just within the firm but also within the entire supply chain. Just as the operations management system is sensitive to problems with its direct suppliers, so too are their suppliers.

Since each tier in the supply chain is influenced by actions taken elsewhere within the chain, some business process must effectively coordinate activities at all tiers of the supply chain. In an information-rich world, it is possible to coordinate the activities throughout the supply chain. An important organizational structure question is: Is this necessary? Some argue that by selecting vendors with both product and production planning capabilities, there is no need to micro-manage the entire supply chain. But there always are folks or ERP vendors that advocate the wonders of large-scale information systems.

Exhibit 5
A Multi-Level Perspective of the Supply Chain



Supply Chain Ownership: The third way to view a supply chain relates to the boundaries of the internal factory. An issue that each firm faces relates to the degree it engages in vertical integration with its supply chain. With vertical integration, control over the supply chain is established through direct control, gained by purchasing controlling interests (ownership) of each supplier in the supply chain. At first glance, vertical integration seems to be very attractive. With ownership, we have control. However, vertical integration suffers from several major problems.

- Your firm may have trouble maintaining the acquired set of capabilities. There is no assurance that the capabilities that you acquire will remain after the supplier is acquired. Would an experienced refinery manager want to work for the refinery-unit of the convenience store chain Seven-Eleven?
- It may limit your options to buy from others who have developed superior product capabilities. It may also limit the newly acquired unit's ability to sell to others—especially your competition.
- It may reduce the flexibility of the original internal factory. What previously may have been a profitable supplier may not remain a profitable unit of your firm. Its sales to other buyers may decrease. What heretofore had been a variable cost may now be a fixed cost to your firm. Higher fixed costs, in turn, reduce flexibility.
- Ownership may involve a more complex control system. You must put in place the systems and processes needed to coordinate their activities with your systems. Putting in place these systems often creates a bureaucracy. Again, a bureaucracy increases fixed costs and reduces flexibility.

The desire to vertically integrate is usually driven by two factors: the desire to lower costs and the desire to achieve greater control of the supply chain. Both motives are suspect.

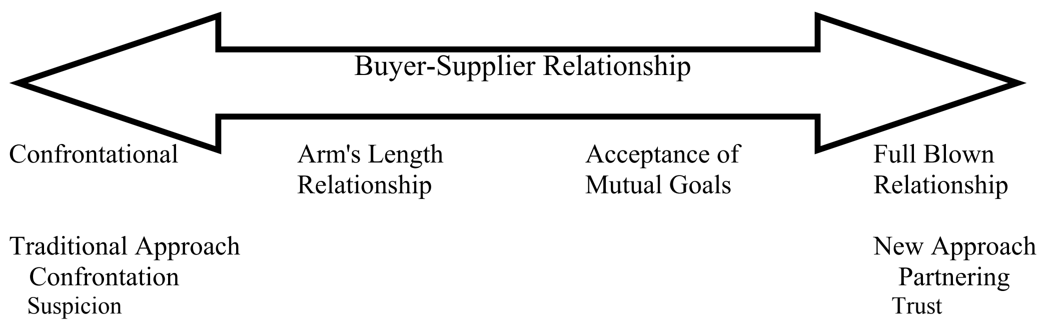
In the ideal supply chain environment, the suppliers and the buyer share the same set of relevant values. Everyone involved understands what constitutes value. In this environment, we do not need the bureaucracy found in vertical integration. It recognizes that the managers in a supply chain are the most qualified persons to manage with their own direct suppliers.

> **Dialogue Driver**:
> Fast food chains often used franchising to provide the human and financial resources to support their rapid expansion. Some are beginning to buy back these franchises. From a value delivery system perspective, does this make sense?

BUYER-SELLER COLLABORATION

The ways in which buyers and sellers interact will vary in some way. Some suppliers work in a relatively formalized and structured manner. While there is a large variety in the types of relationships, we can identify four stages or types of buyer-supplier: [2]

Exhibit 6
Spectrum of Buyer-Supplier Relationships



Confrontation is the traditional buyer-supplier relationship found in many firms. With this relationship, buyers and sellers approach each other with mutual distrust. At the other end, we have *full-blown partnerships*. This relatively new type of relationship is characterized by close working relationships, high levels of trust, mutual respect, and a dramatically redefined operations management system. It is here that we find partnering. Our focus in this section will be on these two extremes in the spectrum.

<u>Confrontation</u>: This is one of the oldest forms of buyer-relationships. This form is most appropriate in product buy situations, which as you recall, have the following traits:

- *Role of the Supplier in the Design Process*: The buying firm is responsible for designing everything that it needs internally. It is not interested in any expertise that the supplier might have. This allows the buyer to maintain control over its products. Suppliers are expected to supply the product as called for.
- *Price is the Primary Basis for Awarding Contracts*: Price is the order winner and the other elements of the value equation are either order qualifiers or not important. In some cases, purchasers are willing to take lower bids for lower quality components that meet the minimum requirements specified.
- *Vendor Competition is Encouraged*: A natural result of buying primarily on direct costs is that the buying firm relies on the old adage that "there is safety in numbers." The large number of suppliers is essentially an insurance policy. If one supplier is unable to meet their delivery or quality obligations, the buying organization can simply turn around to place the same contract with one of the other competing suppliers.

- *Nature of the Relationship*: There is little interaction between the buyer and the supplier. The supplier would never dream of showing up at the buyer's plant just to see if there was any way of offering help or suggestions for improvement. Interaction, when it occurs, is most likely to be the result of an order being placed or a problem. Often, these relationships are marked by a lack of trust.
- *Length of the Relationship*: These relationships are typically short term in nature, often lasting between one to three years. There is no real loyalty present. Both buyer and seller will move on to a better deal when the opportunity exists. Supplier turnover typically is high.

Confrontation is appropriate for mature items and for which there are numerous suppliers available. It is also well suited for ensuring that the buying firm gets the lowest price in the short term.

Confrontation relationships bring with them a large number of important implications for both the supplier and the buyer. Confrontation pressures a supplier to have a cost structure that enables it to offer the lowest price. It needs to fully understand its costs and the likely cost structure of its competition. Suppliers may need to consider restructuring its operations to deliver greater value—perhaps by considering outsourcing or offshore manufacturing options.

For the buyer, confrontation can increase the firm's overhead in one or more of the following ways:

- The buyer incurs all of the design costs. Without input or help from suppliers, it must pay for product design infrastructure. Design engineers must be hired, provided a creative workspace, and managed. All of these actions increase overhead.
- The lack of trust increases the need for exact product specification and inspection.
- It may cost more to manage a larger supplier base, many of which are not familiar with the procedures used by your firm.

It is important to realize that a firm need not adopt a confrontational buying stance for all of its purchases. Some items call for product buys while other items benefit from process buys. Sun Microcomputer recognized this distinction when it set up a dynamic purchasing system for those items that have stable product design characteristics. Its dynamic bidding asks qualified suppliers to bid on many of the commodity-like components that go into its servers. With this A2A process, Sun simply places a request for bid that specifies what, when, and how much it wants and then gets out of the way. It is interesting to note that Sun's approach to commodity purchases actually eliminates face-to-face confrontation by replacing it with a people free transaction. This does not automatically result in the elimination of bad feelings.

On-Line Auctions at GE

In 1999, the head of sourcing at GE's power systems business was experiencing "great savings" running supplier on-line auctions but didn't like the $100,000+ fees they were paying a B2B firm. So they had some Penn State students work with some of GE's software engineers in India and they built a prototype for $17,000 in three weeks. Four months later, the division projected target savings of $50 million a year. But many other GE business units had jumped on the on-line auctions bandwagon and they were promising a billion or so in savings. Welch commented, "I know this sounds like no good deed goes unpunished. You're the guy who got everybody started. You're the damn inventor. Now you have the lowest target." And so it goes in a hyper-learning organization.

(Source: *Jack: Straight from the Gut*, Warner Business Books, New York, 2001, pages 199-200)

Dialogue Driver: If you were a long-term supplier of a commodity-like part, how might you react to GE's bidding system?

Supplier Partnerships: Whereas confrontation emphasizes "survival of the fittest," partnerships emphasize "survival through unity." Partnerships have the following traits:

- They view suppliers as allies -- bound by common interests and common goals.
- They view suppliers as providers of complementary capability, i.e., the supplier provides an expertise or capability that is needed but currently missing in the firm.
- They seek to: maximize value, reduce risk, reduce total costs, and improve competitiveness.

If a firm wants to utilize its suppliers' capabilities and expertise, it must practice different ways of working with its suppliers. In partnerships, the suppliers and representatives from the buying organizations work together as equals and as collaborators. This relationship is frequently characterized by the following traits:

- *Basis for Placing Purchases*: It relies on the suppliers' knowledge base, expertise, and capacity. For example, the 1999 startup, e-machines, was able to build a one billion dollar business with only twenty employees. It did so by working closely with key suppliers who supplied end products and critical knowledge in the areas the firm lacked.
- *Role of the Supplier in the Design Process*: In a partnership, suppliers become involved early in the design process--frequently by means of early supplier-involvement such as that which occurs in concurrent engineering programs. Often they are part of the team that sets down the description of the product concept as equal partners in this process. Their inputs, suggestions, and criticisms are actively sought. They are expected to contribute to the insights gained from their experience in their specific areas of expertise. This demand for extensive supplier involvement early in the design process has a major impact on how the buying organization designs its corporate headquarters or design center.
- *Primary Basis for Awarding Contracts*: In a partnership, the buyer evaluates the supplier in terms of total cost. The buyer recognizes the supplier may have to make significant investments upfront and that these investments must be recovered over future sales of the products. These investments are the costs the buying firm must accept if it wants to benefit from the skills and capabilities of these suppliers. By using a total cost approach, the buyer recognizes that the costs of placing the order with the supplier are often far less than those costs it would have incurred had the same item been designed and built internally or designed and built externally by other suppliers who lacked the needed expertise.
- *Size of the Supplier Base*: With partnership, the supply base is greatly reduced. The goal is not to have a large number of somewhat qualified suppliers but to identify and work with a small handful of competent, qualified, and cooperative suppliers. As W. Edwards Deming once pointed out, "We need fewer suppliers...It's difficult enough to find one supplier who can supply the quality you need, much less two, three or half a dozen." There are several compelling reasons for reducing the supplier base:
  - By increasing the size of purchases placed with each supplier, mutual dependence is created between buying and selling firms.
  - If we were to look at a list of potential suppliers, we would find a small handful of very competent suppliers and a majority that is either average or below average. Eliminating "poor" suppliers can significantly improve quality, lead-time, delivery reliability, flexibility and total cost.
  - Reducing the supplier base creates the opportunity for mutual learning and trust to develop. We can spend time learning about our suppliers, their strengths, and limitations.
  - Reducing the supplier base commits us to the existing suppliers. This commitment fosters trust.
    - *Nature of the Relationship*: In a partnership, relationships must be close, open, and informal. Since partnerships are most effective when dealing with problems, it is difficult to set down all the possible terms and conditions governing the relationship in a contract, i.e., minimize the number of lawyers. Openness and informality is necessary to facilitate the give and take that accounts for any problem solving undertaking.
    - *Length of the Relationship*: A partnership tends to be long term in nature with turnover being very low. The factors encouraging high turnover are absent. Partnership fosters loyalty. A partnership becomes the corporate equivalent of a marriage.

Why Change from Confrontation to Partnerships

We are now faced with customers who want more value and they want it now. Partnerships are ideally suited to the demands of this new type of environment. Instead of hiring those people who can help the firm respond to a new demand, the firm now turns and identifies those suppliers who offer the necessary capabilities. The partnership lasts as long as it satisfies the needs of both parties. As needs change, the firms respond by working together to develop their ability to meet the needs of a changing marketplace. The result is a system that gives us flexibility and speed.

Partnerships work well in the Lexus lane, in part because the following factors have occurred:

- Advances in telecommunication technology: An explosion of advances in such areas as communication, computer power, and graphics has occurred. These developments facilitate the growth of partnerships by allowing the high degree of connectivity required by partnerships.
- A Recognition that firms possess a finite number of core competencies: There is an old saying that he who claims to be masters of all, is master of none. In a similar vein, business strategies argue that a firm is unlikely to achieve core competencies in more than three of four areas. Firms need to seek out suppliers that possess core competency in areas that your firm's capabilities are lacking.

The goal of the supply chain is to deliver products that your customers value. It matters little to the consumer how the supplier was able to create, produce, and deliver world-class value. Just do it!

Dialogue Driver: If we accept the preposition that core competencies ultimately lose their competitive strength, how can a firm strive to ensure the development of the core competencies of tomorrow?

PROCESS TOOLS FOR SUPPLY CHAIN MANAGEMENT

We now shift our attention to the process tools -- those tools and techniques available to the operations manager when dealing with suppliers and the transformed operations management system. We will look at one macro-approach and four part-focused tools.

Cost Reduction by Edict

One downside of partnerships is that buyers with clout often ask their suppliers to "share the pain" in tough times. There are many ways in which this is done, but we will discuss two.

Event-Driven Edicts: When the buyer faces major downturns in profitability, it is not uncommon for them to demand across the board decreases from suppliers. Chrysler was reported to have saved $2 billion in 2001 simply declaring that it would pay 5% for the parts it buys this year and another $3.8 billion over the next three years. This is not unprecedented: a few years back, GM promoted a tough-minded purchasing executive from its Spanish subsidiary. The resulting $11 billion cost savings helped return GM to profitability. *

Since Chrysler values its supplier partnerships, it has created 55 buyer/supplier teams to help find ways to build "the hundreds of boring car parts that the customers don't see." [3] But this program places Chrysler at risk because over the years, it has profited the most from having strong supplier relations.

Continuous Cost Reduction Programs: Other firms have recognized a continual need to enhance one's cost competitiveness by asking suppliers to reduce costs by a smaller but constant percentage each year. Japanese

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* When Volkswagon hired this individual away from General Motors, GM sued to prevent the move claiming that as a VP of Purchasing, he possessed many trade secrets. GM lost.

firms have long expected a small reduction in prices each year. This is an expected benefit of long-term supplier relationships. Nissan and Toyota work with their suppliers to identify areas for cost reductions.

Make-Buy Analysis

The most basic supplier-related decision faced by any operations manager is that of whether a given part or product should be made internally or bought. In the past, this was the major analysis applied to all products, irrespective of whether or not they were related to the core competencies of the firm. With the introduction of partnerships and virtual factories, outsourcing is appropriate for non-core competencies items.

Make-Buy Analysis is a decision-making process built around total cost analysis. With Make-Buy Analysis, our goal is to obtain the supply of products from the source that is the lowest cost. The output of Make-Buy Analysis is a recommendation to either buy or make a specific product. Since it is a process, there are a number of well-defined steps that must be followed to arrive at this decision:

Step 1: Determine if the product being evaluated is related to a core competency of the firm: The very first step is to identify the product being considered for outsourcing. Once identified, next we must determine whether the product is related to our core competencies. If the product is related to a core competence, then the Make-Buy Analysis should stop. This is a strategic decision.

When dealing with core competencies, suppliers can offer products at a lower cost for several reasons. First, they may be willing to make products at a loss simply to learn about our core competencies. For example, Samsung Electronics of South Korea bid for a contract to make microwave ovens under private label for Montgomery Ward. When making the initial bid, the management at Samsung knew that the company would lose money on every microwave that they sold. Why? It knew that it would be competing against firms such as Sanyo, Panasonic, and GE. What Samsung lacked was knowledge of the market and its requirements. By working with Montgomery Ward, Samsung learned what went into a successful microwave and what did not. This experience enabled Samsung to build better products and eventually terminate its contract with Montgomery Ward. At that point, Samsung was ready to compete head to head with the other major microwave manufacturers.

Another reason that a firm can compete in what you consider your core competence area, is that the supplier may be more efficient at building these products. When this occurs, the firm must learn why the supplier is better.

These lessons must be brought back and applied to the firm. This is one reason for the development of Benchmarking.

If the product is not related to the firm's core competencies, then we can consider the product as a candidate for outsourcing and move to the second step in the process.

Step 2: Determine if outsourcing is appropriate for the product: Make-Buy is most appropriate for products in the mature stage of the product life cycle. It is also appropriate for commodities. Make-Buy Analysis is typically not appropriate for products found in the early stages of the product life cycle unless the buyer elects to include this firm as a partner in a process buy situation.

Step 3: Determine the reasons why *the firm* is considering outsourcing the specific product: It is important to determine any other reasons or implications of the Make-Buy Analysis. The decision to subcontract can be driven by such considerations as cost or the need to free up internal capacity. For example, if we find that the transformation process is over-capacity (the load exceeds available capacity), then by having some items subcontracted out, we can free up the associated capacity used by these products and use them for other more profitable items. However, if the decision to subcontract a product results in capacity being freed up and left unused, then we may not experience a cost reduction.

Step 4: Identify, classify, and assess all of the relevant costs associated with the Make-Buy Decision. Involved in this step is classifying the costs as to whether they are fixed, relevant, direct, or hidden. It is at this stage that we now begin to apply the total cost procedures first introduced in Shell 5. The focus in this stage is strictly on *quantitative* costs. We must deal with the hard quantitative costs before proceeding to the qualitative costs (the second part of the total cost approach). All costs involved in any Make-Buy Analysis are assigned to either fixed or variable categories.

Beginning the analysis with such a detailed breakdown of costs by make and by buy is very useful. First, it shows where the various cost advantages are. We can see on what specific cost categories the supplier does better than we do and where we perform better than the supplier. By identifying the areas in which the supplier excels, we can get a better understanding of the nature of the cost advantages possessed by the supplier. These cost advantages might reflect superior efficiency. Alternatively, the reason for the supplier's cost advantages *might be the result of our fixed cost allocation practices*. That is, our accounting system may make the "make" decision look poorer because of the manner in which the various overhead costs are allocated. By knowing both our cost structures and those of our suppliers, we are better prepared for any negotiations.

When dealing with fixed and variable costs, we must be prepared to deal with the problem of how to handled fixed investments such as tooling. Tooling investments can take three forms (of which the first two are fixed while the third is variable):

- Fixed Cost per contract: A one-time cost of acquiring the tooling at the outset of the contract.
- Fixed Cost per order: Cost of maintaining and checking tooling which occurs whenever the products using the tooling are run.
- Variable Cost: This is the cost of tooling used per part (through wear and tear).

In addition, there is the cost of quality. The cost of quality in a Make-Buy Analysis deals with the costs of getting the required number of good pieces.

Step 5: Identify and assess all qualitative costs associated with the Make-Buy Analysis. Qualitative costs differ from quantitative costs in that they are more difficult to measure and the values of these factors are often highly subjective (varying from decision-maker to decision-maker). In the case of a Make-Buy Analysis, we find ourselves faced by numerous qualitative factors such as:

- Loss of control by releasing the work to a supplier;
- The risk of dealing with a new supplier.
- The importance of dealing with a supplier with a proximity advantage.
- The importance of dealing with a supplier with world-class management processes.
- The importance of dealing with a supplier whose value structure closely parallels ours.
- The degree to which the supplier is willing to work closely with us and accommodate changes in production schedules.
- The dangers associated with losing the internal skills in building those products that are considered for release with a supplier.
- The labor-management climate that exists within the supplier.
- The quality of the warranty repair and support systems in place at the supplier.

Qualitative costs are often central to the "Make-Buy" decision when international suppliers are involved. With increasing globalization of supply chains, international suppliers are often being considered . There are very good reasons for considering an offshore supplier, such as superior quality, lower prices, advanced design and production capabilities, and the product is not available domestically.

Step 6: A Review of the Capabilities of Current Suppliers. Next, we must review the technical, financial, quality and manufacturing capabilities of our current suppliers. This review is done to see if the suppliers can realistically handle the current and future business being considered for them. This review is future-oriented rather than being concerned about past performance.

Step 7: An Assessment of New Suppliers. If considering a new supplier, then we must assess its capabilities. This comparison can be done against the current supplier or your factory's capabilities. This benchmarking helps us position the new suppliers relative to a set of standards. With this positioning, we can better evaluate the real attraction offered by a lower price. A low price offered by a new supplier with systems and capabilities far below those of our current suppliers or the best-in-class suppliers is no real bargain.

Step 8: Make a Decision and Implement It. We now have enough information for a decision. It is time to make it. If we are going to buy the product, we must identify which supplier (or suppliers) will receive the order and the anticipated benefits associated with the decision to make as compared to buying. If we decide to make the product, then we lay out the reasons for this decision. In implementing the decision, we worry about such matters as negotiating the contract and terms and conditions of the buy.

Step 9: Monitor the Decision and Review and Revise as Necessary. Once we make the decision, the Make-Buy Analysis does not end. It requires one more step -- that of monitoring the resulting decision. The goal here is to determine if the actual results are in line with the estimates and to identify potential problems. With this step, the Make-Buy Analysis process is completed.

Vendor Scheduling

Vendor scheduling links the production activities of the vendor to planned activities of the buying firm. The goal is to mutually support the production schedules of the buyer and supplier firms. We are interested in making sure that the supplier is always able to provide the transformation system with the specific goods with the appropriate quality at the right time, place and cost. Timely information makes good reliable suppliers.

Vendor scheduling can be done in a number of different ways. It can be driven by a list of orders released periodically by the buyer. The orders simply tell the supplier what products have to be provided, in what quantity, at what time, and where. It is the suppliers' responsibility to make sure that these orders are filled. The problem with this approach in practice is that it tends to encourage decoupling through the use of inventories. The supplier produces parts that are placed in its finished goods inventory. When the orders are received from the buyer, they are first filled from their inventory.

If the supplier does not know what goods it is expected to deliver until the moment the orders are received, then these orders may require changing the current master production schedule and creating a new one. The result may be wasteful rescheduling of the supplier's system. Alternatively, the buying firm can decide to link the supplier to their internal operations management system through the use of a computerized production planning and scheduling system. The operations manager can provide the suppliers with access to the production schedules for the components that they provide. This access is either by mail (the schedules are sent to the suppliers via mail) or electronically. In this case, the supplier can downloading the schedules to their own system. Both buyer and supplier benefit from this transfer of information.

Value Engineering

Value Engineering (AKA Value Analysis) is a structured process aimed at improving product design while maintaining the function provided by the product and the marketing appeal to the customer. Value-Engineering programs typically involve cross-functional teams. The teams often involve suppliers. To be a member of a Value Engineering team, the person must have critical information about the product, its function, its marketing appeal, and the manner in which it is made. Value Engineering projects are most effective during the early stages of product design but they can be used to squeeze costs out of mature products.

To provide a formal vehicle for supplier involvement during the design stages, many companies have modified simultaneous engineering by introducing *Early Supplier Involvement* (ESI) programs. In many of these ESI programs, Value Engineering is often used as the vehicle for focusing attention on a specific goal or objective -- that of reducing product cost.

In general, Value Engineering is a major undertaking. It requires a significant commitment of corporate resources, time, and effort. However, many firms are willing to make these investments because of the potential benefits offered by successful value engineering programs:

- Average purchasing costs have fallen by 25%. The general rule is that a minimum 10% reduction can be achieved without really trying while reductions of up to 75 % are not uncommon.
- The rate of return on value engineering programs is significant, yielding up to a 100-to-1 return on investment.
- Value Engineering has resulted in improved customer satisfaction. When properly applied, it enhances all elements of customer satisfaction (cost, quality, lead time, and flexibility) while improving the performance to cost ratio (i.e., value).
- Value Engineering fosters lucky discoveries. In exploring new technologies and materials, Value Engineering helps the user uncover discoveries that can significantly reduce costs (e.g., the use of plastic as a replacement for steel in the drill example previously discussed).
- Higher employee morale. Value Engineering encourages and fosters teamwork and creativity. It encourages people to look at problems differently.

The starting point for all Value-Engineering activities is the *function*. Functions describe what the part or product does, not what the part or product is. A paper clip, for example, is not a paper clip. It is a method for marking pages. It is also a method for keeping certain papers together. Every function can be broken down into two categories: functions that make the product work and functions that make the product sell.

During the process of assessing functions and their associated costs, the following questions are used to help direct effort and focus attention:

- Can the function or the part itself be eliminated?
- Can the part or product be simplified?
- Can the part or product be altered to accommodate a faster method?
- Can standard parts or materials be used?
- Can a higher-cost material be used that will simplify the design and/or production?
- Can tolerances, finishes, tests, or packaging be reduced in cost?
- Can other features important to the customer (e.g., service, safety, flexibility) be pursued?

Recently, Chrysler announced that it had been able to reduce the cost of making its 2002 PT Cruiser by making hundreds of tiny changes in the design of the parts going into this car. [4]

Supplier Certification/Evaluation

It is not enough to link suppliers to the operations management system. Effective relationships need recognition. This need for recognition is provided in part through *Supplier Certification/Evaluation* (SCE) programs. With these programs, the buyer proclaims that the following vendors have achieved the levels of excellence expected of suppliers.

SCE involves two activities: supplier certification and supplier evaluation. Supplier certification focuses on the supplier’s business processes. Supplier evaluation deals with their performance. Each supplier knows how it is doing according to well-understood performance metrics.

With supplier certification, our goal is to identify and develop “good” suppliers. The implication is that the buyer intends to work primarily with these suppliers. A “good” supplier is defined both by its product and its processes. Good suppliers are expected to have in place business processes that are clearly documented, understood, and more important, under control. The industry equivalent to vendor SCE is ISO 9000—a program focused on documenting the processes used.

Supplier certification can be carried out through on-site visits. That is, a cross-functional team can visit the supplier's facilities. They study, through first hand observation, the operations of such processes as:

- the material handling system
- the capacity and production planning systems
- the scheduling and shop floor control system
- preventive maintenance
- the product design system
- quality control
- data base management
- housekeeping

When visiting the operations, we would focus on such areas as documentation (presence, completeness, accuracy), control procedures, specific statistics tracked, and user knowledge of the processes and their associated corrective procedures. For example, it is not uncommon during one of these visits for one of the members of the visiting team to talk with an operator on the line and ask that person how they would handle problems involving machine breakdowns in order to provide insight of how processes are managed.

Supplier evaluation *is an essential part of the feedback process*. It is communication that tells the supplier how they have done in the past in terms of specific performance goals. It also provides a mechanism by which we can tell the supplier that we have a problem with their performance. In many ways, supplier evaluation is similar to the testing process with which nearly every student is familiar. Like the student evaluation process, supplier evaluation is used to satisfy certain important objectives:

- Supplier Evaluation acts as a Score-Board: The evaluation process tells suppliers how they are doing. This comparison can be done using a set of minimum criteria that the suppliers are expected to meet (e.g., all supplier deliveries cannot be received any later than 1 day after the due date). The comparisons can also be done relative to other suppliers.
- Supplier Evaluation Clarifies Expectations: When we begin to evaluate someone else, we begin to define what it is that we are looking for. These expectations operate at two levels: the minimum criteria that a qualified supplier *must* satisfy and the criteria that define superior performance. Suppliers that do not measure up are then expected to improve by changing their processes.
- Supplier Evaluation Identifies Strengths and Weaknesses: This information facilitates improvement by directing attention to those critical weaknesses that must be improved.
- Supplier Evaluation acts as an Audit Trail: Over time, the evaluations document the supplier's performance and provide a basis for determining whether we will keep a supplier. If a supplier has repeatedly received poor evaluations and has not taken sufficient corrective action, then the decision to drop that supplier should come as no surprise. The supplier has had sufficient warning.

To be carried out effectively, any supplier evaluation systems must have the following traits:

1. Simple to use and understand.
2. Consistent with the objectives of the buying firm: How we evaluate our suppliers should be consistent with how we compete in the marketplace.
3. Generate meaningful measures: The evaluations should generate results that are readily understood by the supplier. Then they can use the information to take appropriate actions.
4. Consist of a limited number of performance measures: Too many measures lead to confusion.
5. Provide rapid and timely feedback regularly. Often it is initiated after a problem involving the supplier's products have been encountered at the buying organization's site. In general, it is a good rule of thumb to assume that the more frequent the evaluation, the better. The events that led up to

the evaluation are fresher in the mind of the supplier so corrective actions are easier to identify and take.

6. Provide tough but realistic goals for the supplier.

SUMMARY

Emerging management thought and evolving information technologies have impacted the supply chain management function more than the other functions. Two concepts are changing management practices—the concepts of value and core competence. These along with information technology advances now make it possible to create full blown partnerships that enable firms to achieve the speed and flexibility to succeed in fast paced markets. The tools used by supply chain managers remain useful but each must be viewed within the context of these newer possibilities. The e-commerce craze is over—but rising from its ashes are technologies that are having a powerful effect on operational effectiveness throughout supply chains. The sales, service, product design, manufacturing and purchasing functions all will be integrated by information technology to create and deliver products that customers truly value.

End Notes

1. Doz, Yves and Gary Hamel, *Alliance Advantage: The Art of Creating Value Through Partnerships,* Harvard Business School Press, Boston, 1998.
2. Bote, Keri R., *Strategic Supplier Management: A Blueprint for Revitalizing The Manufacturer-Supplier Partnership*. New York, New York, American Management Association, 1989.
3. Robyn Meredith, "The Anti-Iacocca," *Forbes,* August 20, 2001, p.50.
4. Ibid, p. 51.

Expected Learning Competencies

Before putting Shell Ten down, you should ask yourself the following questions. Am I able to explain:

9. What constitutes a firm's supply chain and the ways in which the parties transact the flow of materials and information within it
10. Both the traditional and emerging roles of a firm's purchasing function. Be able to explain what is meant by the term e-purchasing
11. The various types of supplier-buyer relationships and when each type makes sense in a value driven system
12. What the major trends impacting supply chain management are, especially the roles of information technology.
13. What the product buy and the process buy concepts are and when each is an appropriate model for purchasing behavior.
14. What each of the supply chain management tool does and the situations in which they are appropriate.
15. What your instructor added to this shell and why he or she thought that it was important enough to warrant its inclusion.

Frequently Asked Questions

Instructors have been known to ask questions similar to the following:

1. Describe how a firm's supply chain system can enable of firm to gain a competitive advantage, Provide three examples to illustrate your argument.
2. Use your knowledge of business history to describe how the supply chain systems of large American firms have evolved from the early days of the Ford Motor Company to the Dells of today.
3. Describe how the job description of a firm's purchasing manager has changed in the last twenty years.
4. How have information technologies, such as bar coding, changed the way we manage supply chains today.
5. When a firm elects to buy some of its supplies using a GE-type auction, this is most appropriate approach for buying:
    a. Products that will give us a core competence
    b. Commodities
    c. Products well endowed with new technologies
6. With full=blown partnerships, which of the following generally is not true?
    a. The buyer evaluates the supplier in terms of total costs.
    b. The supply base is greatly reduced, i.e., the number of firm that you buy from is less.
    c. The relationships tend to be open and long standing
    d. Come on Teach, they all are characteristics of partnerships
7. Make-buy analysis is only done for product buys.
8. Vendor scheduling can be used best in confrontational style buying relationships.
9. Most supplier certification programs involve inspecting more than just the good being sold.
10. Supply chain management involves only the manufacture of goods, not services.

BUCKET THREE
MANAGING FOR VALUE

The four shells in this bucket focus on the execution phase of operations management. They assume that the product has been designed, the physical facilities built, and the target customers well identified. It then becomes the task of the operations manager to perform the prerequisite tasks with the resources provided.

Bucket Three begins with Shell Eleven—Short Term Operations Planning. It describes the activities operations managers do to utilize the facilities designed in Bucket Two to make the world class-products created by the firm's product innovation systems. It is here that operations managers transform information, human, and material resources into customer-pleasing products.

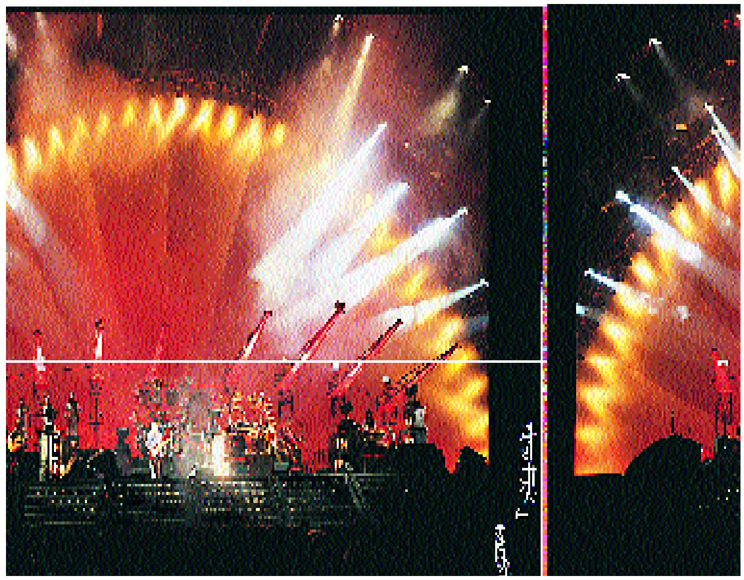
Shell Twelve focuses on how operations managers strive to achieve conformance quality, i.e., to make goods and services that meet the design specifications articulated by the firm's product innovation processes. It builds on the general tools introduced in the OM Toolkit to describe how these become an integral part of the firm's total quality management program. While it stresses the importance of statistics within TQM, it also emphasizes that TQM is *a management process* that uses statistics but achieve results through people.

Shell Thirteen introduces the three basic means that firms use to manage the flow of tangible things through a supply chain. These are: independent demand inventory management systems, materials requirements planning, and just in time systems. In each case, the importance of collaboration, cooperation, and information technology are discussed.

The last shell deals with getting the work done—or at least doing the scheduling that is a precursor to actually performing tasks. Scheduling work covers this activity both in services and manufacturing operations. It includes some of the traditional local decision rules that industry has found useful over time and the newer theory of constraints approach to scheduling.

SHELL ELEVEN

SHORT TERM OPERATIONS PLANNING



Pink Floyd to Go

As the plane approached the Phoenix airport, I marveled at the monstrous stage being constructed for a Pink Floyd concert in Arizona State's football stadium. A night in a hotel adjacent to the stadium provided an unsolicited secondary experience with the spectacle of the show. Kaleidoscopic lights and laser beams lit the sky above the stage's 130-foot, McDonalds'-like arch. My windows pulsed with quadraphonic sounds from 300 speakers that spread the music far beyond the boundaries of the stadium. The British rock group gave fans a truly ear-pleasing, eye-popping experience.

The next morning, crews began to dismantle the stage that they had built only days earlier. They had used it for a single night's performance. The band was scheduled to play next in El Paso on Tuesday and then moved on to Dallas for a Thursday-Friday night gig. How could the crew tear down the entire set and have it ready for another show in two days?

It turns out that they don't. The 700-ton Phoenix set was just one of three that hopscotch the country for the band's 22-show tour. Each of the three sets has a setup crew of 200 that is responsible for getting everything ready for the next show. Besides preparing the stage, this team had to hire people and service firms to perform all of the other business processes that a successful rock concert requires. These included: printing, selling, and taking tickets; providing security for the set and the audience; hiring food and beverage vendors; and cleaning up post-concert litter. The tour's operations managers even hired a group of traveling doctors to administer to fans overcome by the excitement of the day.

This band relies on successful execution of its operations planning process. Each concert represents a sub-project within the larger 22-show tour. To ensure success for these projects, managers must secure the necessary resources to efficiently and effectively complete the tasks of each key business process. Based on the crew's work, each concert customer will form an opinion of the total concert experience. Did the band still have it? Did the food and drink meet expectations? Were the portable personal relief facilities ample in number and acceptably clean? In short, was the show fun and worth the hassle?

The ultimate performance metric is the fan, but after each gig, Pink Floyd strives to have its backers, the community, and suppliers all saying, "See you next year." This achievement hinges on effective planning and being capable of executing the necessary activities. The technical aspects of the sound and light systems should leave fans amazed. News reports should focus on the fulfillment of promised experience rather than the antics of beer-stained rowdies. Good operations management is essential if Pink Floyd's organization is to accomplish its fan satisfaction goal.

Source: "Pink Floyd's Retrogressive Progress," *USA Today*, April 25, 1994, p. 1D.

Shell Eleven
Short Term Operations Planning

Table of Contents

Learning Objectives for Shell Eleven

After reading this shell and thinking about its content, you should be able to:

1. Understand the role short-term operations plays and how it is linked to other long-term planning processes.
2. Understand how each of the following inputs is used in the short term operations planning process:
   a. Aggregate demand forecasts
   b. Demand tracking signals
   c. Current shop load conditions
   d. The state of the economy
3. Understand how a company's business environment shapes operations planning.
4. Demonstrate how to use each of the following production planning tools:
   a. Input/Output Control
   b. Aggregate Production Planning
   c. Master Production Planning

INTRODUCTION

The fans leaving the stadium after the Pink Floyd concert probably understood little of the integral role its operations planning process played in creating their delightful product experiences. OM processes should remain in the background. Pink Floyd's fans did not come to the show to witness the OM function, but to be entertained. If the entertainment had failed to satisfy them, no amount of OM skill could have saved the day.

Effective planning is the unseen hero of most successful business endeavors. Customers deserve effective implementation of realistic operations plans. When all does not go well, problems result. We often call these problems, but in actuality, they are usually a symptom of an inaccurate short-term demand forecast, poor operations planning, or ineffective execution of operations plans. In the entertainment world, one only needs to revisit Woodstock to understand what happens when the necessary operations planning infrastructure fails.

When discussing operations planning, it is useful to recognize its hierarchical nature. Within the OM, practitioners categorize planning processes as being either: operational, tactical, or strategic.

Exhibit 1
The Operations Planning Hierarchy

Level	Customer	Business Activity
Strategic	Corporate/Senior OM Executives	Marketing Strategy Product Innovation Supply Chain Structuring Capital Budget Process
Tactical	Regional/Plant Level	Intermediate Term Planning Plant Utilization Strategy Capacity Budgeting Organizational Control
Operational	Operations level	CRM Materials Management Scheduling Work Managing Human Resources

As one moves from strategic planning to operational planning, three distinct trends occur:

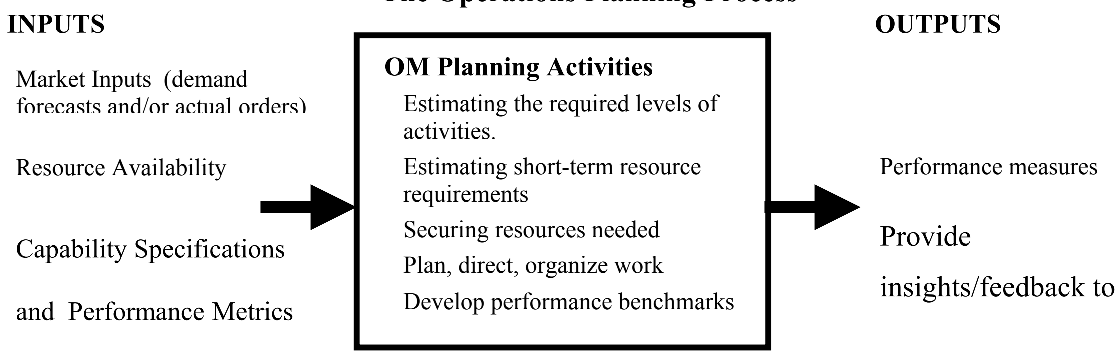
- The *time horizon* for the planning process becomes shorter. Strategic planning's time horizon requires planners to think in terms of years. Operational planning involves time horizons in weeks or less.
- The *level of detail* used in the planning processes becomes more detailed as one approaches operational planning. Strategic planning often is done on an aggregated basis, i.e., in financial terms, or aggregated physical terms, such as tons of steel. Operations level personnel need more detailed numbers so that they can schedule actual production. A fast food restaurant manager needs to know the projected volume of Chicken McNuggets sales so that the right amount will be on hand.
- *The planning interval becomes more repetitive* as one moves toward operations, planning often is done daily or as needed. One wag once said, "We don't do planning. We do re-planning, *all of the time*!" But such are the needs of operations managers striving to do the best job in an uncertain environment.

Planners normally are not operations-level decision makers**.** The planner's job is to collect relevant data, analyze it to find meaning, and then make recommendations to line management. In small businesses, line management performs these activities because staff often doesn't exist. In large organizations, *some* planners confuse ownership of data with organizational power.

In this shell, we focus mostly on operational planning processes that *enable* rock stars and others to give world-class performances. Recall that effective system design requires the firm to develop a fundamental understanding of what customers value. This is transformed into a set of capability specifications that define what business processes must do to meet the needs and expectations of customers. To be a success, management must then develop business processes with these value-delivering capabilities. Finally, a performance measurement system should be in place to assess the organization's effectiveness.

Most of the decisions needed to create these capabilities involve strategic commitments, i.e., the siting and sizing of facilities, the acquisition of equipment and information systems, and the creation of an organization with a culture that serves the corporate strategy well. The shells in Bucket Two described how firms should make the strategic *long-term* resource commitments that will enable its operations function to achieve its corporate objectives. There are a number of operational decisions that also must be made in the *short to intermediate time* horizon to ensure that the operations function has the resources needed to do its job.

Exhibit 2
The Operations Planning Process



The inputs to the short-term operations planning process come from the following four sources:

- A clear statement of the organization's mission along with an identification of who the targeted customers are and a profile of each customer family's values. At the extreme, these are families of one.
- Operations systems with clearly understood capability specifications. Each capability specified should have matching performance metrics
- Information that describes market conditions, e.g., orders received and the demand forecast. Information inputs often are a mix of detailed actual orders and aggregate demand forecasts. In some instances, knowing the planned marketing programs and promotions of both the firm and its major competitors provide useful inputs.
- Current system status, including information pertaining to the availability of the factors of production needed to carry out a plan. These include labor, raw materials, and transportation. Planners need to know the factors of production on hand, i.e., the current work force, current levels of work in progress, and known commitments from suppliers.

The first two inputs specify the general expectations the firm has for its operations function, i.e., what it must do, for whom, and how the firm plans to win satisfaction from these targeted customer families. The last two inputs provide the operations planning function with the situation's specifics, i.e., what specific customers want or are likely to want and what factors of production operations must have to accomplish the expected.

SHORT-TERM DEMAND INPUTS

In Shell 6, we discussed how the firm should go about designing its demand information system (DIS). This involved identifying the attributes of the demand inputs that would be feasible and most useful to the business processes requiring these inputs. Understanding where the most useful market/demand information could be found was also discussed at the design phase of business infrastructure planning.

At the operations planning level, understanding what is happening in the marketplace is the most important input. Operational planning serves two types of internal customers. The first wants to know "How are we doing?" and "Has anything significant happened that may cause me to rethink the business plan?" The second internal customer wants to know "How much production should my area be prepared for?" and "Exactly what will it be expected to make?" While both types are asking for detail, the nature of the detail is different. The first wants information that will be useful to a business plan reevaluation process. The second wants details that will help them to make the right stuff. Neither likes surprises.

Aggregate demand inputs to the short term planning process can either be actual customer demand, customer intentions, or market indicators. When the number of products is small, such as the sale of jet aircraft engines, short-term demand can be a census of all incoming orders. If on the other hand, you are selling light bulbs, it makes sense to use sample data to gain a sense of the market. Jack Welch, GE's former CEO, tracked the average number of light bulbs purchased by individuals since he had learned that when times are good, consumers buy them by the dozen. When less confident, they buy light bulbs one at a time.

A second way to gain a sense of short-term market conditions is to look at market indices that have in the past been good indicators of what will be happening in your market place. Within the electronics industry, the semi-conductor bill-to-book ratio indicates whether or not the industry is receiving orders at a faster rate than it is shipping them. A national survey of purchasing managers provides a broad sense as to whether or not the business outlook is looking up or down. The key to making this information useful is to be able to link this exogenous data to how well your firm is doing. Ideally, finding a leading indicator for your sales provides you with timely inputs to your operations planning process.

One increasingly important method to gain a better sense of the market demand is to simply ask customers what they plan to purchase. Supply chain collaboration has been called "close encounters of the best kind." Getting close customers is not always possible, but the CPFR initiatives should be explore before one expends too much time trying to go it alone.

A third way to gain a sense of how well the company is doing is to look at factory load and the backlog of work in the order file. Comparing this aggregate measure against plan and prior year's data givens a broad sense of the firm's demand.

Dealing with Out of the Box Data

Another way to gain a firmer sense of marketplace doings is to record and highlight out-of-the-ordinary phenomena. Here, subjective reporting works best. These events may be viewed as aberrations in time series–-data points that you wish weren't there because they mess up your model. But management needs to know the unusual in part because it does not like being blindsided. It also foments management curiosity, a key input to the corporate learning process.

Disaggregating Demand Data

Detail is a necessary attribute to the operational planning process. Detail provides operations with demand/usage information that the system needs if it is to make the right quantities of the right items at the right time. Detail is needed both for end products and the parts needed to make end products. Since each end product requires a mix of parts, preparing forecasts for each part's usage pattern often is a monumental task. Let's see how this can be done at each level.

The nature of the end-product demand input is a function of the market orientation that the firm is using. In make-to-stock environments, the firm must base its short-term production plans on forecasts of what it anticipates it will sell. At the selling end of the supply chain, the firm must place *resource bets* on what items customers will want. Bad bets result in unsold items, slower inventory turnover, or stock outs. As one moves up the supply chain, operations planning often experiences demand when reorders occur. Because reorders are done periodically and often in lots, a demand pattern that is a smooth flow of end-product sales is transformed into lumpy, intermittent demand pattern upstream. In this situation, a firm's operations planning process suffers since it does not know first hand what is selling and what is not. In an IT driven world, this need not be the case, but it requires cooperation from the players at the retail level.

With the MTO, ATO, and ETO market orientations, operations planning uses actual orders to plan production activities. If market demand exceeds the plant's demonstrated capacity, then the planning system needs to inform sales and top management in time to make timely actions. Ideally, the plant's capacity can be augmented with additional resources. If this is not the case, marketing must be advised so as not to make promises that the firm cannot meet. If demand is less than planned, resource levels must be reduced.

Translating end product demand into part demand requires the planning process to know three things.

- It needs to know **what** is needed to make each product. In OM lingo, this is called a *bill of material*.
- Since some parts are used to make more than one end product, planning needs to consolidate these parts requirements to determine *how much* is needed to support all demand.
- It needs to know *when* parts need to be made in order to be available for the next stage of production. This can be a difficult task because planners do not always know how operations will actually produce each order for an item.

To solve this problem, the operations manager has a choice. If parts demand is largely driven by a small number of end products, it is possible to develop a computer-assisted process to translate end product demand into part demand estimates. This can be and is done by firms using an approach called *materials requirements planning*. This topic is covered in the Shell 13 (Managing the Flow of Materials).

Dialogue Driver:
Assumed that someone in your household plans means a week in advance. That person starts planning making end-meal decisions, e.g., chicken on Monday, streak on Tuesday, etc. How might that person disaggregate these end-meal decisions into something that the purchasing who goes to the supermarket can use? Is there any other source of information that you would want to use before making the shopping list?

Demand Tracking

The other choice is to *track demand* rather than forecasting it. This often makes sense when there are too many items to forecast or when management lacks the wherewithal to provide meaningful inputs to the forecasting process. If you had to forecast the usage or demand for 10,000 parts, could you? The problem often is that the people who have the best read on what is happening in the marketplace are too busy doing their other activities to devote sufficient time to make detailed forecasts. And the employees that have the time often lack the market contacts needed to have a good read on what is happening.

Tracking demand simply reports what has happened in a systematic way. The demand tracking system systematically collects and consolidates data, translating into information for operations planning that is reasonably accurate and timely. It uses *management by exception* to highlight those items whose demand seem to be varying from their normal demand pattern. Part usage that fits the anticipated pattern need not be reviewed. Parts exhibiting unexpected usage patterns are forwarded to management for corrective action.

Tracking systems should do three things: identify changing demand, not be fooled by noise, and be simple to use and understand. These goals can be in conflict with one another. For example, yesterday's usage of a part was ten times what usually happens. Should we base plans on this new phenomena, or should we rely on the typical usage rate? Not using this information may result in our missing a change in demand, but using it as a new usage rate may mean that we have reacted to noise. Management may not have the time or the inclination to respond to every blip.

One common noise-suppressant is to use averages to track demand. Plans can be based on the average parts usage in five-day intervals. This will smooth out blips, but if they continue to occur, the average will eventually build in the higher usage rates in the average.

Exponential Smoothing

Keeping track of a daily usage for a large number of items was a problem for early computer systems. Extended time series were often needed to capture cyclic trends—such as seasonal factors. But extended time series averaging posed a problem for early computer systems since the data storage and computation time requirements taxed computer capacity. This problem was solved by R. G. Brown who created exponential smoothing--a technique that greatly reduced the need to store data and perform arithmetic computations.

Exponential smoothing assumes that the demand or usage for the next period will be a linear combination of the last period's actual and the last period's forecast. Mathematically, this can be expressed as:

$$F_{t+1} = \alpha\, d_t + (1 - \alpha)\, F_t$$

where F_{t+1} is the forecast for the next period

F_t was the forecast we had for the current period

d_t is the actual demand or usage we experienced in the current period

α is the smoothing coefficient (some call this a fudge factor)

If a smoothing coefficient of 0.10 is used, this says that we will give 10% weight to the last period's demand experience and the remainder to the last period's forecast. If the actual demand was 110 in a period in which the demand was forecasted to be 100, then the forecast for the next period would be.

$$F_{t+1} = (0.10) \times (110) = (1 - .0.10) \times (100) = 11 + 90 = 101$$

Note that 10% of the forecast error, i.e., 110 – 100, was factored into the new forecast. If a firm wanted to make tracking more sensitive to current events, it only needs to increase the smoothing coefficient.

This rather simple method has worked well in industry. It met the need for reduced data storage and reduced computational speed. It is easy to explain since it uses common sense to weigh the current and the past. And it may even impress your peers within the firm since it sounds sophisticated.

But best of all, it works and it can be easily modified to meet special needs. If some items have more erratic demand, just increase the exponential smoothing for these items. If trends or seasonality is present, the models can easily be expanded to include these factors. Cumulative forecast errors can be tracked to identify the items for which the current model is not working. Management intervention can then occur.

Dialogue Driver:
Can you explain exponential smoothing just using words -- without using an equation?

Other Inputs to the Short-Term Planning Process

The second input to the operations planning box involves resource gathering. Here, the operations planners' task is to figure out what, when, and how much of each factors of production is needed to support an anticipated level of activity. This business process provides inputs that result in purchase and work orders.

When MTS firms act on incorrect demand assumptions, this results in either: unwanted inventory, unmet customer demand, or wasteful expediting. Firms with the other three do-to-order market orientations, i.e., MTO, ATO, and ETO, may bet wrong by securing an incorrect amount of capacity. Insufficient resources result in either wasteful expediting or customer dissatisfaction. Too much results in underutilized productive resources. The strategic planning process must provide planners with guidelines as to how much *reserve capacity* is needed to support the time-to-product goals of the firm.

The third OM planning activity involves supporting operations, i.e., helping operations performing the tasks needed to satisfy customers. *Execution is the province of line management*. It involves the organizing and directing facet of the management process. The operations function is *the* internal customers of the operations planning process. If short term planning is done well, operations will do it job well. If it is flawed, either by wrong forecasts or poor resource planning, the folks in operations are the victims. They must face both the unsatisfied customers and dissatisfied top management who just can't quite understand why their plans never seem to be executed. So a fundamental understanding of the needs and capabilities of the operations is an essential input to operational planning processes.

Operations planners may be responsible for another key task -- they use their distant-sighted lens to serve as scouts for the firm's strategic planning process. They should be looking for emerging threats,

* To better understand why this method is called exponential smoothing, expand equation 1 by placing the formula used to forecast today's demand. Repeat this process and you will see that a mathematical expression occurs in which the weight given each period's demand as we go back into the past to get:

$$F_{t+1} = \alpha d_t + \alpha(1-\alpha) d_{t-1} + \alpha(1-\alpha)^2 d_{t-2} + \alpha(1-\alpha)^3 d_{t-3} + \alpha(1-\alpha)^4 d_{t-4} + \alpha(1-\alpha)^5 d_{t-5} + \cdots$$

So when α=0.10, we reduce the weight given each period as we go back through history by $(1-\alpha)$ raised to a higher power. In mathematics, this is called a negative exponential function, but Brown dropped the term "negative" because it had negative connotations.

opportunities, and ways to enhance effectiveness. If they are closest to the customer, they are likely to be the first to experience the phenomena not anticipated by strategic planners. Whether or not a firm wants its front line players to be the eyes and ears in the marketplace is an organization design issue.

For example, a fast food chain with highly standardized products and product delivery systems might not want its key front line players being creative. A McDonalds manager might have said, "Dammit, just get the Big Macs out according to Oak Park's specifications." Such an approach risks not seeing an emerging trend.

OPERATIONS PLANNING IN SERVICES

Recall that most services consist of a product bundle of tangible goods and intangible services. As such, OM's planning goal for services consists both of assuring that operations has sufficient human resources to perform at the expected level of service and that the right amounts of personnel and the other stuff needed to satisfy anticipated demand. This task is made more difficult by the inherent nature of services, namely:

- The intangible component of the product bundle occurs when it is rendered.
- The demand arrival pattern of services is a source of uncertainty.
- The amount of capacity that is demanded by service-seeking customers often is difficult to predict, even after they have arrived.

Against this backdrop, operational planners are given a specific set of marching orders in the form of capability specifications, i.e., 95% of all arriving customers will be served within 3 minutes. The challenge of the operations planners is to secure and provide the short-term resources needed to achieve the service goals as outlined in the capability specifications. This challenge is often made more difficult because the customer may judge the service transaction in terms of the total product experience. A customer's service experience often is a sequence of events. Failure to achieve customer satisfaction in any one of activities, such as the credit approval process, may mean that the organization's entire performance will be downgraded.

Also included in this challenge is the task of measuring how well the system performed given the actual level of resources. The tradeoffs are simple. Too many resources may result in superior service but at a higher cost. Too little resources will result in sub-par service quality, some of which may go undetected because dissatisfied potential customers quietly slip away undetected. Worse yet, they may share their bad service experiences with their friends.

There are a number of ways planners can take to achieve stated service quality objectives. These are:

- *Straight resource placement*. This method accepts the demand pattern as it is believed to be and the existing business processes as a given. The task is to place humans and other needed resources in the right locations and hope that these resources are sufficient to achieve the organizations goals. If the goal demands a high level of service performance, then sufficient levels of reserve capacity will be needed. If the organization is cost oriented, then the famous "let them wait" service stance is appropriate.
- *Demand management/modification*. This method attempts to "influence" customers to demand services at times that are mutually satisfactory to both parties. These efforts often require customers to schedule appointments, as is routinely done in beauty salons. In effect the customer buys the service on an as available basis. Others seek to influence demand patterns through the use of information and economic incentives. Supermarkets and fitness gyms inform customers as to when they are busiest. Airlines and resorts use *yield management* to assure that their "perishable capacity" is not lost, i.e., they sell units of capacity at lower prices if the prospect of the unit of capacity being sold at regular prices is dim.

- *Resource flexibility*. This approach seeks to respond to demand and demand service uncertainty by having flexible service resources. Service flexibility can be achieved by:
  - Having resources, people, and suppliers that can be made available quickly. Banks use retired workers to work during peak demand periods. Firms use quick response suppliers and premium shipping services to help achieve these ends.
  - Having resources that are capable of doing more than one task. Cross training employees attempts to achieve this end. In some cases, higher-grade raw materials are substituted for out-of-stock lower grade materials.

Each of these provides additional degrees of freedom to the operations planner, but the planner still has the task of finding that mix of short-term resources to get the job done.

Lastly, one goal of operations planning that often isn't stated. This is that the operational planning process should foster within the employees at the operations level, a sense that they are working for a well-run, people-caring firm. While responsibility for employee motivation and training lies elsewhere in the management process, a firm's ability to succeed in this area can easily be undermined by an operational planning process that leaves employees without the necessary resources to do their job well.

Service Planning Tools

There are a number of tools that operations planners use to make their recommendations. The tool selected is often a function of the complexity of the objectives, the degrees of uncertainty present, and the skills of the planners. They range from simple trial-and-error to complex mathematical models.

- Trial-and-error: This is the oldest and most common method used to plan services. It says, based on what we have experienced in the past. It uses this to determine the “best” resource profile for future periods? It is at its weakest when management does not strive to learn from past experience. Symptoms of this state are lack of records of past performance and a basic lack of curiosity. Survival is their goal and the consequence of success is complacency.

  At the other extreme are the active learners. They constantly ask: "How are we doing?" and "What could we do better?" They use metrics to assess how many units of demand key resources can support. In short, they are always using their far-sighted lens in search of the better way. Active learners often use analytical tools to help to become more effective, such as:
- The Deming Wheel: Experimentation is a root cause of learning. OM planners can design experiments to assess the effectiveness of alternate resource profiles. This is an especially potent tool in service organizations that are able to measure performance accurately at their multiple outlets.
- Process flow analysis: Since a key to effective planning is to know what one might expect from a process or a set of processes, it is important to develop a keener understanding of capacity and to identify bottleneck situations. This has the added benefit of getting planners away from their desks and closer to reality. Knowing how things get done at the shop floor level is a key trait of effective planners.
- Mathematical Models: Operations planners have long used certain mathematical models to assist in developing plans. One issue that must often be addressed in service businesses is determining the right number of servers within the system, i.e., determining how many bank tellers do we need to successfully serve an assumed demand pattern. If one can assume that demand arrives with a Poisson distribution and service times can be approximated by a negative exponential distribution, then queuing models can be used to determine a system's performance. If the conditions required by queuing theory cannot be met, then computer simulation application packages often permit server level problems to be simulated using the appropriate distributions for arrival rates, service times, and customer routing protocols.
- Supply Chain Collaboration: Many of the advances in planning are the result of enhanced information technology capabilities and the emerging willingness of firms to engage in inter-company collaboration. While many operations problems cannot be solved optimally, it has become apparent that an increasingly large number of them can be resolved with the use of better, up-to-date information and cooperation. In the product innovation area, we decried the "over-the-wall" approach as being wasteful. So too is it in

operational planning. An analogy on the home front might be: "Gee, if I knew that you were bringing seven of your friends home for dinner, I would have planned our evening meal differently."

OPERATIONS PLANNING IN MANUFACTURING

The operations planning challenge for manufacturing activities also is shaped by the values of the targeted customers that in turn define their system's performance metrics. Manufacturers of products with a high tangible component will require greater emphasis on getting the right amounts of raw materials and supplies than might normally occur in services. But goods often must be accompanied with intangibles, such as post-sale support, warrantees and customer service. Since a customer's total product experience with a product involves all facets of the product bundle, operations planning must assure that operations has the resources to deliver both the tangibles and the intangibles that customers expect.

Operations Planning in Cost-Focused Environments

If a product is a commodity, then the focus of the operations function is to make products that meet market standards at the lowest possible cost. Firms often achieve this goal by one or more of the following:

- Tactic 1: To secure the factors of production, i.e., raw materials, components, and labor, at the lowest possible price.
- Tactic 2: To operate the factory in the most efficient manner, i.e., the amounts of inputs needed to produce a given level of output are minimized.
- Tactic 3: To produce a mix of goods with the greatest combined market value for a given set of inputs.

Each of these tactics has a system design (D) and an operations (O) component. For example, the location of a factory is a system design issue that should take into account both the acquisition costs of each factor of production and the subsequent downstream product distribution costs. Once sited, the operations planning task is to secure each factor of production at the lowest possible cost. To distinguish between system design and operational tactics, we refer to these tactics as Tactic 1-D and Tactic 1-O in the sections that follow.

Tactic 1-O is usually the responsibility of purchasing for goods and human resource management for labor. Operations planning's supporting role is to provide these functions with information that will help them make correct and timely decisions. Purchasing needs to know when and how much of each good is likely to be needed over the planning horizon. In addition, it needs to know how operations will actually be executed. In some instances, the inputs to the production planning process may be so uncertain as to make it risky to actually purchase goods. It may be prudent to wait until actual orders are received. In other instances, long procurement lead-times force purchasing to order goods in anticipation of emerging demand.

Operations and human resources use operations plans to support their workforce adjustment activities. If persons with the needed skills are hard to hire, then the importance of workforce planning is greater. If the skills are plentiful or easy to create via training, then these hiring can be made on an ongoing basis.

Operations Planning in Time-Focused Environments

When customers demand that goods be readily and/or quickly available, the focus of operations and its planning functions is materially affected. In MTS environments, operations planners must help operations make the right inventory stocking decisions. Here too, there are systems design and an operational facet of the planning process. Placing retail stores, distribution centers, and inventory stocking points close to the customer is a system design issue. So too is the design of the information processing system since efficient, timely feedback from the market is a key input to the inventory placement decision-making process.

Operations planning's task is to collect and analyze this data and then provide the firm with meaningful information to support *operation's* inventory stocking decisions.

When the market orientation of the production process calls for operations to initiate assembly, manufacturing, and/or engineering only after receiving an actual order, the challenge of operations planning is to provide the system with sufficient resources to fully utilize the quick response capabilities that the system was designed to achieve. If the system doesn't have quick response capabilities, this is a strategic system design failure. Planners should not be expected to make a PT Cruiser respond like a full sized van.

With do-to-order market orientations, the operational planning task is to stock the system with the right amount of resources at the right locations once the system design phase has provided it with the factory's capability specifications. A beneficial consequence is that it may relieve factory management from the onus of feeling that they have to operate the plant in the most efficient manner. A certain amount of reserve capacity often is necessary to assure that a system is capable of responding in a timely manner. Well-designed performance metrics have accomplished this.

The tactics operations planners use to achieve objectives in a time-focused environment are:

- Tactic 4: To place product or product factors of production at those points of the supply chain that enable operations to respond within the time frame demanded by targeted customers.
- Tactic 5: To deploy factors of production with quick response capabilities. These can be either equipment with minimum setup requirements or highly adaptive humans.
- Tactic 6: To configure production resources into quick response systems, i.e., using manufacturing cells rather than job shops, mixed mode assembly lines rather than batch assembly lines, etc.
- Tactic 7: To free productive resources to respond to time-sensitive orders by reducing the amount of non-time-sensitive orders in the system.

Each of these tactics has a system design facet and an operational planning facet. For example, how one configures plant equipment clearly is a system design issue, but the resulting system may offer operations the option of diverting some resources into quick response teams when market demands warrant. The latter would be an operations planning issue.

Operations Planning in Product-Flexibility Focused Environment

When customers demand high degrees of product variety, operation's challenge is to achieve the best tradeoffs between providing customers with the demanded variety in a timely manner and keeping the productive resources effectively deployed. This challenge is similar to that discussed in the time-focused manufacturing environment. The difference is that here, one often is trying to *postpone* making products and product placement decisions until the latest possible moment.

In a make-to-stock environment, operations tries to satisfy its customers' product needs by placing a sufficiently wide variety of goods at locations convenient to the customer. Two questions need to be addressed: which items will the customers want, and how many of each should be stocked at each location. Both require us to forecast customer demand. But the correct answer to the second question can be influenced by the ability of the supply chain to quickly respond to a replenishment order. For example, when the supply chain can refill an order within two days, this allows a store to stock a wider variety of product in smaller quantities while still achieving the same customer-fill rate performance metric.

With the MTO, ATO, and ETO market orientations, operations can enhance its product variety capabilities by using some of the same tactics that are used in fast-to-product environments. Tactics 4 thru 7 can be used to satisfy a customer's need for variety provided that the manufacturing lead time does not exceed the time a customer is willing to wait. There are two tactics that are used to support product variety requirements:

- Tactic 8: To place within the system key components and subassemblies which are likely to be used by subsequent orders. Assemble-to-order systems extensively use this tactic.
- Tactic 9: To initiate production of "generic" finished goods that can be customized at a latter stage with the options and features that a specific customer orders.

This last tactic illustrates how some of these tactics can be used to support the goals of other tactics. While the goal of producing generic finished goods may be to enhance product variety capabilities, it also allows a system to achieve production efficiency goals by allowing a MTO plant to work when actual orders may not be sufficient to keep the plant adequately loaded.

Dialogue Driver:
Where have you encountered businesses existing in each of the above three planning environments? What told you that each was planning as you indicate?

PRODUCTION PLANNING TOOLS

Over the years, the following tools have been developed to help achieve operations planning goals:

Resource Allocation Models: Resource allocation models are used either to produce a desired product mix at the lowest possible cost or to achieve the maximum amount of profit from a given mix of resources.

Examples of cost minimization problems are:

- Producing animal feed with specific nutrition attributes at the lowest possible cost.
- Selecting the least cost mix of productive resources to achieve a projected load of work.

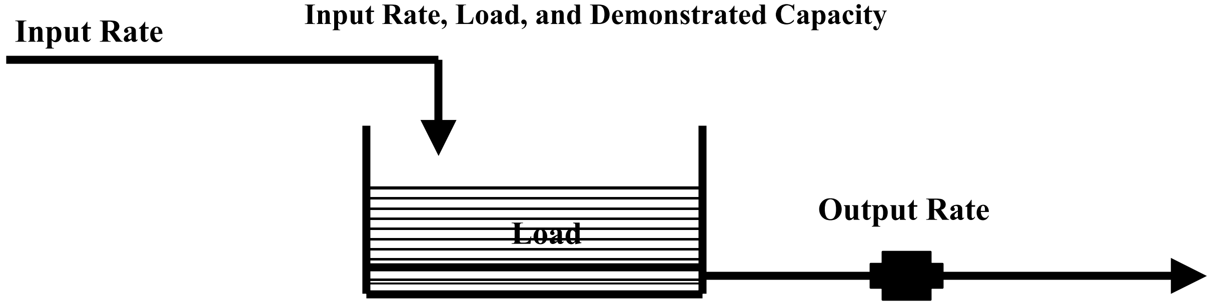
Examples of profit maximizing problems are commonly found in material flow companies, such as:

- Slaughtering animals into the highest value of meat and meat by-products.
- Refining crude oil into highest value flows oil and chemical products.
- Transforming logs into the highest value mix of forest product.

Resource allocation models are most appropriate in commodity-like settings. The solutions often result in solutions that some customers might object to. For example, if the goal is to maximize the number of persons a server can handle in a given period, an allocation model would select only those with the smallest service times and forgo serving customers needing more time consuming service. In animal feed problems, the solution will be the least cost solution but only a non-voting animal would eat it. As a test, you might want to try giving your family pet the least costly food. But most family pets have the voting power of a spouse.

Input/Output Control: After developing an estimate of the demonstrated capacity of a process, operations managers often seek to control the flow of work, either throughout the factory or to selected workstations, to avoid overwhelming or wasting available capacity. Input/output control manages work flow to match the demonstrated capacity of this process. This method adjusts the valves at each end of the pool of work in Exhibit 3 to maintain stable relationships among inputs, outputs, and load on the process.

Exhibit 3
Input Rate, Load, and Demonstrated Capacity



Operations management system often use the term, *load* to define the volume of work that remains for a process to complete at any time. Load depends on the input rate of a process, its capacity, and perhaps lags in processing activities. Generally, an input rate that exceeds demonstrated capacity increases load; an input rate less than demonstrated capacity decreases load. We have experienced the service equivalent of input/output control whenever the restaurant hostess asks us to have a seat in the bar until your table is ready. Restaurants have long understood that its service image suffers whenever its customers have to wait for an overworked food server to initiate service. It doesn't hurt that the bar is a high profit center.

Shop-floor managers need to manage load to ensure that work can be arranged in efficient groups or efficient sequences. Certain machines or key employees perform some tasks more effectively than others. The "right" load allows managers to route jobs in a way that maximizes these benefits while still completing orders by their due dates. Too high a shop load causes stress and congestion. Too low a shop load may starve the system thereby creating inefficiencies as machines and workers wait for their next assignment.

Input/output control prevents these problems by applying the classic management saying: you plan your work and then work your plan. It sets a production plan that indicates the amount of work that should flow in and out of the system for each period in the planning horizon. It defines the planned rates and then compares it with the actual rates. Deviations from plan indicate that something unexpected is happening which in turn may indicate a need for managerial action.

Input/output control is an *aggregate* workflow-planning tool. As such, some general need to define workflow and shop load is needed. Weyerhaeuser measures the flow of work through its processes in cubic feet of wood. Others might measure the dollar value or standard hours associated with orders received, orders in process, and orders shipped.

Another benefit of managing a shop's load is that it makes scheduling easier. Many of you have been in a line at Disneyland and seen a sign saying, "If you are in line here, you can expect a wait of 42 minutes." This information helps you plan the day or manage your frustrations better. Production planners also benefit if they know how long it takes for a job to flow through shop. When shop load is maintained at a stable level, it is possible to make better estimates as to an order's expected stay within the shop. This helps in two ways. First it provides the planners with a basis for setting priorities when releasing work to the shop. If there are twenty jobs waiting to be introduced, each of which has a promised ship date, then these can be released to the shop based on this priority. Second, understanding how long work is likely to take within the shop helps operations quote better customer due dates. If realistic customer due dates indicate that the firm is at risk of losing a competitive advantage, then the firm needs to either do something to discourage "less-than-desirable" demand or increase the factors of production available to the shop. This can be done by: hiring more workers, scheduling overtime, or farming out some of the work to other plants or contract some of the work out to other firms.

When we get to the scheduling shell, we will see that timing when work is done often is critical. This is needed for two basic reasons. The supply chain folks need to know when the needed components must be on hand. This is particularly true when the elapsed time between the start of work on an order and its completion date is long. For assembly lines, this is less of a problem because the order flow time is usually less than one day. But if we are assembling F16 fighter aircraft, a job's stay in the factory may be as long as a year. If we are planning the work for a multi-stage production order, planners need to know when each stage is likely to be done. Actually, the planners do not know this because while they know the sequence in which parts will be processes, they don't know how long an order will wait in line before men or machines perform the next needed task. Perhaps if they had a huge mathematical model that would result in a detailed production schedule of the appropriate planning horizon, they would be able to do this—provided no changes took place. These models are usually too unwieldy, or even impossible to solve at the shop floor level.

But production schedulers are like bumble bees in that neither knows that what they must do is impossible—so they just go ahead and do it. Since the problem cannot be solved, production schedulers resolve the problem by either restructuring the processes or by breaking the problem down into do-able sub-problems. As we saw earlier, a firm's market orientation impacts the production lead times. We also noted that cellular manufacturing can reduce the amount of time orders wait to be processed. Thirdly, we could dissolve the problem by transferring much of the work to suppliers or contract manufacturers with quick response capabilities. Attacking the problem in this matter is a system design issue that should be addressed before it becomes a short-term operations planning problem.

Dialogue Driver:
Describe where you have experienced input/output work flow control in the services? How can it enhance the value of the product a service delivers?

Time-Phased Production Planning

The second approach production planners use to know when parts and people will be needed is to recognize that at each stage, an order is either: waiting to be processes, being processed, or waiting to be transported to the next work station. Consider a problem in which an order requires the processing times shown in the left most columns of Exhibit 4.

Exhibit 4
Two Sample Production Planning Plans

Operation Number	Processing Time	A Zero-Wait Schedule	A Production Plan with Four Hour Waits Before Each Operation
1	1 hour	X	WWWWX
2	4 hours	XXXX	WWWWXXXX
3	2 hours	XX	WWWWXX
4	7 hours	XXXXXXX	**W**WWWXXXXXXX
5	2 hours	XX	WWWWXX
Elapse Time		0 – 16	0 – 19 – 40

Key: W's indicate waiting and the X's indicate work measured in hours

With the left-most plan, no waiting occurs before each operation and the order can be completed in 16 hours. If we were scheduling the flow of parts needed to support the fourth operation, we know that these would be required at the start of the seventh hour. This would only be a feasible plan if there were no other jobs in the shop or this order was given the highest priority—so high that all other jobs would be cleared off the next workstation so that the job in question would not have to wait.

But most jobs do not have the shop solely to themselves. They must compete with other jobs for the shop's scarce production resources. So operations planners devise simple rules to provide a means to deal with this conflict. The plan shown in the right-most part of Exhibit 4 uses a simple four-hour waiting period as a means to allow each workstation to deal with uneven flows of work to its station. If this is a workable heuristic, then the operations planner can then use this assumption and tell the suppliers of the components needed to support the fourth operation to have all items there at the start of the 19th hour, as is indicated by the **W**. Why not four hours later? Because this method of scheduling tells the fourth work station operator that it can do this job anytime between the start of the 19th hour and the start of the 23rd hour. Starting it early might mean that the parts are not available. Starting it after the 23rd hour will result in the job falling behind schedule. This would place the fifth workstation operator at a disadvantage.

Another simple planning heuristic is to assign operations to time buckets—usually one operation per time bucket. In our example, let us assume that a time bucket is one day in a one shift factory. Then this job would be scheduled as shown in Exhibit 5.

Exhibit 5
A Production Planning Plan Using One Day Time Buckets

A Production Plan with One Day Time Buckets

Operation Number	Processing Time	Day 1	Day 2	Day 3	Day 4	Day 5
1	1 hour	X				
2	4 hours		XXXX			
3	2 hours			XX		
4	7 hours				XXXXXXX	
5	2 hours					XX
	Total 16 hours					

This simplification extends the production lead-time to forty hours, i.e., sixteen hours of work will be completed in forty hours. In the so-called real world, it is common to find firms that are using the job shop process choice to have orders spend 95% of their time waiting. If this is unacceptable, then one must change the process.

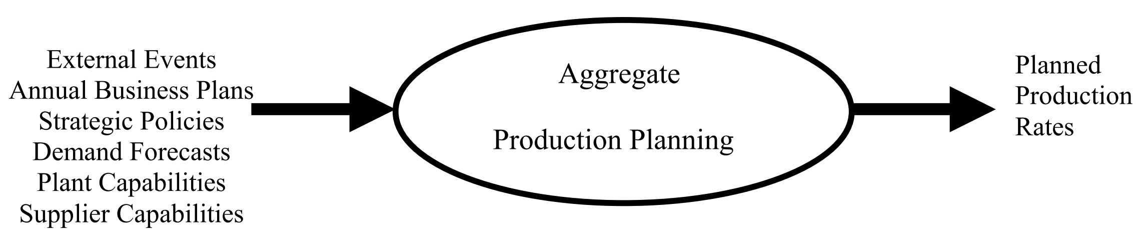
These examples are used to illustrate how production planners use time-phased planning to manage their task. While they are not actually scheduling work, they are creating plans that enable others within the supply chain to manage their jobs better. Purchasing has a better idea as to when it should schedule the flow of work to the plant. Production has an idea as to the flow of work and shop load conditions that it should anticipate. If they see a problem, then they can then initiate actions that will either get the appropriate production resources on hand or to forewarn marketing that some of the promised deliveries might not be possible.

Dialogue Driver:
Where have you used the time-phased concept in planning your work this semester? Or do you plan?

Aggregate Production Planning

The aggregate production plan specifies planned rates of production, inventory levels, and employee staffing rates and policies. Aggregate planners transform the following inputs into planned production rates.

Exhibit 6
Aggregate Production Plan Inputs



The assumptions that underlie an organization's budget often become inputs to the aggregate planning process. If business conditions materially change during the course of a fiscal year, however, updates should incorporate recognized deviations. Planners should communicate any such change to the key individuals in sales, marketing, and finance since major shifts in an aggregate plan significantly affect their operations. Exhibit 6 describes the inputs to the aggregate production plan.

The level of detail for an aggregate production plan often covers a single product family. For example, Ford's truck plant needs an aggregate plan for its pickup models rather than separate plans for individual combinations of features. This plan might direct the process to make 4,350 F150 pickup trucks rather than 872 red F150 pickup trucks with specific options and other trucks with different packages of features.

The capabilities of the plant, supplier, and the distribution network are defined along part family lines. Since these are constraints, the production planning process may elect to focus more heavily on those that are likely to limit the options of the planners. Why waste management's time focusing on inactive constraints?

The goal of aggregate production planning centers on defining the combination of production rates, employee staffing levels, and inventory patterns that satisfies the needs of the firm. This statement emphasizes the search for a satisfactory plan rather than an ideal one; planners should not waste resources in a futile search for optimal arrangements for every resource in an environment subject to change. Others argue that the goal of minimizing costs should guide aggregate planning. This can improve a plan as long as it does not jeopardize the other elements of the value equation: quality, flexibility, and time.

Mathematical Formulas for Aggregate Production Planning: To understand production tradeoffs better, it is useful to express the aggregate production-planning problem in mathematical terms. To simplify the model, we assume that a plant produces only one product family. We also focus the analysis on cost minimization, although it could pursue some other objective. With this background, the problem amounts to this: Given D_t, the demand forecast for Period t in the T-period time horizon, determine the feasible production rate, P_t, for each corresponding Period t that will result in the lowest possible cost. The aggregate production plan usually includes several relevant costs.

- Basic Production Costs: This category covers both fixed cost and variable costs to manufacture the product. Since this planning process deals with aggregate product information, it takes an aggregated unit cost, V, and a period cost, F. The basic production cost incurred in Period t is:
  $PROD_t = F + VP_t$ for $t = 1, 2, 3, 4, ..., T$
- Costs of Changes in the Production Rate: Certain production processes may experience costs when their rate of operation changes. These costs normally result from hiring and firing workers. Aggregate production planning usually assumes that the number of workers needed to produce one unit of equivalent product changes in a linear way. The number of workers needed in Period t is:
  $W_t = aP_t$

  Then the number of people hired in Period t is:

  $HIRE_t = W_t - W_{t-1}$ if $W_t > W_{t-1}$ 0 otherwise

  Likewise, the number of people fired in Period t is:

  $FIRE_t = W_{t-1} - W_t$ if $W_{t-1} > W_t$ 0 otherwise

  If the firm incurs a cost of C_h to hire one employee and a cost of C_f to fire one, then the cost of changing the rate of production is:
  $CHANGE_t = C_h(HIRE_t) + C_f(FIRE_t)$
- Inventory Holding Costs: The firm also incurs costs to hold and maintain inventory, also frequently assumed to vary in a linear relationship with the production rate. A conservation of mass equation can give the amount of inventory at the end of Period t:
  $I_t = I_{t-1} + P_t - F_t$

This states nothing more than beginning inventory plus the amount that the process will produce minus what forecasts indicate that the firm will sell. If C_i is the unit inventory holding cost, the inventory cost is for period t is:

$$INVCOST_t = C_i I_t$$

Planners can restate the aggregate production-planning problem as:

Minimize $z = \sum (PROD_t + CHANGE_t + INVCOST_t + BACKCOST_t)$ for $t = 1, 2, 3, \ldots T$

Subject to:

$I_t = I_{t-1} + P_t - F_t$ for $t = 1, 2, 3, \ldots, T$ (Conservation of mass constraints)
$P_t < PMAX$ Production capacity constraints
$I_t < IMAX$ Warehouse capacity constraints
$HIRE_t < HIREMAX$
$FIRE_t < FIREMAX$ Human resource policy constraints

Clearly this model could become more complex. It might include additional variables to reflect the costs and capacity of overtime production. It might add some lower limit on inventory to minimize the chances of a stockout and expediting. This relatively simple model should suffice, however, to illustrate the tradeoffs of aggregate production planning.

Aggregate Production Planning with Variance: Such a formal statement of costs and their relationships may tend to oversimplify aggregate production planning. System variance quickly scatters these neatly aligned numbers into a confusing jumble. If planners can easily and accurately forecast the patterns of demand without any significant seasonal variations to disrupt the data, then they face a relatively simple problem. (Of course, this statement also assumes that they find factors of production readily available throughout the planning horizon.) Without complications, the production plan can mirror the demand pattern.

Some difficulty may cloud the picture if planners cannot rely on the availability of a major factor of production, such as labor or a raw material, throughout the planning horizon. The production plan must then reflect the effect of this fact. For example, planners for a winery clearly must schedule crushing operations to follow grape harvesting patterns.

If planners question the accuracy of their demand forecasts, they may face more complex problems. The firm may want to keep investments in inventory low to avoid significant risk of holding more than it needs. In general, production planners should accumulate inventory to help level production rates only if the expected cost savings from smoother production exceed the expected costs of holding the stock. Estimates of inventory costs should include:

- Excess product cost, i.e., the costs of making more than customers want
- Product obsolescence cost, i.e., the costs of holding old stock after product designs or fashions change
- Product deterioration costs, i.e., the costs of reductions in quality of stock before the firm can sell it

The firm can smooth production by accumulating inventory most effectively when it incurs minimal losses due to these costs. Unfortunately, planners cannot know most of these costs. Accounting data may provide a good starting point for calculating the cost of inventory, but this function collects data for reasons other than planning. Planners must expect to massage accounting numbers considerably to translate them into meaningful aggregate cost coefficients.

Along with resource availability and inventory levels, demand seasonality contributes to system variance. Operations managers like to produce at level rates, but customers lack the training to see the benefits of steady demand. They arrive when they want the firm's product. While demand management might solve this problem completely in some dream world, planners for real markets will need to devise strategies to accommodate seasonal variations in demand patterns.

Production Planning Strategies: Resource managers develop individual solutions to planning problems caused by system variance. These firm-specific arrangements generally represent one of three *pure strategies* for accommodating mismatches between demand and production capabilities:

- Chase strategy: This strategy sets the production rate equal to the demand rate. It then increases and decreases the firm's pool of human resources as needed, usually through hiring or firing permanent staff, perhaps supplemented by temporary workers.
- Level-production strategy: This strategy sets the production rate equal to the average demand rate. It then accumulates inventory during slack demand and distributes goods from inventory during peak demand periods. Human resources remain at a constant level.
- Variable-hours strategy: This strategy sets the production rate equal to the demand rate and keeps staffing levels stable. It compensates for demand variations by adjusting the number of hours that individuals work to make capacity match. Clearly, the success of this strategy depends on the extent of demand variability and the willingness of workers to accept uncertainty in their incomes.

Individual firms devise infinite combinations of these three pure strategies to suit their own circumstances.

Each of these pure strategies has its strengths and weaknesses. The chase strategy minimizes the costs of holding inventory, including the risk of investing scarce resources to accumulate the wrong products. The firm gains this benefit at the cost of potentially alienating employees. They may well return the firm's weak commitment to them, leading to low morale, high absenteeism, and uncaring attitudes.

Some firms succeed using this strategy by selecting employees who care little about employment uncertainty; any warm body will do. To reduce the risk of poor quality with such casual employees, they may automate their production processes to eliminate virtually any possibility of a mistake as McDonald's has done in designing its French-fry cookers. Firms may also try to vary the flow of work to match demand by adjusting orders from subcontractors. This merely downloads the problem to suppliers, but they may handle the variance by filling gaps with orders from other customers.

The level-production strategy is an operations manager's dream. It ignores the priorities of JIT manufacturing, however, and invests in inventory as a buffer. This may not create unduly high risk if a significant percentage of the firm's work load comes from mature products for which resource managers can easily forecast demand. They must answer a key question to judge the suitability of this strategy: will the benefits of a stable work force more than offset inventory holding costs? These benefits depend, of course, on the firm's ability to hire skilled employees or to economically train new employees in needed skills.

The variable-hours strategy tries to achieve the best of both worlds. It seeks to keep its key human skills while avoiding the costs and risks of holding large inventories. Lincoln Electric, the manufacturer of welding rods and equipment, uses a variation of this strategy. It guarantees 4 days of work per week to permanent workers, even during slow periods. To make this strategy work, the firm builds some inventory during slow periods and it hires temporary workers to meet peak demand without any guarantees of work hours.

The trend among American manufacturers to rely increasingly heavily on temporary workers reflects in part the attraction of a modified variable-hour strategy with its combination of volume flexibility and stable core of skilled, committed employees. If anyone doubts this phenomenon, note that Manpower, the temporary employment agency, had over 742,000 individual placements in 1994 in the United States alone.

A cynic might state a simple rule of thumb for balancing permanent and temporary workers: If a firm can easily find workers and the work does not require highly polished skills, it should hire temps; if good workers are scarce and the work demands strong skills, it should hire permanent employees. A quantitative problem might make this decision rule more concrete.

MASTER PRODUCTION PLANNING

Resource management moves from general, aggregate plans for entire plants or large sub-processes to detailed specifications for near-term production. The master production schedule (MPS) transforms inputs from marketing and operations management into a document that defines the goods that specific shops will produce in definite quantities at definite times over a 6-week to 8-week planning horizon. The master production schedule represents the most important plan in the resource-management system because it becomes an agreement between marketing and manufacturing that defines the execution activities of the OM system over the short term. This agreement is particularly important in make-to-order systems since it reflects the firm's commitment to deliver products by the dates promised to customers.

The master production scheduling process deals with more detailed information than aggregate planning in part because operations managers need precise information about what the firm expects of them. To generate the necessary detail, planners disaggregate higher-level production plans to transform them into master production schedules. This disaggregating process is illustrated in Exhibit 8

Exhibit 8
Disaggregating Demand

	January	February	March
Demand	1,200	800	600

Product	1	2	3	4	5	6	7	8	9	10	11	12
Cherry Cola	200		200		200				150			
Cola		300		400			500			350		
Diet Cola	100				100				100			

Exhibit 8 shows that the aggregate production plan anticipates making 1,200, 800, and 600 2-liter bottles of soda over the 3-month planning horizon. Shop-floor workers need a more detailed plan to achieve this goal. To plan their work, they need a week-by-week schedule that specifies what flavors to make and when.
The master production schedule shown in the bottom half of the exhibit provides this information. It tells workers on the shop floor how much of each flavor to make in each period, or time bucket.

In the real world, the master production scheduling process becomes more complicated. A manufacturing system with only a fair degree of complexity might process components through seven or eight manufacturing stages, including fabrication operations and assembling steps that join numerous parts into subassemblies. The process probably integrates parts purchased from outside vendors. It culminates in a final-assembly plan that combines numerous internally manufactured components, purchased components, and subassemblies into end products that delight customers.

After deciding which production-planning strategy best suits their firm, planners can then determine its resource needs over the planning horizon. These projections help the procurement process to forge cost-effective supplier relationships. Suppliers appreciate reasonably accurate estimates of a customer's future needs, so sharing this information can enhance these ties.

Aggregate figures for individual periods over the planning horizon often fail to provide enough specific information to support production planning. Operations managers need to know specific demands like the dimensions of lumber to buy, the option packages to install on pickup trucks, the types of beer and container sizes to make in a brewery, and so forth. The master production schedule provides this information.

SUMMARY

In this shell, we have focused on short-term production operations planning. These are the resource management planning activities that are done after the long-term capacity and capability planning decisions have been made. Here we work with tactics, i.e., those more detailed activities that are designed to help the firm achieve its long-term strategic initiatives.

Operational planning, like any business process, is driven by the needs of its customer. In Exhibit 1, we differentiated three levels of operations planning and indicated the customers and customer needs often found with tactical and operational planning activities. In Exhibit 2, we noted the inputs, activities, and outputs of short term operations planning. We noted the difference in the OM planning activities in service and manufacturing firms. The nature of these activities is influenced by the structure of the product delivery systems.

Two production planning tools were introduced—input/output analysis and aggregate production planning. The uses and limitations of each were discussed. Lastly, we introduced master production scheduling and some of the time-phased concepts that help operations managers deal with the timing of the production and purchasing decision-making.

Finally, let us reiterate that there is a distinct difference between operations planning activities and operations-level execution activities. It is the role of the operations planner to help both marketing and operations understand what is doable and within the realm of the existing factors of production. As the Pink Floyd introductory piece indicates, operations-planning, if done well, is invisible. This is a good thing.

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Expected Learning Competencies

Before putting Shell Eleven down, you should ask yourself the following questions. Am I able to explain:

16. The roles of operations planning. How it differs from strategic planning and the actual execution of plans.
17. The different internal customers for operational plans, the time horizons that are most useful, and why plans need to be disaggregated provide operations managers they need.
18. How the operations planning function utilizes demand information in its processes.
19. The three types of operations planning environments, and the tactics operations planners use in each to enhance the likelihood that operations managers will have sufficient resources to accomplish their job.
20. What some of the tools that operations planners use and how they contribute to an organizations effectiveness.
21. What your instructor added to this shell and why he or she thought that it was important enough to warrant its inclusion.

Frequently Asked Questions

Instructors have been known to ask questions similar to the following:

1. Compare and contrast what the typical operations planner does managing a restaurant and a manufacturing operation—say a job shop.
2. Explain the relationship between the most appropriate planning horizon and the lead times associated with securing short-term resources.
3. Explain how operations planning differ when operating in each of the three planning environments.
4. Which of the following operations planning tools tries to maintain the "right" load within a system?
   a. Master production scheduling
   b. Input-Output control
   c. Aggregagte production scheduling
   d. Mostly b but to a certain extent master production scheduling does this too.
5. Which planning environment is most likely to place product or factors of production at those points in the supply chain that enable operations to quickly respond to customer demand?
   a. Product flexibility oriented environment
   b. Cost focused environment
   c. Time focused environments
6. Which of the following operations planning tools most extensively used time phased planning?
   a. Master production scheduling
   b. Input-Output control
   c. Aggregagte production scheduling
7. The goal of master production scheduling is to locate the optimal production plan.
8. To make exponential smoothing more responsive, one should increase its smoothing coefficient.

SHELL TWELVE
MANAGING FOR QUALITY

Doing It Carl's Way

Carl Fabrege's decorated eggs have long been considered works of art. What most people don't realize is that most Fabrege eggs were produced under his tutelage *by his* artisans. When an egg was completed, the artisan would bring it up to Mr. Fabrege, who would inspect it carefully. If he liked what he saw, the artisan would be praised. If not, Fabrege would smash the egg mightily with his fist. The result was a collection of decorative eggs that are the marvel of art lovers to this day. However, this "go/no go" inspection process did not do much to advance human resource management practices within Czarist Russia. Today, total quality management programs rely less on fists and more on respecting the contributions of empowered employees.

Theory Y contends that most workers want to produce quality products. However, individuals remain powerless without access to appropriate tools. Bill Conway, an early TQM practitioner, made this point effectively when speaking with some visiting executives. Conway started the meeting with a challenge. "Suppose I ask two of you to enter a contest where the winner will win a trip around the world. I suspect that this reward will motivate each of you to strive to win this trip for you and your family. The contest is to see who can drive a nail into this wall the quickest. The nail should be placed 48 inches off the floor and into the first 2x4 stud from the left corner of room. One of you will get a hammer, a stud finder, and a tape measure. The other will just receive a hammer. Who do you think will win?" The answer was obvious. Motivation and management encouragement is important. But to be successful, employees must have tools—the right tools to do the job right.

Source: A verbal discourse with Steven A. Melnyk,

Shell Twelve

Managing for Quality

Table of Contents

Learning Objectives for Shell Twelve

After reading this shell and thinking about its content, you should be able to:

1. Briefly explain the evolution of quality management and the key roles of Deming and the Japanese.
2. To understand both that statistics is a critical element of total quality management and that TQM is a lot more than the application of statistics. Management matters.
3. Describe and illustrate the use of the following quality management tools:
   a. All of the generic information gathering tools introduced in the Operations Managers Toolkit
   b. Process Capability Measures
   c. Acceptance sampling and 100% inspection
   d. Control Charts
4.. Recall the tenets of the learning organization and then be able to relate their application to total quality management programs.
5. Distinguish between designing quality in and quality conformance.

INTRODUCTION

Simply put, quality is achieved when a product meets the customer's requirements. With Carl Fabrege, quality was achieved when, *in his eye*, the egg matched *his* lofty standard of quality. But in a customer-driven world, defining quality isn't quite that simple. If we are going to be consistent with our customer-specific definition of value, then each customer may have specific customer requirements. Indeed we might even need to differentiate between a customer's requirements and the customer's expectations. A product might be "good enough" to meet a customer's need, but it is unlikely to truly satisfy customers until it exceeds their expectations. In this shell, we use this demanding standard for measuring quality.

Quality management can be divided into two distinct, but inter-related areas. The first is *design quality*. A product's design quality is an output of the firm's product innovation process. Shells 8 and 9 describes how the product innovation process required product designers to first understand the needs of targeted customers and then develop products and product delivery processes that are capable of meeting and exceeding the customers' expectations.

The second area is *conformance quality*. This measures the extent to which a process is able to deliver a product that conforms to the product's design specifications. While many think of this in terms of manufactured goods, it also applies to services. FedEx's guarantee that every package would be "positively, absolutely delivered by 10:30 AM" the next business day clearly establishes a quality standard against which it intends to be measured.

The beneficiaries of quality are many. Obviously the customer benefits whenever a firm designs, produces, and delivers a product that is perceived by targeted consumers as being of high quality. But the players within the supply chain also benefit. When raw materials and component parts are delivered in conformance with product specifications, supply chain players benefit by not having to engage in wasteful activities, such as inspection, worry, and the maintenance of "just-in-case" inventory. Manufacturing processes benefit because their activities can be performed more efficiently when everything fits better. Indeed, the auto pioneer, Henry Ford could not efficiently operate his assembly lines until he was able to buy and make parts that were sufficiently precise to permit easy assembly.

Humans within a product-transformation process benefit whenever they experience a sense of pride in doing things that delight customers. They may also experience a sense of relief when their boss smilingly approves the quality of their work. Or they may experience the joy of seeing a delighted customer using the product that your firm took part in designing, making, or selling.

Downstream distribution and retailing players benefit by stocking and marketing goods that they can rely on to be made according to specifications. Nobody in the distribution channel enjoys products being returned. Returned products are a *symptom of poor quality* and they cost much more money than most firms realize.

So most people within the supply chain have a vested interest in maintaining a flow of high quality goods. Few consciously choose to generate poor quality. Nonetheless, poor quality practices within the American industry almost brought the domestic economy to its knees during the 1980s. At the end of WWII, an aide to General Douglas McArthur advised the Japanese not to plan on making anything for the American market because "*there is nothing that Japanese industry can make that would be of sufficient quality*." My, how times have changed. In the early 1990s, a German consumer was quoted as saying, "I can't think of anything made in America that I would want to buy." Fortunately, we have learned much in the last fifteen or so years that has helped American firms and their products get back into the game.

A Brief History of Quality Management

Long before the Japanese quality revolution, some civilizations were renown for the quality of the products. Damascus was renown for its swords; China for its porcelain products. In most instances, the products sought were goods and the buyers were from elite classes or religious orders. Because the buyers held the power, the artisans had strong incentives to please their customers—*or else*.

The advent of the European industrial revolution caused a *disconnect* between the makers of goods and their buyers. The application of Adam Smith's *division of labor concept* enabled firms to use unskilled workers to operate water or steam powered looms. Early managers exhibited little concern for their employees, who for the most part were peasants who had been forced to relocate from the rural communities to the cities. The saying "Do it my way or take the highway" was the management practices of the day.

The economies of scale the industrial revolution made possible resulted in levels of production far greater than local markets could consume. That meant the goods had to be marketed over a large area. Fortunately, the British Empire's mercantile system met this need. Raw materials were secured in the colonies, transformed into manufactured goods, and then sold in both the domestic markets and the colonies. Trading companies assumed the role of assuring that the goods would be made "correctly." Few standards existed so buyers had to rely on the sellers' reputation.

The inability to make parts to standard dimensions limited the ability of European manufacturers to achieve economies of scale when assembling goods. At one point, the English army had 40,000 muskets awaiting repair because each repair part needed to be custom-made to meet the unique need of each weapon. It was easier to build a new weapon than to diagnose what was needed and then make a custom part to fix it.

In the early 1800s, Eli Whitney's factory developed the capability to make standardized parts. This process capability enabled his firm to win a contract to make 10,000 rifles for the American army. The American industrial revolution was born. Soon after, European manufacturers were lamenting that there was no way for them to be able to compete against "the American manufacturing system." Ironically, in the 1960s, similar phases were being expressed about the Japanese manufacturers. How times had changed.

Early in the 20th century, American Telephone and Telegram experienced a need for more reliable products. The advent of emerging telephone networks demanded that remotely sited equipment be reliable. Three seminal developments resulted from this need for enhanced service quality. The first occurred when Dodge and Romig developed an application of statistics that enabled purchasers to *infer* the quality of lots of incoming parts. This tool became known as acceptance sampling. The second occurred when Shewhart developed a statistical procedure that would tell machine operators when the likelihood of a process being out of control was high. This procedure took samples from a process' output and then immediately measured the part being made. The information gained from the sample is used to decide if the process should keep running or be stopped to correct some problem. Today, this tool is called a control chart. The third development was the famous Hawthorne experiments. This was an early recognition that behavioral factors played a key role in the performance of workers.

During WWII, the quality and sheer volume of the goods made by America's industrial arsenal were credited with being a key success factor for the Allies' armed forces. The transformation of the domestic manufacturing infrastructure to a war footing achieved legendary proportions—especially when you consider the fact that most of the nation's skilled work force volunteered or was drafted into the armed forces. Some feared that the replacement of men within our factories with women would cause a drop in quality and productivity at a time when the war effort needed it most. When this did not happen, many industrial leaders were perplexed. When they studied the phenomenon and asked "How were they able to do it?" The answer was, in part, "Unlike men, women listened and asked for directions."

Another phenomenon of note was that during WWII, the maximum effort meant that even pointy-headed academics were pressed into national service. In England, a problem solving approach called *operational research* was developed. It was one of the first formal efforts to use a multi-disciplinary approach to problem identification and problem solving. This effort was also aided by the development of early "thinking machines," an item that we know now as computers.

After WWII, General Douglas McArthur faced the monumental task of trying to "run" Japan at a time when most of its infrastructure lay in ruin. He said "get me some of those geniuses from Bell Labs (AT&T's R&D arm) to help recreate a telecommunication system. They taught the Japanese some of the best practices the British and Americans had developed to produce high volumes of quality war materials.

In the late 1940s, a number of initiatives were started within Japan to use quality methodologies to help rebuild the economy. In 1946, The Union of Japanese Scientists and Engineers (JUSE) was created "to engage in research and dissemination of knowledge of quality control." They soon realized that Japan and its industries could be revived in part by implementing the quality control procedures practiced by American manufacturers during the war. Earlier in the 20th century, an observer noted Japan's ability to "adopt, adapt, and become adept." In the 1950s, Japan seemingly refined its learning capabilities further.

They listened to one individual, W. Edwards Deming, who had once worked with Shewhart. Deming had long espoused his theory of quality in America, but not many American firms listened. In 1950, he conducted a seminar, which had the following outline:

1. How to use the PDCA cycle to design products to enhance quality.
2. The importance of having a feel for dispersion in statistics.
3. Process control through the use of control charts and how to use them.

His message was well received and the love affair between Deming and Japan began. Each year in the 1950s, Deming returned to Japan to teach, listen, and learn. He became one of their quality gurus.

Japan's other quality guru was Joseph M. Juran who taught top and middle managers the roles they had to play in promoting quality control activities. Juran's work resulted in a refocusing of Japan's quality control activities to make it *the* overall concern for the entire management. Together, these two individuals helped Japan start what we now call the Japanese Quality Revolution.

In the 1950s, Armond Feigenbaum, a GE quality management specialist, developed a program called Total Quality Control. Feigenbaun defined TQC as:

> "an effective system for integrating the quality development, quality maintenance, and quality improvement efforts of the various groups in an organization so as to enable product and service at the most economical levels, which allows for full customer satisfaction."

While the victorious Americans saw little need to modify their ways, the Japanese were listening.

Many years later, when someone asked what they based their quality assurance programs on, Kaoru Ishikawa, the father of Japan's TQM movement, responded that Feigenbaum's TQC was the basis, with one exception. Whereas American management had industrial engineers and shop level plant supervision running its programs, the Japanese approach placed this responsibility broadly to include hourly workers. Ishikawa noted, "Japan's quality movement has never been an exclusive domain of QC specialists."

After WWII, Japan was racked with labor unrest—often led by Communists. The nation was in turmoil. The leaders of Japan and its industrialists responded by defeating these politically inspired industry-wide unions and replacing them with company-wide unions. The company unions adopted a village mentality where workers and management shared similar goals. What was good for Toyota *was* good for its workers. The resulting collaboration between workers and management formed the basis for Japan's quality revolution.

Soon, quality initiatives, such as quality circles, were springing up all over. High school students were taught basic statistics which would provide Japan's factories with workers capable of becoming effective players in the emerging total quality management programs. By 1970, Americans looked with awe at Japan's worker-level quality programs, such as its quality circles in which workers, staff, and line management *volunteered* to work, often on their own time, to find problems and give their recommend solutions.

In recognition of Deming's contribution, Japan created the Deming Prize in 1951. This annual award recognizes a company or individual for active contributions to the development of quality management tools or to the spread and implementation of quality improvement programs.

In the 1970s, certain American firms started to listen to Deming and Juran. Phillip Crosby wrote the classic *Quality is Free*, which adapted Japanese TQM concepts to make them easier to accept by American manufacturers. Soon quality consulting was a booming business. Americans asked, "How long do you think it will take us to catch up?" Deming who responded, "What makes you think that they are standing still?"

In the ensuing years, many in the Western world have studied just how the Japanese do it. No silver bullet has been found -- just a recognition that Japanese style quality management means that we were going to have to learn how to do thousands of little things right. The real lesson from Ishikawa is that everyone, from top management to the employees on the shop floor, has to buy into a program that continuously improves the firm's products and product-delivery processes. This requires understanding the needs of target customers.

The sad thing is that many Americans think we have moved beyond the quality revolution. As one Silicon Valley MBA student once told me, "TQM—oh we did that three years ago." My response was, "Too bad-- it didn't take." It is true that in the Lexus lane, the importance of speed is more important that it was during the 1970s. Indeed, doing things "right" may slow one down. But while quality may now be an order qualifier, poor quality is an order loser in most marketplaces. Hence the need to engage in continuous quality improvement must remain a key factor in order for a business to remain competitive.

> **Dialogue Driver**:
> What similarities do you see in Senge's learning organization and Japan's TQM movement?

In the next section, we explore some of the lessons the late W. Edwards Deming contributed to the quality management movement. We in no way want to imply that the contributions of Joseph Juran and Phillip Crosby are any less valued. The omissions of the Japanese quality gurus should also not be considered a slight. Without their challenge, America might never have risen from its post WWII funk.

THE CONTRIBUTIONS OF W. EDWARDS DEMING

W. Edwards Deming was born in 1900 in Sioux City, Iowa. He earned a bachelor's degree in physics from the University of Wyoming and a doctorate in mathematical physics from Yale in 1928. For the next eleven years he worked as a mathematical physicist for the U.S. Department of Agriculture where he gained his first experience with the theories and practices of statistical science and statistical control. During this time, he encountered Walter Shewhart's studies on variability within the manufacturing process. Shewhart saw the need to gain control over this variability as a critical management task. Deming would expand on the importance of variability in his theory of variance. From 1939 to 1945, Deming was involved extensively with the American Bureau of the Census and the U.S. weapons industry.

Deming envisioned quality management as an organization-wide activity rather than a technical task for inspectors or a specialized quality-assurance group. He stressed that quality is a management responsibility. It is management's responsibility to create the systems and processes that generate quality. It was his contention that a firm could never *inspect quality into a product*, i.e., that a quality product combines a good design with effective production methods. Both were required before a firm could ensure quality.

Deming created a set of guidelines for achieving quality. Application of his guidelines usually requires a radical change in every aspect of an organization's management. When someone asked Deming to justify the need for his TQM recommendations, he answered, "You do not have to do this, survival is not compulsory." He contended that American firms survival depended on making such changes rather than assuming that past success assured continued operations. But few in America seemed willing to listen.

The essence of Deming's philosophy is embodied in his fourteen points for management. They are directed at management---not workers. His 14 points *for management* are:

Exhibit One

Deming's 14 Points for Management

1. Create consistency of purpose for continual improvement of product and service.
2. Adopt the new philosophy for economic stability.
3. Cease dependency on inspection to achieve quality.
4. End the practice of awarding business on price tag alone.
5. Improve constantly and forever the system of production and service.
6. Institute training on the job.
7. Adopt and institute modern methods of supervision and leadership.
8. Drive out fear.
9. Break down barriers between departments and individuals.

10. Eliminate the use of slogans, posters, and exhortations.
11. Eliminate work standards and numerical quotas.
12. Remove barriers that rob the hourly worker of the right to pride in workmanship.
13. Institute a vigorous program of education and retraining.
14. Define top management's permanent commitment to ever-improving quality and productivity.

Point 14 meant that Deming would not work with a company until *he felt* a commitment from top management.

Deming's Theory of Variance

Most of Deming's work revolves around his theory of variance. This theory views variations from standard activities as a major source of problems for all firms. Variance causes unpredictability, which increases uncertainty and reduces control over the processes. Management's task is finding the sources of variance and eliminating it to significantly improve performance through continuuous improvement.

Variance can come from many sources but each can be categorized as either controlled or uncontrolled. A controlled variance responds to efforts by a worker to correct or manage the activity. An uncontrolled variance reflects the impact of some factor outside the control of the employee. It is unreasonable to expect an employee to correct the cause of an uncontrolled variance, but sad to say, they often shoulder the blame.

Exhibit 2
Categories of Variances

	Common Cause	Special Cause
Controlled variance	Management	Worker
Uncontrolled variance	Management	Management

Workers or managers can correct a controlled variance by changing either its common cause or by removing a special cause. A cause is called common when it is systemic to an OM process, such as low employee morale due to low wages. A special cause would be Laura's bad attitude since she feels that her pay scale is lower than what others doing the same job are being paid. This table reemphasizes the pivotal role of managers in TQM since management bears responsibility for three of the four cells.

Dialogue Driver: Can you think of a product or process where variability is desirable?

TOOLS OF TOTAL QUALITY MANAGEMENT

The use of tools, many of which you learned in your introductory statistical course, is an essential part of a TQM practitioner's life. While some may be able to see solutions to problems residing in complex industrial settings, most breakthroughs are the product of systematic analysis. A guideline to start this endeavor was stated by John Burr when he stated:

"Before you try to solve a problem, define it.
Before you try to control a process, understand it.
Before trying to control everything, understand it.
Start by picturing the process."

We suggest that you revisit the section on Senge's learning organization in Shell 5 since it provides the basis for operations-level quality management.

Total quality management uses two types of tools to advance quality: management tools and statistical tools. *Management tools* for quality form theoretical frameworks and mental models that act as magnifying glasses through which managers can examine processes that affect the firm's design and delivery of quality. These tools provide general guidelines and rules of thumb.

While TQM relies heavily on empowering employees, even empowered employees need more than authority to succeed. Recall Bill Conway's nail hammering story because it drives home the importance of access to the right tools. These enhance people empowerment by providing analytical techniques and procedures to help them measure and improve the quality levels of their firm's processes.

Nature of Variables

TQM practitioners need data and tools to help manipulate it. Without this data, or with the wrong kind of data, the tools are useless. Analysts can measure process conditions with either *variable data* or *attribute data.* Variable data measures quantifiable process conditions. Variable data contains the most information. To illustrate this, consider how your course grade works. On the three course exams, you received a 70, 98, and 96. Your average grade was (70+98+96)/ 3 = 264/3 or 88.1. If the course grade was based on the mean, you would have earned a B+, which is then posted in the university's computer. The letter grade is attribute data. Note how information about your performance is lost, i.e., that you did well on two of the exams but had one bad hair day. In a similar vein, when a quality management program records whether or not an item is either good or bad, information is lost. How bad was the rejected item? By a tad? Or by a mile?

Variable and attribute measures are linked. An analyst can convert variable data into attribute data. If we took a sample of 20 from subsequent batches of production, we could record the number bad in each sample. This would be variable data. If, however, we classified each sample as either "Accept the batch" or "Reject the batch," then we have lost information. If the decision is made at the shop floor and not recorded, we cannot reconvert the output data back to variable data format. This distinction may become important because some TQM tools need variable data while others can manipulate either variable or attribute measures.

Process Tools

TQM relies heavily on process tools. These tools can be categorized as falling into three types:

<u>Process Exploratory Tools</u>

1. Histograms display the range and shape of recorded variable data.
2. Check sheets display what is happening in a context of some other attributes.
3. Pareto analysis displays the presence or lack thereof of most likely events.
4. Process flow analysis documents how activities are or should be performed within a system.

<u>Tools to Explain Relationships</u>

5. Cause and Effect diagrams help analysts search for possible relationships between a perceived problem and possible causal factors.
6. Scatter plots use two or three-dimensional graphs to visualize the relationships existing or not existing amongst the variable data.
7. Plan-do-check-act provides a systematic way to explore relationships through experimentation.
8. Brainstorming uses open-ended group thinking to explain for what has been observed.

Quality Management Decision-Aiding Tools

1. Process capability--statistical tools that help us understand the likelihood that a process will be able to make units that meet the engineers' specifications.
2. Acceptance sampling—sample-based procedures that are used to decide whether or not to accept a batch as being made in conformance to a set of product specifications.
3. Control charts--a sampling procedure for deciding if a process is operating under control.

The first eight tools were discussed in Shell 5. In the following sections we describe the last three.

Process Capability Measures: C_p and C_{pk}

As stated earlier, a key concept within TQM is the concept of variance. Sources of variance are many, in part because activities are rarely done exactly the same way each time. The output of a machine varies as a function of the raw materials being used, the setting on the machine, the extent of machine and tool wear, and the temperature on the factory floor. The combined effect these factors have on the performance of a process is called process variation. *Process variation is the amount of variation one might expect if the process were operated the normal way using the normal input stocks and run the right way by a trained operator*. The *process width,* (P), is the range of variable data readings taken under normal operation conditions. Whether or not a process with a given P will be able to turn out acceptable products depends on what the process is being asked to do. To understand why this is so, it is necessary to note that the specifications of a part is driven not by what the machine can do *but by what the part's dimensions needs to be*. Engineers define a part specification wide (S) that can satisfy the customers' need for functionality and reliability. S defines the desired level of dimension variance, i.e., the interval between the lower and upper limits on key performance dimensions. The implicit assumption is that any part with dimensions that fall within this specification range will perform acceptably.

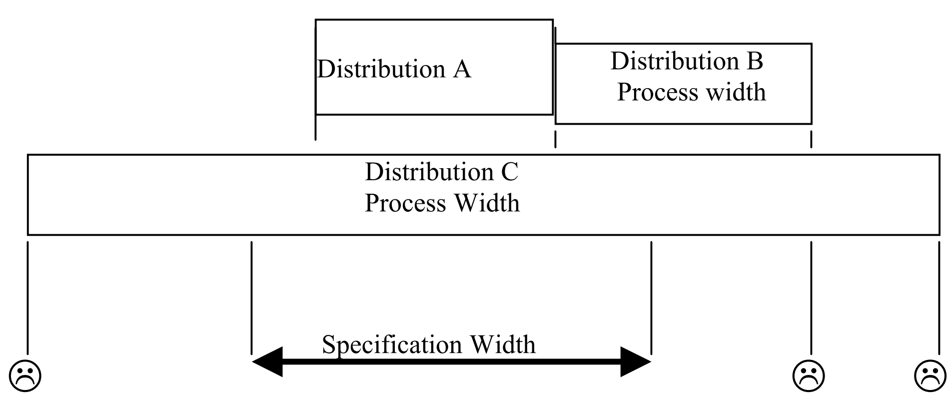
Based on these two measures of variance, TQM practitioners calculate the process capability ratio:

$$C_p = \text{Specification width} / \text{Process width}$$

Most process distributions are open-ended, however, with only lower limits on performance data, so statisticians often set limits at 3 standard deviations on each side of the mean. The resulting range encompasses over 99 percent of a normal distribution.

To illustrate the application of C_p, Exhibit 3 shows three different distributions of process performance data. All have the same specification width.

Exhibit 3
Three Possible Situations



Distribution A shows process variance that falls well within the specification width shown by the heavy line. It is highly likely that all units produced by this process will meet the engineer's design specifications. The second distribution, B, has the same process width but it is incorrectly centered. Hence more than half of the units produced by this process will fall outside the engineer's specification. Clearly an adjustment needs to be made. Distribution C represents a bigger problem because the process width exceeds the specification width. The resulting C_p indicates that this process meets specifications only a fraction of the time. Such unacceptably wide process variance requires management intervention to reduce it.

In general, a larger C_p value indicates a more reliable and predictable process and a higher probability that the process will satisfy or exceed the engineers' requirements. In fact, some buyers use C_p values as part of their supplier-selection mechanisms. Before placing an order, such a firm requires evidence that the seller's process can met or exceed some minimum C_p value in order to ensure that the process will be able to meet or exceed the needs of the customer as represented by the specification width.

Golf and Process Capability

In the game of golf, the designers of golf courses are required to have greens with holes with a diameter equal to C. Assume that you are as good as Tiger Woods. The process width of your putting process has a process width of P=*f*(Distance). Within six feet, P is less than C, i.e., you never miss a gimmie, i.e., a sure thing. As the distance to the hole increases and the undulations of the green becomes greater, your process width increases while the hole remains the same diameter—it just seems smaller.

Some statistical musings of a hacker

C_p effectively measures process capability, but only for a process with a centered distribution of performance data. You are trying to hit the center of the hole--aren't you? The process capability ratio assumes that the mean of the process distribution coincides with the midpoint of the specification width. That was not the case with Distribution B. The value adjusts for any difference between the center of a distribution and the midpoint of the specification width by adding a correction factor to the calculation. Mathematically, C_{pk} equals

C_{pk}= (Closest Engineering Specification – Process Width Mean) / (One half the process width)

This requires some explanation. If a process is off center, then its mean is closer to one of the specification width end points than the other. We use that point since it will denote the severity of the problem. We use one half the process width because we used the mid-point of the process width to calculate.

To illustrate how to calculate each of these process capability statistics, consider a problem with the following characteristics:

Process Width	Low value = 60.3	High value = 60.6	Process width mean = 60.5
Specification width	Low value = 60.2	High value = 60.6	

Then

C_p = (60.6 - 60.2) / (60.6 – 60.3) = 0.4 / 0.3 = 1.33
C_{pk} = (60.6 – 60.5) / 0.5*(60.6 – 60.2) = 0.1/0.2 = 0.5

The fact that the process mean lies close to the upper limit of the specification width means that this process quite likely will produce an unacceptable number of off-spec parts—even though the C_p seems to indicate no problem. As is the case with archery, aim matters.

If engineers design parts that cannot be made given current process capabilities or operations managers assign workers to machines incapable of holding to the desired specifications, the result is often poor quality and frustrated workers. You have to have the right tools to do the job right. Both C_p and C_{pk} provide operations managers with tools that help avoid product specification/process capability mismatches.

Acceptance Sampling

With acceptance sampling, we are dealing with a similar problem but from a slightly different prospective. The problem that acceptance sampling seeks to assist is the following:

Given a lot of goods that has just been delivered or produced, how can we tell if it is acceptable?

By acceptable, we mean, "Does an *acceptable proportion* of units in the lot meet part design specifications?" We are not asking, "Are *all* of the units in the lot good?"

Acceptance sampling is one of the oldest statistical methods in the OM Toolkit. Recall that this tool was developed at AT&T in the 1920s. In a sense, the importance of this tool has declined in part because many supply chain relationships have *dissolved* this problem by placing the responsibility for conforming to quality specifications squarely on the shoulders of the supplier. In effect, modern supply chain management argues that one should only be buying goods from suppliers who have their act together.

Nonetheless, there are situations in which the quality reliability of a supplier or a process are suspect. Legal contracts may even require it as a part of a particular activity. Hence we will proceed but will not try to give a full-blown coverage of acceptance sampling. For a more detailed discussion, we refer you to the OM Toolkit or one of the references cited at the end of this shell.

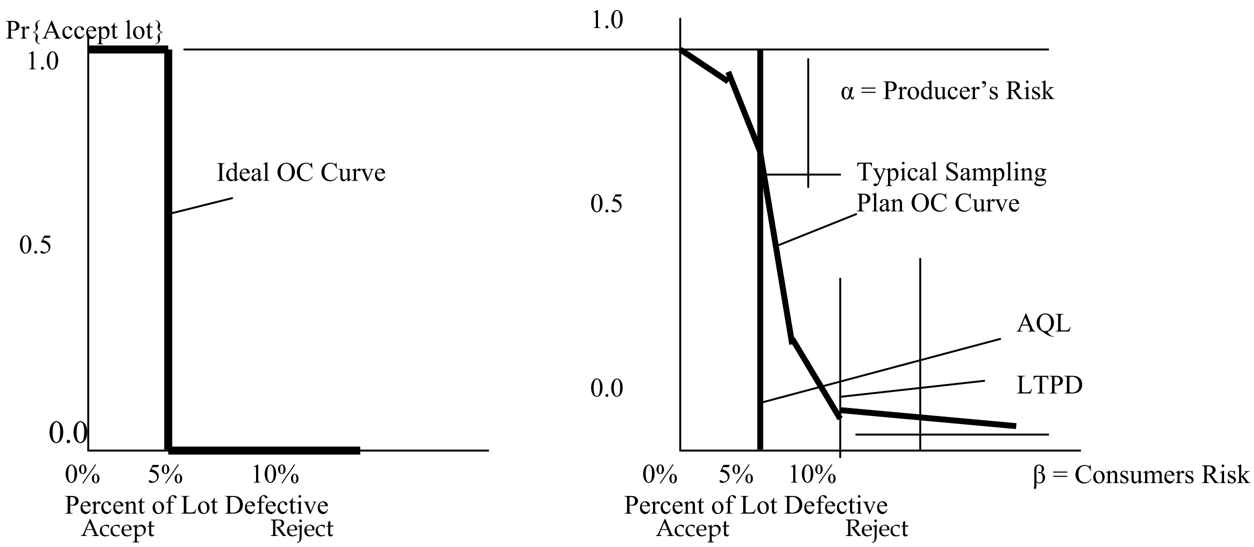
Given a need to assess the quality of incoming lots, the operations manager must select from one of two options—100% inspection or inferring a lot's quality based on sample statistics. In the past, inspecting 100% of the parts in a lot were impractical because it either cost too much or the nature of the testing process adversely impacted the quality of the good being inspected. But with advances in automatic inspection technologies, this option should not be automatically ruled out. Next time you open a bottle of beer, look at the bottle cap. This item is subjected to 21 different online tests in a process that makes 10,000 caps per minute.

The second option is to take one or more samples randomly from the lot. Each item in the sample is measured or otherwise evaluated. This measurement may record either variable data or attribute data. For variable data, a sample mean is calculated. For attribute data, the sample statistic usually is the number of bad products found in the sample. The sample statistic is then compared to a performance metric, which is called the acceptable quality level (AQL). If the sample mean falls in the unacceptable range, in a single sample procedure, the batch is rejected. Otherwise the batch is accepted. We used the term single sample procedure because some sampling plans call for additional information to be secured when the sample statistic falls in a gray area, i.e., the sample mean is close to being accepted but not quite.

To illustrate, suppose we needed to inspect incoming lots of 1000 parts. We have decided that what we would like our sampling plan to do is reject any lot with a fraction defective greater than five percent, i.e., we would be willing to accept a lot with 950 on-spec parts but not 949. What we would like is a sampling plan that would make the correct decision 100% of the time. But if sample data is used to *infer the actual fraction defective*, mistakes will be made, i.e., good lots will be rejected or bad lots will be accepted.

To deal with these types of mistakes, the creators acceptance sampling use a performance metric which is called the *operating characteristic curve*. The OC Curve describes the performance of the sampling plan. In the ideal case, it will always be right, i.e., it will always accept the lot whenever the actual fraction defective is at or below the *acceptable quality level*, (AQL) which is defined as the poorest quality that we are willing to accept. And we would want to reject the lot when the actual fraction defective is above the AQ.

Exhibit 4
Acceptance Sampling Curves when AQL = 0.05



In acceptance sampling, we take a random sample, say of size 5, and then measure each part sampled by some means. This information is then used to declare the acceptability of the lot. If the number defective in the sample is zero, the chances are good that the lot is good. But if the number of defective parts found is greater than zero, then one might infer that the lot's fraction defective is greater than 5%. Do we know this for sure--of course not but that is what statistical inference is all about.

We can calculate the probability of making erroneous decisions by using statistics. If the true fraction defective was zero, i.e., all 1000 parts are good, then the probability of rejecting an acceptable lot is zero. What if the lot's fraction defective was 0.05? From statistics, we calculate the probability that a sample of size five could experience no bad parts. The probability of getting five straight good products would be:

$$Pr\{All\ Five\ Good\} = (0.95)5 = 0.77$$

Which says that 23% of the time we will be accepting a lot when the true fraction defective of the lot is 0.05. In the same manner, we could calculate the probability of getting five out of five good parts in each sample. These probabilities define the shape of the OC curve shown on the right side of Exhibit 4. Remember, this is the OC curve for a sampling plan in which we randomly take a sample of size five and only accept the lot when all five parts in the sample are good.

We could continue by determining the height of the OC curve at each possible fraction defective. Fortunately, the folks at the Columbia University Statistical Research Group have done all of this for us in the late 1940s, so if you need to calculate the numbers for an OC curve, you can refer to any quality control reference and look for the appropriate table at the end of the book.

The folks who created acceptance sampling also recognized that not all bad lots are equally bad. For example, if the actual fraction defective in a lot was above 10%, *we really want to reject that lot*. This upper limit is called the *lot tolerance percent defective (LTPD).* If in our example, we used LTPD = 0.10, then the chance of our incorrectly accepting a bad lot is shown by the space noted by β that is shown in Exhibit 4. The risk of accepting a bad lot when measured at the LTPD is known as the Consumers' Risk.

Type I errors occur whenever you reject a lot that is actually good enough to be accepted. This is called the Producer's Risk because the person making the goods incurs a cost when none should have been. Type II costs occur whenever a lot that really should have been rejected is accepted, i.e., the fraction defective was in excess of the LTPD. This is called the consumer's risk because the customer incurs a subsequent cost when it starts to use the goods and finds a higher proportion of defective goods than it had requested.

In most sampling plans, when a lot is rejected, the entire batch is subjected to a 100% inspection with the bad units being replaced with good ones. The *average outgoing quality* of the lots that passed inspection and the rejected lots that had the bad parts replaced with good ones, can be calculated using:

$$AOQ = (p\,P_a\,(N - n)) / N$$

Where, N is the lot size, n is the sample size, p is the lot's fraction defective, and P_a is the probability of a lot being accepted p. There is a slightly different formula for the case when the bad goods are just removed before shipping, but we need not go any deeper for now.

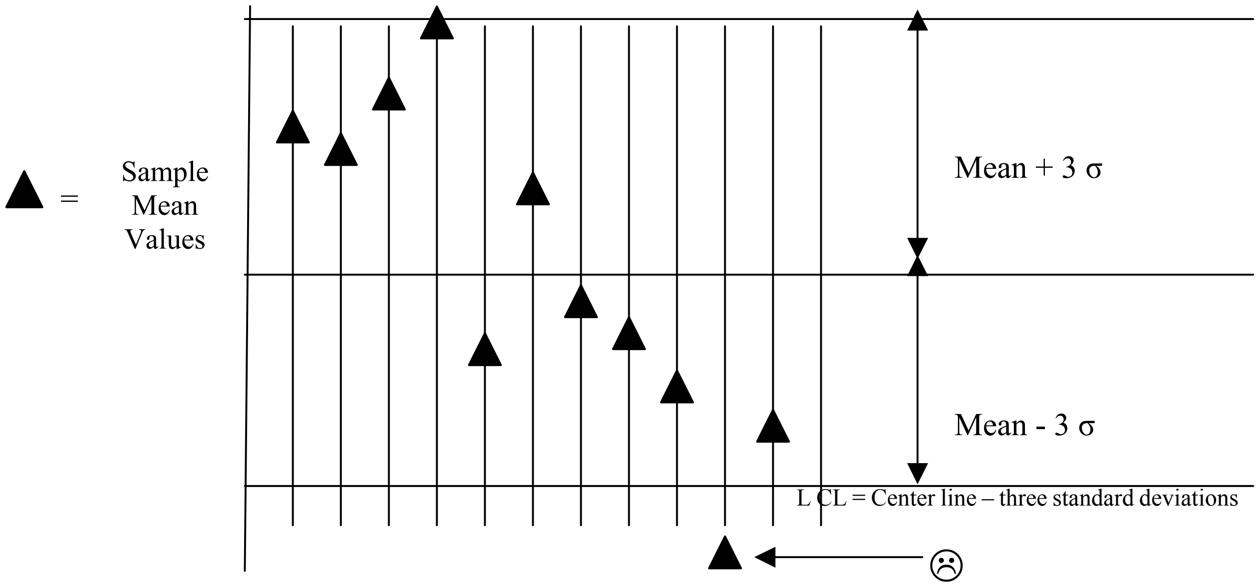
Control Charts

The TQM statistical tools discussed so far have presented basically static information. Histograms and check sheets, for example, consolidate data to show an overall picture of a process at one time. Pareto analysis identifies and rank orders potential problem areas in a current process. However, none of these tools accurately represents changes in performance data over time or the responses of data over time to variations in materials, employees, equipment condition, or methods. TQM practitioners track process performance over time and assess the operations manager's control of a process based on control charts. Most readers treat statistical process control (SPC) and control charts as synonymous.

A control chart plots data collected over time across a set of limits for the upper and lower boundaries of acceptable performance in Exhibit 5. Sample statistics that fall between these two limits indicate acceptable performance; any points that fall outside these limits indicate problems with the process that generated the performance data. Operations managers consider points outside acceptable limits as indicators of a need to intervene to improve the operation of the process. They typically set performance boundaries to correspond to an interval plus or minus three standard deviations on either side of the mean of the distribution. They attribute divergence from the mean of any points that fall between the upper and lower limits to random variations. Sample statistics falling outside the limits indicate an underlying problem with the process.

In this example, the process seems to be under control until the tenth sample. Up to sample ten, we did not have sufficient information to reject the hypothesis that the process was under control. But we should have

Exhibit 5
Limits of Acceptable Performance for Control Charts



noticed the downward trend. Humans do not have to be complete automatons or slaves to control chart methodology. If you see something good or bad happening, think about it and seek to avoid the bad and capitalize on the good. The term out of control need not be bad. Consider what would happen if you, as a C student, returned home after a semester with a straight A average. Clearly you are out of control--but it isn't bad. You need to do find out what you currently are doing that is enhancing your performance metrics.

To construct a control chart, consider the following data, which was collected by an industrial engineer who took twenty samples of size 5. The variable data collected is shown in Exhibit 6.

Exhibit 6
Hard Disk Seek Times in milli-seconds

Sample No.	1	2	3	4	5	Mean	Range
1	12.2	12.3	12.4	11.8	12.7	12.3	0.9
2	12.3	12.1	11.8	12.2	12.3	12.1	0.5
3	12.4	12.7	12.3	12.5	12.3	12.4	0.4
4	12.5	12.3	12.3	12.1	12.1	12.3	0.4
5	12.1	12.4	11.9	12.0	12.3	12.1	0.5
6	12.6	11.8	12.2	11.9	11.9	12.1	0.8
7	11.8	12.1	12.5	12.8	12.5	12.3	1.0
8	12.5	12.8	12.0	12.5	11.9	12.3	0.9
9	12.1	12.3	12.0	11.9	12.1	12.1	0.4
10	11.2	12.3	11.8	11.7	11.9	11.8	1.1
11	11.7	12.2	12.2	11.7	12.1	12.0	0.5
12	12.4	12.2	12.1	12.1	12.1	12.2	0.3
13	11.7	12.1	11.9	11.8	11.9	11.9	0.4
14	11.8	12.2	12.2	12.1	12.2	12.1	0.4
15	11.9	12.3	11.8	11.9	12.1	12.0	0.5
16	12.3	12.4	13.0	12.3	12.2	12.4	0.8
17	11.9	12.6	12.6	12.9	12.1	12.4	0.9
18	11.9	12.0	12.7	12.7	11.9	12.2	0.8
19	11.4	11.6	12.4	11.9	11.8	11.8	1.0
20	11.6	11.8	12.4	12.3	11.2	11.9	1.2

TQM practitioners use the following 10-step process to construct and use an x-bar and R–charts.

1. Initialize the system and collect data to calculate performance limits. The data from which the analyst calculates the control limits for both charts should come from a process known to be under control. TQM practitioners often gather this kind of data from processes just after major overhauls, when they know that they can rely on smooth operations. The nature of this data should match that of the process that the control chart will monitor. In general, this data should reflect about 100 observations.
2. Group observations into samples. Next, the analyst groups observations into coherent samples that share some common trait (e.g., data from a single production run or from one day or shift). For each sample, the control-limit calculation requires the number of observations (n). In general, a larger sample size allows the analyst to calculate tighter limits, leaving a smaller gap between the upper and lower limits. However, this increased precision comes at the cost of gathering more data. The variable k denotes the number of samples needed for the control-limit calculation. Exhibit 6 groups the 100 data points into 20 samples of 5 observations. In this example, n equals 5 and k equals 20.
3. For each sample, find the sample mean. For each sample, the analyst should calculate the sample mean, i.e., take the sum of the n measurements and then divide by n. For the first sample from Exhibit 6, sum the five data points (12.2 +12.3 + 12.4 + 11.8 + 12.7 = 61.4) and divide by 5 to arrive at 12.3 after rounding. Repeating this calculation for each sample gives the 20 sample means.
4. For each sample, find the range, R. The range measures the difference between the largest and smallest values. For the first sample in Exhibit 8, R equals 12.7 minus 11.8, or 0.9. The analyst must repeat this calculation for every sample.
5. Calculate the overall mean, i.e., the average of the sample means. This often is call x-bar-bar. In our example the average of the sample means equals 12.14.
6. Calculate the average of the ranges. In our example, this is 0.69.
7. Compute control limits. To calculate the positions of the control limit lines, the analyst enters values from Exhibit 6 in the equations:

$$\text{Upper control limit for x-bar} = \text{x-barbar} + A_2 * \text{Rbar}$$
$$\text{Lower control limit for x-bar} = \text{x-barbar} - A_2 * \text{Rbar}$$

The values for A_2 are taken from the following table, which is found in most statistics books. The value A_2 times R-bar equals three standard deviations.

<u>Values for Setting Control Limit Lines</u>

n	**A_2**	**D_4**	**D_3**
2	1.880	3.267	0.000
3	1.023	2.575	0.000
4	0.729	2.282	0.000
5	0.577	2.115	0.000
6	0.483	2.004	0.000
7	0.419	1.924	0.076

The D_3 and D_4 values are used to calculate the upper and lower values for R charts. To calculate the limits for control chart, the following procedures are used:

Central line = the average of the sample ranges, aka R-bar

$$\text{Lower control limit} = D_3 * \text{R-bar}$$
$$\text{Upper control limit} = D_4 * \text{R-bar}$$

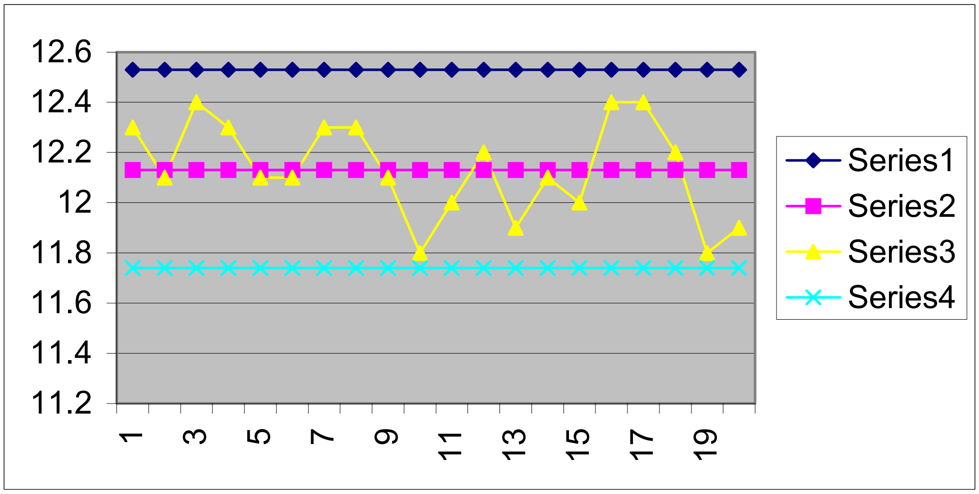
After entering these values and the product performance data from Exhibit 6, these equations give the control limits for the chart, as summarized in Exhibit 7.

Construct the control charts. With this information, the analyst can construct the control charts. By convention, the centerline appears as a solid line and broken or dotted lines mark the control limits.

Plot the x-bar and R values on the charts drawn using the above boundaries. These boundaries are then to be used to evaluate the outcomes of future sample statistics, i.e., for samples 21, 23 ,23, and so on.

Document the procedures used to determine the control charts. These define the procedures that are to be used in subsequent samplings. When this is plotted using Excel's graphics, we note that all sample means fall within the upper and lower control limits as is shown in Exhibit 7.

Exhibit 7
The x-bar chart during the first 20 periods



Interpreting Control Charts: Usually, control charts point out problems as places where sample means or range values appear outside the control lines. This signals managers or workers to stop the process to identify and correct the underlying problems that caused the faulty data. Control charts may also indicate a need for intervention in the process in three other conditions, however.

1. *Trends*: A control chart indicates a trend when successive points seem to fall along a line moving either upward or downward. A trend in control ch   art data indicates some continuing change in the process. This may warrant intervention before the trend line progresses to generate an actual defect.
2. *Runs*: Truly random variations will not exhibit any pattern in the distribution of data around the central lines. However, runs in a process place points in apparent cycle about the central line, defining a run of points above the central line followed by a run of points below. Such cycles indicate systematic problems in the process that require attention.
3. Hugging: This occurs when various points appear so closely grouped around the central line that they seem to show no variation in the data. Hugging usually indicates some intervention in the process to limit or eliminate variation. In other words, some action is masking the natural variation in the process. The TQM practitioner must uncover and remove this limiting force, due to employee action or whatever cause, to reveal the true operation and natural variation in the process. Hugging prevents the analyst from judging whether the process as currently constituted really operates under control or some outside force is taking unusual measures to produce acceptable results.

TQM and Statistical Methods

A number of years back, a quality consultant posed a challenge to some managers. He broke the managers into two groups and each was assigned the task of pounding a nail into a board. The reward was a trip around the world--so both groups were highly motivated. The first group was given a highly inspirational lecture on the importance of quality. The second group was given a hammer. Which group do you think will win? The point is that TQM programs need tools--statistical and computer assisted methods to help managers glean meaning from data.

SUMMARY

In this shell we did two things. First, we provided a historical perspective of quality management and how it has impacted the operations management function. Particular emphasis was placed on the works of Deming—the leading quality guru of the Japanese Quality Revolution. Secondly, we introduced three new TQM tools, process capability coefficients, acceptance sampling, and control charts. While we do not want to imply that these are only tools in the Operations Managers' arsenal, many of the other generic TQM tools were introduced earlier.

References

1. Deming, W. Edwards, *Out of Crisis,* MIT Center for Advanced Engineering Study, Cambridge, MA,1982.
2. Duncan, Acheson J., *Quality Control and Industrial Statistics*, Irwin, Homewood, Ill., 1974.
3. Garvin, David A., *Managing Quality*, Free Press, New York, 1988.
4. Ishikawa, Kaoru, *What is Total Quality Control? The Japanese Way*, Prentice-Hall, Englewood Cliffs, N.J., 1980
5. Juran, Joseph M. and Frank Gryna Jr., *Quality Planning and Analysis*, McGraw-Hill, N.Y., 1980.
6. Logothetis, N., *Managing for Total Quality Control from Deming to Taguchi*, Prentice Hall International, Hertfordshire, U.K., 1992.

Expected Learning Competencies

Before putting Shell Twelve down, you should ask yourself the following questions. Am I able to explain:

1. How quality business processes have been classified into two broad categories, i.e., design quality and conformance quality.
2. The evolution of quality management and the major contributions made by Deming, Juran, and the Japanese.
3. Why Deming sought to eliminate or minimize variance within operations management systems. Is this always desirable?
4. What TQM is and what the major components include.
5. The role of statistics and when sampling is necessary and why it is increasingly becoming less necessary. What is acceptance sampling and why has its used diminished?
6. How to use process capability and control charts. Be prepared to transform data to demonstrate the use of each.
7. What your instructor added to this shell and why he or she thought that it was important enough to warrant its inclusion.

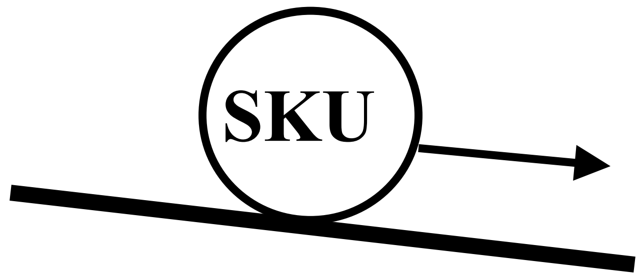
Frequently Asked Questions

Instructors have been known to ask questions similar to the following:

1. Explain how the value equation and quality are related?
2. Appraise the quality of a Big Mac purchased at a McDonald's outlet. How might your analysis be customer specific?
3. How have computers, information technology and computer-assisted manufacturing impacted the ways companies go about managing quality?
4. Which of the following has contributed to the declining use of acceptance sampling?
   a. Vender certification programs
   b. The feasibility of 100% inspection
   c. Both a and b
   d. None of the above
5. When information from a sample is used to reject a lot and it turns out that the lot was good, this is called:
   a. A Type I error
   b. A Type II error
   c. A Type III error
   d. Come on Teach, you can not reject a good batch
6. Deming's 14 points were directed a management.
7. If a process has to bad chance of making a good part, its C_p will be greater than one.
8. If a machine's C_p varies from job to job, then we can conclude that the process is out of control.
9. The upper limits of a control chart are determined by engineering specifications.
10. The only acceptable reason for declaring a process "out of control" is if a sample mean falls outside the control char's upper or lower control limits.

SHELL THIRTEEN

MANAGING THE FLOW OF MATERIALS



A Rolling SKU Gather Fewer Costs*

Ten miles west of the Ohio-Pennsylvania border is Delphi Automotives' new Cortland factory. Its 120 presses turn out a billion plastic housings a year for electronics connectors that are used in the automotive industry. Recently, *Fortune* magazine featured this plant as being one of America's elite factories. One of the things that make Cortland world class is its "e-manufacturing network," which monitors each molding machine, its tools and fixtures, its orders, and its inventories.

John Stefanko, the plant superintendent commented: "You'll see lights blinking, and you'll see automatic guided vehicles moving around, but what you don't see is just as important as what you do see." One of the things that you don't see much of is inventory. When nylon pellets arrive in sealed, reusable bins, each bin is bar coded to record which machine will use it and when the raw material will be used. When needed, the bin a vacuum sucks the material into pipes that deliver the material as needed to the machines.

Each machine downloads each part's "golden recipe" that is stored in the plant's IT system. Once a run has begun, the nylon pellets are pulverized into powder, heated to a liquid state, and then injected into the machine's mold. Each cycle produces two to thirty-two parts, depending on the die used. The parts are cooled and then transferred to an awaiting box. An online inspection system evaluates each part as it is ejected from the machine. Off-spec parts are diverted to a separate bin. Three consecutive faulty parts trigger an alarm that alerts the operator to the fact that corrective action is needed. This rarely happens so each operator is able to monitor 15 machines.

When a box is filled, the system prints a label and an automated guided vehicle (AGV) transfers the product to finished inventory storage. Within a day, the unit is shipped to a nearby plant for the next manufacturing process. Delphi's manufacturing software controls and coordinates all plant activities: from the shipments of pellets into the system to the ultimate delivery to automotive customers. With its new zero defect reputation and fast to product capabilities, Delphi hopes to extend its customer base beyond the cutthroat automotive industry.

Source: Julie Creswell, "America's Elite Factories," *Fortune*, September 3, 2001

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* The term, SKU, stands for stock keeping unit. Operations managers often gage the size of an operation by asking how many SKUs a system has.

Shell Thirteen

Managing the Flow of Materials

Table of Contents

Learning Objectives for Shell Thirteen

After reading this shell and thinking about its content, you should be able to:

1. Describe the three ways the operations function has used to trigger the flow of materials.
2. Briefly describe the evolution of inventory management practices and the role emerging information technologies have and are playing to support this key business process.
3. Explain the costs and assumptions associated with the classic EOQ and the production lot scheduling model.
4. Describe the impact of collaboration or the lack thereof within inventory management systems.
5. Understand the fundamentals of materials requirements planning and when it should be used. You should be able to write Excel formulae to demonstrate your understanding of the MRP record and how they are linked.
6. Understand the basics of just in time management systems, their key assumptions, and the type of business environments in which it has the best chance of success.
7. Explain the linkages that exist between TQM programs and JIT programs. What must be present if JIT is to succeed?
8. If your competitor is a world-class user of JIT, how might you gain a competitive advantage?

INTRODUCTION

The goal of inventory management is to direct the flow of the right materials through the right processes so as to have product delivered to the right customers in a timely, cost-effective manner. While inventory management started early in the 1900s, evolving information technologies have revolutionized the ways leading edge firms think of inventory today. Although inventory remains an asset in a financial sense, world-class inventory management has become an asset in a strategic sense.

  - o The driving philosophy of inventory management often is: *The faster inventory flows through the system, the better.*
- o Demand forecasts are the most important input to the inventory management process
  - o The best source of demand information is the customer, either in the form of a firm customer order or as part of a collaborative process. Customer guesses generally are better than supplier guesses.
  - o If the customer can not or will not provide this input, then use your analytical skills to understand the patterns of past demand and then ask if the past a good predictor of the future?
- o Keep the inventory management process as simple as is possible.
  - o Optimization techniques may not result in an optimum inventory control system
  - o KISS should be considered guiding strategy. (KISS stands for keep it simple stupid.)
- o Use information technologies to their fullest so as to create the most responsive information flow presented in its most useful form.

In the introductory story, each of the above was being practiced. Once a firm production order was received from its downstream plant, the nylon pellets were transformed into finished injection molded product, inspected, and then shipped. No more than was requested is produced, partly due to its online quality control system. The few rejected products were immediately ground up and recycled. What Delphi and other world-class companies do is deliver value to their customers, i.e., they deliver a quality product with the right features when their customers need it.

In some situations, customers expect vendors to have some inventory on hand so that they can examine, try on or out, and otherwise experience the product before deciding to buy. Many consumers are this way, although rising B2C sales indicates that this is becoming less so for some products such as books. When the customer does not have to take physical possession of a product immediately, the strategic decision becomes that of deciding where inventory is best placed to stock product or product components in the supply chain.

In other situations, customers (end product buyers and, circa 2002 are:supply-chain customers) do not need on-hand inventory, but they demand on hand stock to ensure that their needs will be met in a timely fashion. This is *just-in-case inventory* may be a *symptom* of past supply chain shortcomings. The need for *JIC* inventory diminishes when effective production planning is matched by proven fast to product capabilities. When a firm plans its work and then works its plan reliably, the frequency of emergency orders diminishes. Likewise, when a firm has sufficient manufacturing flexibility, quite possibly by maintaining reserve capacity, it is able to produce goods at the right times and quantities as needed -- once again reliably.

The placement of inventory within a supply chain is a strategic system design issue. For example, the decision to utilize an assemble-to-order market orientation usually is done to broaden the product variety that a firm can offer its target customers. One consequence is that any firm using do- to order market orientation will have no finished goods inventory. If the firm must respond quickly, it must either maintain component inventories or have vendors with quick response capabilities. Market orientation decisions are strategic. *Decisions that relate to the replenishment of these inventories are operational issues.*

In this shell, we introduce some basic operational inventory management concepts and practices. Three traditional ways to stock or replenishment inventory are discussed (independent demand inventory management, materials requirements planning, and just-in-time inventory management). Throughout the shell, we shall strive to place each issue in the context of the larger strategic question: "How might this decision influence the firm's ability to satisfy the firm's marketing strategy?"

Dialogue Driver: Many medical operations use whole blood. Where is the best place to store it?

A BRIEF HISTORY OF INVENTORY MANAGEMENT

A historical review of inventory management reveals a cyclic pattern in which it oscillated between using micro approaches that apply local decision rules that assist making individual SKU stocking decisions to the using macro approaches that strive to manage SKU inventory on a system wide basis. Inventory management began at the micro level when Ford Harris first used mathematics to answer the shop floor level question "How many units should be made in one batch?"[1] The person asking this question sought to resolve the economic tradeoff problem. Making a product in larger batches meant that lump sum production setup costs could be spread over all units made in a batch. But larger batches meant that more units would be placed in inventory, thereby increasing holding costs. Harris created the classic *economic order quantity* (EOQ) formula that used unit inventory carrying costs, a fixed production setup cost, and an estimate of the annual demand to find a minimum cost batch size.

Over the next five decades, hundreds of inventory models were developed to help determine the optimum inventory policies over just about every conceivable inventory-stocking situation. They answered two basic questions, **how much** should be produced or ordered at one time, and **when** should that order be placed.* Most of the models developed dealt with these issues on a single product decision-making was done with no consideration of the decision's consequences on the other items that the firm held in inventory. These were called local decision rules.

In the 1960s, two new wrinkles were added. The first was the result of the migration of computers out of the accounting realm to the factory floor. Computers were used to track the demand for items kept in stock. SKUs were given numerical names to define products and parts precisely. Computers like it that way. In these early inventory systems, predetermined reorder quantities and reorder points were used to trigger replenishment orders. In order to get the third input to the EQO formula, exponential smoothing was used to estimate the demand rate. Recall, that early computers had limited memory so the information storage requirements of these simple formulae did not tax the computers' capabilities.

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* There is a third type of question: **Who** should we purchase the goods from? or **What process** should we use? The purchasing function dealt with **who** questions. Production planners usually decided **what process** questions.

Three of the major shortcomings of these early computer-based inventory control systems were:

- They triggered orders of goods based on historical and current demand rates. If the future was likely to be different than the past, then some other means needed to be used to prevent the production or purchase of goods that were unlikely to be sold quickly.
- They used local inventory management decision rules to generate lot sizes and reorder points. No consideration was given to how busy the factory was and the factory's storage capacity. Operations managers dealt with these problems by demanding longer production lead times to give them some flexibility over their operations. So if a production run might take six hours of machine time, the system used a longer lead-time, say one week. This is equivalent to your instructor giving you one week to do a six-hour homework assignment. While this seems like a reasonable lead time, the result was a less responsive supply chain with more work in progress inventory.
- They did not use all of the information available. The local decision rules did not allow for the fact that the usage rates of many component parts are related. For example, the usage rates of hamburger buns and meat patties both are driven by Big Mac sales. Early inventory management systems did not use this information so they treated the usage rates for buns and patties as having *independent demand*. The Big Mac example is trivial, but consider what happens when hundreds of parts go into making an automobile. It made little sense to track and forecast the usage of items individually when a much smaller number of end products actually drive component usage rates. This recognition led some to concentrate on end product demand forecasts and then use these to calculate the likely usage rates for all of the components that are needed to make end product items.

The result was that while these early inventory systems made dealing with large number of SKUs manageable, an unintended consequence was a less responsive system with low inventory turnover rates.

The second wrinkle was that some practitioners saw a solution to their long held concerns that local inventory rules did not effectively use all of the information available. They noted that early, computerized inventory control systems did not recognize that the demand for most component parts was *dependent* on the production of end products. For example, the demand for parts needed to make a bike can be determine once we know how many bikes the firm plans to make. This led to the development of a *dependent demand* inventory planning system that came to be known as *materials requirements planning* (AKA MRP).

Today, MRP is used whenever the number of part types is high, and *dependent* on the planned production of finished goods. One advantage of MRP is that it is able to handle uneven end-product production plans. This allows operations to build what will be needed, not what we had just sold. It also enabled operations planning to consolidate component usage that was driven by the different end products that used that item. Lastly, by using a system-wide approach, the users of MRP were able to see how a proposed plan would impact the plants human, machine, and inventory resources. The plan was not optimal, but when done right, it provided marketing and operations with a mutually agreeable, do-able production plan.

By the 1970s, many American companies had fully developed world-class MRP systems. Operations managers proudly proclaimed that their MPR systems were certified as a Class 1 system. While they had much to be proud of, top management noted that certain Japanese firms were kicking butt in the marketplace by producing goods of higher quality, lower costs, and seemingly better product designs. When we studied their manufacturing systems, two "silver bullets" were found. The first was total quality management and the second was the Just-in-Time (JIT) manufacturing system. JIT manufacturing has many features but we will cite two here. The first was a micro inventory-triggering mechanism called *kanban cards*. Think of a kanban as an egg carton that holds twelve eggs. When the last egg is used, the empty carton is sent upstream to signal that another dozen eggs should be secured. When this system is used throughout a factory, the system coordinates the rate goods are made with the rate goods are being used. Normally, this is a good thing.

The second feature of JIT was that it strove to eliminate *system variance* by scheduling the same level of work each day within a planning period. Whereas an American company would schedule all production of model A together, a JIT-based system would divide that amount by the number of days in the planning period in order to make the same amount each day. If 500 units of a certain model of bicycles were to be made in a twenty-day planning period, the JIT system would make 500/20 = 25 units each day. The use of load leveling enables JIT to use micro-rules to order individual items because it has planned the system wide rate at which production will occur.

There is much more to JIT, but it is suffice to say that this tool revolutionized many American manufacturing systems. Its benefits were obvious. The amount of inventory needed to support JIT systems dropped dramatically. It required its workers to strive to eliminate all forms of waste. Machine setup practices are studied to reduce production setup times. System reliability was the goal and system variance was the enemy. The need for large-scale computer inventory control systems, including MRP systems, is reduced. Unreliable suppliers are purged from the supply chain and inbound logistics are modified to enable the firm to bring in only what was needed when it was needed. Manufacturing had become simple and fun again If only we could get our customers to order goods in an orderly way. And cut out or minimize those engineering changes!

In the 1980s, MRP's role was expanded to something called MRPII, which stood for Manufacturing Resource Planning. This system-wide approach extended the MRP to include other factors of production such as human resources, machine capacity, and financial considerations. Soon operations planners had merged their systems with accounting control systems. This made sense since both the accounting and operations were using the same transactions to drive their systems, i.e., both accounting and operations needed to know that Production Order #3572-6 had moved from work center 45 to work center 81 and that $278.54 of costs had been incurred at work center 45. Since this was 22% above the standard costs, it sent a red flag to management that for some reason, performance had not occurred as planned. Once again, we see another application of management by exception.

As the century ended, these systems had evolved into something called Enterprise Resource Planning (AKA ERP). Alas, the PC-practitioners had lost a battle and the MIS departments were on the rise again. At this time, it is too early to say if ERP is the solution or the beginning of a new problem. Early evidence does indicate that implementation of ERP systems is expensive.

In the 1990s, another innovation began to show up in supply chains--something called collaboration. It was based on the observation that the cause of unwanted inventory or unmet demand was that the players within supply chains players acted independently. Within the food distribution supply chains, they noted that "special car-load" price promotions caused buyers to buy in an intermittent pattern. Wal-Mart recognized that Proctor and Gamble's Pampers Division management probably understood the demand for diapers better than it did. Out of this came an inter-company group that called itself "The Collaborative Planning, Forecasting and Replenishment Committee (AKA CPFR) with the mission to "improve partnership between retailer and suppliers through co-managed processes and shared information."*

From this brief overview of the evolution of inventory control, you should note that what started out as a simple question at the shop floor level has continued to expand. First, it expanded to a plant wide planning tool, then a company wide system, and it now is a supply chain wide endeavor. It started out with mathematics as the basis for its process improvement and then expanded to an information technology based revolution. And lastly, it started out as a set of local, optimization-based decision rules and then proceeded to collaborative thinking. As we start out the next century, we no doubt will see these trends expand to include the customer as the starting point for the whole process. In December of 1999, Nike announced a web-based program that will allow its customers to design and personalize athletic shoes per their whim—for an additional cost of ten dollar.

Dialogue Driver:
In the future some products will include inexpensive chips that emit a radio frequency telling a wireless system were things are and when they have been removed, say by a customer. What impact will this emerging technology have on retail and supply chain inventory systems?

A TAXONOMY OF MATERIALS MANAGEMENT ENVIRONMENTS

The number of ways to manage the flow of goods within supply chain is too many to survey here. So we have elected to present a taxonomy that categorizes: inventory types, the nature of their material flows, and some of the more common ways in which firms manage the flow of materials. Some of the more common ways to categorize the attributes of inventory and inventory control systems are:

Attributes of Inventory

Within Process Status

- *Raw Materials* provide the inputs to a product transformation processes. The form of each input may range from a basic material, such as salt, to highly fabricated items, such as a computer monitor. Often, what you consider a raw material to your process is a finished good of your supplier.
- *Work in Process (WIP)* generally refers to assets at some intermediate stage within a manufacturing or service system. For example, within a job shop, once an asset has been removed from raw material inventory and starts its route through the job shop, it is classified as work-in-process inventory. It remains so until it is transformed into the desired finished product. Can you think of WIP within a service organization?
- *Finished Goods* are products that have been transformed into the state desired by customers. In some systems, this is not a clean distinction since some items are developed to a saleable state but additional features may be added per specific customer requests.
- *Mistakes* refer to items in inventory that are the results of bad decisions, unforeseen circumstances, and/or poor process control.

Within Supply Chain Location

- *Upstream Inventories* refer to inventories held by your suppliers and their suppliers.
- *Product Transformation Inventories* are process related items described in the first category.
- *Wholesale Inventories* are inventories held by mid-distribution system players
- *Retail Inventories* are the stock retailers acquire for sale.

- *Customer inventories*: in certain supply chains, an end product user will stock inventories in anticipation of their use. Sometimes customer inventory is placed on consignment with the user.
- *In-Transit Inventories* are the assets that are between shipping and receiving points.

In addition to the location attribute of inventories, there are a number of other ways to characterize them:

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* While we discussed this in Shell 6, you might want to revisit this organization's web site at http://www.cpfr.org

Product Attributes

- *Standardized items* are products that meet industry standards and are not made to the specification of any one customer.
- *Customized items* are products that are made to meet unique customer specifications.

Customer-Product Linkages

- Goods made or purchased to meet specific customer orders
- Goods made or purchased in anticipation of customer order—most often these are standardized products—but not always.
- Goods sent back by supply chain partners and/or their customers.

Economies of Scale Factors

- Manufacturing economies of scale
  - *Setup driven considerations* seeks to spread setup costs over larger batch sizes
  - *Process stability driven considerations* seeks to keep the process running once hard to gain process stability has been achieved.
- Transportation economies of scale
  - *Truckload considerations*
  - *Other* transportation mode considerations
- Other Considerations
  - *Market promotions* cause buyers to purchase more in order to get price discounts.
  - *Price uncertainty* may cause firms to lock in costs if they anticipate price increases or decreases.
  - *Availability uncertainty* may cause some to buy goods when they can get them—thereby minimizing the risk of being out of hard to get goods.
  - *Seller well-being*
    - The product is perishable or easily rendered obsolete
    - The threat of theft is significant if left unguarded
    - Product placement can aid or hinder the marketing of the product

Other ways to categorize inventory situations are by:

The Direction of the Flows

- *Toward the ultimate customer*: this is the normal direction of flow
- *Back toward one of the suppliers*: usually this is an undesirable situation but nonetheless it needs to be managed. Believe it or not, some customers actually enjoy returning slightly used merchandise.

The Extent of Ride Sharing

- *The good travels alone* either in truckload quantities or as less-than-truckload shipments
- *The item is combined with other items* going from one or more vendors to the buyer

Shipping Service

- *Seller provides* shipping service
- *Buyer provides* shipping service

Attributes of Transformation Process Flows

- *Product Flow Patterns*
  - Continuous flow such as from a chemical process
  - Intermittent flow, such as from a job shop

- *Order Trigger Mechanism*
  - Orders triggered independently, such as by a reorder point or kanban mechanisms.
  - Orders driven by orders of higher-ordered items, such as end products (See MRP section)
  - Orders triggered by collaborative planning processes

Attributes of Supply Chain Players

- *Degree of Cooperation and/or Collaboration*
  - Product buys predominate
  - Process buys are the norm
- *Nature of Information Flow Connectedness*
  - Snail-mail, telephone and telex are the norm
  - Advanced information technology networks
- *Inter-firm Proximity*
  - Vendors are widely distributed often globally
  - Vendors are close, i.e., within one day's travel
  - Onsite vendor (Vendor within your plant)

In each instance, the analyst needs to understand the nature of the buyer-supplier relationship. In some cases, the attributes are the result of an effective supply chain system design process. Then the task will be easier. In other situations, the inventory manager must make due with an existing situation. In either case, the goal is to create a flow of goods that effectively makes and ships goods in a timely fashion.

Dialogue Driver

What would you have to different if the state of the good changes with time, such as plant growing?

INDEPENDENT DEMAND INVENTORY CONTROL

As was noted earlier, single product inventory decision rules seek to answer three micro-questions:

- *How much* should be ordered for the next batch?
- *When* should that batch be ordered?
- *Who* should we buy it from or how should we make it?

One way to answer these questions is to use the following six-step procedure:

- Develop a fundamental understanding of the problem at hand. What would management accept as viable objectives? What type of model will best serve the user?
- What are the relevant variable costs and customer service parameters?
- Select the decision variables. This can be an economic lot size , or the time between orders, or whatever works best for your problem.
- Write a total cost equation that expresses the problem's relevant costs in terms of the decision variables selected. Also draw a profile of how inventory will behave over two or three order cycles.
- Determine the best solution using a means most understandable to you and your client. You may be able to solve the problem with calculus, a graphical approach, or a spreadsheet. The choice is yours.
- Evaluate the results in terms of its sensitivity to the cost and demand assumptions used. Explain these to your client and make sure that he or she understands the limitations of the model.

To illustrate this process in use, suppose that we need to develop the optimum quantity for the following problem. The firm seeks to determine the minimum cost order quantity for an environment in which the following assumptions can be made:

- Demand arrives at a constant rate of 36 units per day. We will use the symbol D to denote demand
- A production setup cost of \$100 is incurred each time a new batch is run. C_s is the setup cost.
- The cost of carrying inventory over from one day to the next is \$0.25 per unit. C_I is the holding cost.

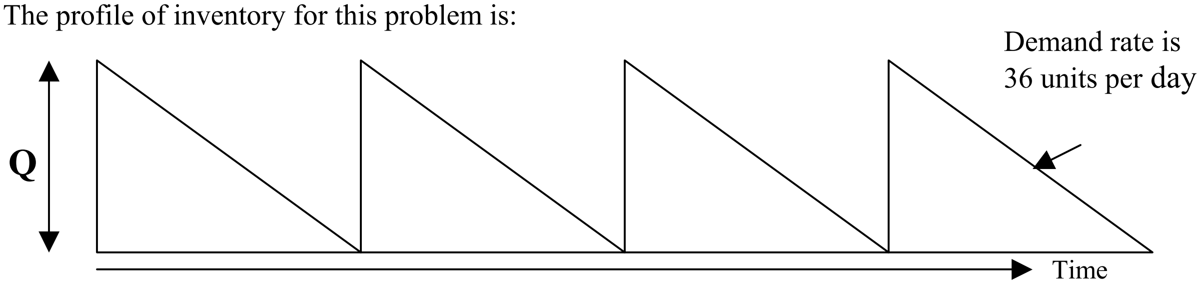
If we let the order quantity Q be the *decision variable*, then the total cost equation for this problem is:

Total cost(Q) = Inventory costs + setup costs

= C_I times average inventory level + C_S times number of setups

$TC(Q) = C_I *(Q/2) + C_S * (D/Q) = \$0.25 * (Q/2) + \$100. * (36/Q)$

The profile of inventory for this problem is:



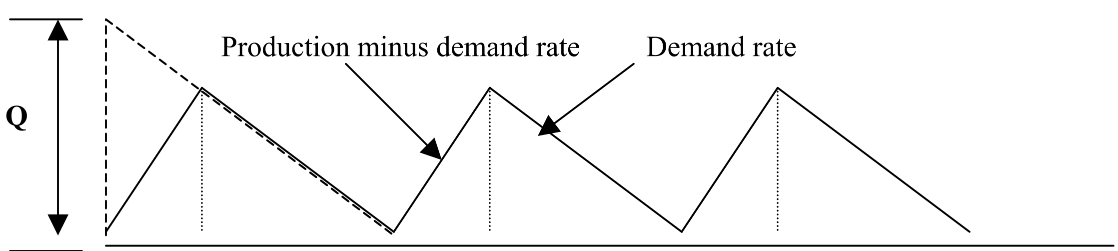
We assumed that the order quantity Q would arrive at the start of each cycle. From geometry, recall that the average height of a triangle is one half its height so our using Q/2 to denote average inventory makes sense.

To solve this problem using calculus, we take the first derivative with respect to Q and set it equal to zero. When we do this we get:

$(-1)(C_I)\, Q^{-2} + C_S D = 0$ which when rearranged is $Q^2 = 2DC_S / C_I$ or $Q = (2DC_S / C_I)^{1/2} = 170$ units

This is called the *classic economic order quantity model.* Note that it answers the *how much* question .

This is but one of the many economic order quantity models that have been developed to help answer the how much question. Another is called the *production-lot scheduling model* and it differs only in that it assumes that the batch is received as it is made. If production occurs at a rate of p units per hour and demand occurs at a rate of d units per hour, then inventory rises and falls in the following manner.



When you write the total cost equation for this set of assumptions and then differentiate with respect to Q, the following economic lot size formula results:

$$Q = (2DC_S / C_I)^{1/2} *(p/((p-d))^{1/2}.$$

Note that the first term simply is the classic economic order quantity model and the second term is an adjustment that reflects the fact that the maximum inventory level is lower. If the production rate is substantially larger than the demand rate, then this model converges to that of the classic EOQ model.

Question: Which will result in the larger lot size? Since p/((p-d) is greater than or equal to one, then the lot size obtained using the production lot scheduling model will always be greater than or equal to the lot size obtained from the classic lot size model.

To determine when to reorder, one needs some additional information. First one needs to know how long it will take to for an order to arrive. This is called order lead-time and is designated with the letter L.

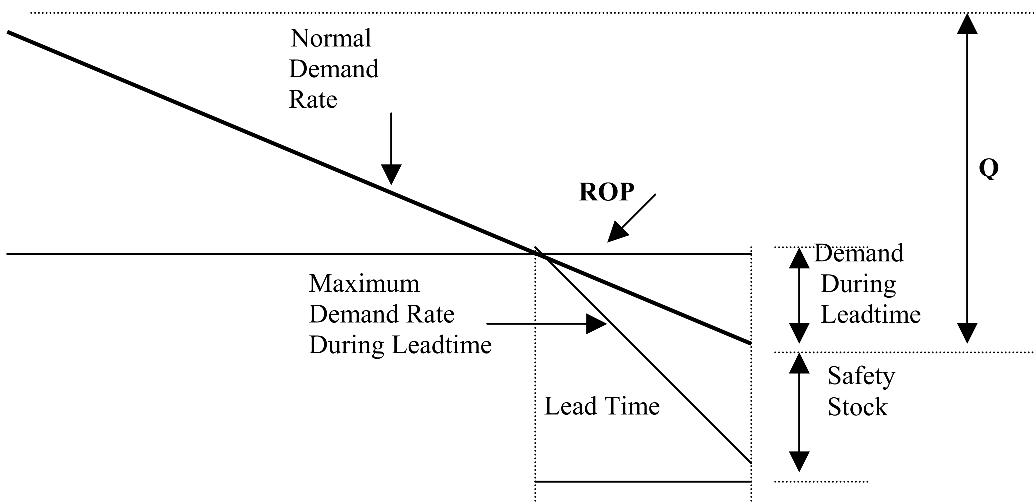
Secondly, we need to know the demand that will occur during lead-time. If the demand rate is constant, then the reorder point simply is the lead-time times the demand rate during lead-time.

ROP = Reorder point under the constant demand assumption = d*L

where d is the demand rate in units per day. If demand occurs at a constant rate, then the next order will arrive just as the last unit of inventory is sold.

But most businesses do not exist in an environment without uncertainty. This uncertainty can come from many directions. Obviously demand during lead-time will vary. So too might the length of time it takes to get the ordered goods. And the number of defective units in a shipment may also contribute to uncertainty. As a result, most firms find it necessary to carry *safety stock* to ensure product availability.

The amount of safety stock carried is a function both of the level of uncertainty present and the service level called for by the business strategy. If the firm is supplying a commodity, the need for safety stock is diminished. But if being a reliable supplier of goods within the supply chain is consistent with the firm's strategic goals, then some means to determine the right level of buffer inventory must be found. Conceptually, the challenge of finding the reorder point is illustrated in Exhibit 1.



When the level of inventory crosses the ROP, an order of size Q is made. If demand occurs as expected, the goods will arrive at point A. If however, demand occurs at the maximum likely rate, then all of the safety stock will be depleted just as the order arrives at point B. The trick becomes that of determining the amount of safety stock that will be sufficient to give the firm the desired service level.

This problem is made slightly more difficult by two factors: The first is that the demand that occurs during the lead-time may not be independent. If we have a probability distribution for daily demand, it may not be accurate to assume that the demand during a three-day lead-time will have a variance that equals the sum of the variances of the three individual days. Remember that covariance term? In some instances, a high level of demand during day 1 may indicate an increased likelihood of there being high demand in days two and three. If the demand during the days has a positive covariance, then the variance of demand for a three day period will be larger.

The second problem occurs when we state that we want to achieve an annual service level of 95%. By this we mean that we want to be able to assure that we meet 95% of all demand annually. Note that the firm is only at risk during the end of an order cycle. It follows that the fewer order cycles that occur during a year, the less the firm will be at risk. This observation means that selecting the right levels of Q and ROP are not independent. The smaller the lot size, the larger the need for safety stock in order to achieve the desired level of customer service.

Conceptually, we need to determine that level of safety stock, SS, that will achieve our service goals. The expression we need to solve is:

$$ROP = u_d * L + SS_{0.95} \quad \text{where } u_d \text{ is the mean demand daily demand}$$

The cost incurred to achieve this additional level of safety is $C_{SS} = C_I * SS_{0.95}$.

At this point, I am going to punt because to continue would result in coverage in greater detail than I want in our introductory shells. Let me suggest two alternatives for solving the safety stock level problem. The first is a quick and dirty method that sets the safety stock level by asking two questions. The first asks, what is the longest likely lead-time? Your records should provide an estimate of L_{max}. Then review your records to find the maximum demand that has occurred in any L_{max} period span. Divide this number by the mean daily demand to find this worst-case reorder point.

The third micro question, who to have supply the item has undergone considerable change. For non-commodity items, this decision has been upgraded to a vendor selection issue. As was discussed in Shell 10, when an item is suited for a capability buy, the decision as to who should be the vendor is made once and then only reviewed periodically. If an item is suitable for a product buy, the buyer may put it out for bids each time the inventory system indicates that an order is needed. One new wrinkle in this area is the use of e-commerce as a means to efficiently search for the most cost effective, qualified supplier.

Dialogue Driver

Earlier, we introduced the concepts of solving, resolving and dissolving problems. How has this approach be used to deal with the how much and when to order decision?

Common Independent Demand Inventory Systems

Over the past fifty years, a large number of inventory control systems have been developed—so many that practitioners developed a language to describe them. Some of the more common systems are:

- *(R,Q) systems*: This perpetual inventory systems constantly monitors the inventory level. Whenever the number of units on hand and on order fall below the reorder point R, Q units are ordered.
- *(s,S) systems*: This perpetual inventory systems constantly monitors the inventory level. Whenever the number of units on hand and on order falls below s, an amount sufficient to bring it up to S is ordered.
- *(t,S) systems*: These are periodic order review systems that review the number of goods on order and in stock every t time periods and then orders enough to bring this number up to a reorder level S.
- *(t,R,Q) systems*: This *periodic order review system* checks the number of goods on hand and on order every t periods. If the number is below R, an order of size Q is made. Otherwise, no order is placed.

Each of these approaches develops local decision rules to answer both the how much and when micro decisions. None use any information about future demand or the current load of the plant.

MATERIALS REQUIREMENTS PLANNING

As was mentioned earlier, MRP was created because pioneers, such as Oliver Wight, recognized that existing inventory control systems were not effectively utilizing all of the information at hand. They noted that demand for parts within some manufacturing systems were not independently determined. In many factories, the actual usage of parts was being driven by the end product assembly operations that used those parts. For example, the demand for a bicycle seat is a function of the final assembly of bicycles that use that seat. It made no sense to them to continue using independent inventory control systems, such as an (R, Q) system when they could calculate the actual seat usage from the plant's final assembly schedule.

The MRP tool requires the following five inputs to its planning process.

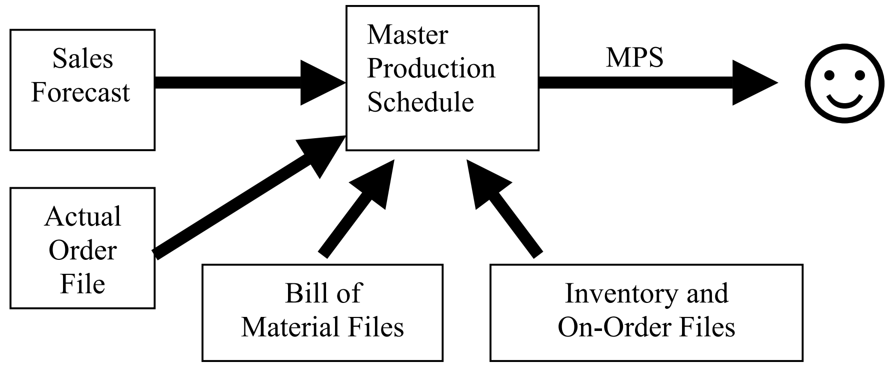
- *A master production schedule* that specifies the firm's requirements for final products by time period. These time periods are called time buckets, which may be days, production shifts, or weeks.
- A *bill of material* for each end product in the master schedule. A BOM defines the number and type of components that are needed to make each product. Your mother would have called this a recipe.
- *Planned lead-times* for each process within the system. A planned lead-time is not the amount of time an operation will require. It is the amount of time we allow a department to perform the task.
- Accurate information relating to the *status of all final product and component inventory* on hand.
- Accurate information on *the status of all outstanding orders for components*—when and how many?

Of the five elements, the master scheduling process is the most important. The person serving as the master scheduler serves as an information buffer between the demands of marketing to satisfy customer orders and the operations that process them. The MPS process seeks to achieve the possible by looking at the resources available before promising marketing when each order will be produced. If inventory, machine capacity, or human resources is not available in sufficient quantities, then it is the responsibility of the master production scheduler to either secure the additional resources or to scale back the obligations of the master schedule.

The master scheduling process adds detail to the production planning process. In the aggregate planning process, production is planned using generic units, i.e., number of cars, etc. The customers of the MPS process need detail. OM needs to know exactly what they are to make. The folks in sales need to be able to tell their customers when their orders will be completed.

Factory demand often is a mix of actual orders and forecasted demand, as is shown in Exhibit 2.

Exhibit 2
The Master Production Scheduling Environment



The master production schedule has a planning horizon that consists of a fixed number of time buckets. One key task of the master scheduler is to synthesize the demand forecasted for each item with the actual order file. Fore example, consider the following situation.

Product: Model 45BJ21	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Forecasted Demand	500	550	450	400	300	300
Orders received	450	600	300	200	100	50
Max (forecast, actual)	500	600	450	400	300	300

During the first week, actual orders lag behind that forecasted. The reverse is true in week 2. And in the next four weeks, the number forecasted exceeds actual, but that is not unexpected since this firm's customers have come to expect a two-week lead-time. The question becomes, what should the master scheduler include in the firm's final assembly plan?

One rule of thumb is to use the larger of the two, as we have shown above. But you might argue that 450 should be used in week 1 since it is unlikely that customers for the additional 50 units will arrive at this late date. You might even argue that the forecast was right, but that 50 units of demand was delayed by one week. Who knows! This is why it is important for the master scheduler to work closely with marketing to base the final assembly plan on the best set of numbers.

The second key input to the materials requirement planning process is the bill of material for each product included in the final assembly plan. For the model 45BJ21bicycle, two types of bills of material are shown in Exhibit 3. The first is a single level bill of material. It is called that because it only shows the components that go into making that bicycle model—not the things that are needed to make each of the components. The bill of material on the right is called an indented bill of material. Components indented once go into making the end products. Components indented twice go into the once indented component immediately above it.

Exhibit 3
Sample Bills of Materials

Single Level Bill of Material

Bicycle Model 45BJ21
1 Frame (Part F345)
1 Seat (Part WA250)
1 Brake Kit (Part B321)
1 Front Wheel Assembly (Part FW100)

1 Hoop (Part H23A)
36 Spokes (Part S2301)

1
Wheel Assembly (Part RW 101)

Indented Bill of Material

Bicycle Model 45BJ21
1 Frame (Part F345)
1 Seat (Part WA250)
1 Brake Kit (Part B321)
1 Front Wheel Assembly (Part FW100)
1 Rim (Part R23)

10 inches of wire (Part W239)
Rear Wheel Assembly (Part RW 101) 1 Rear

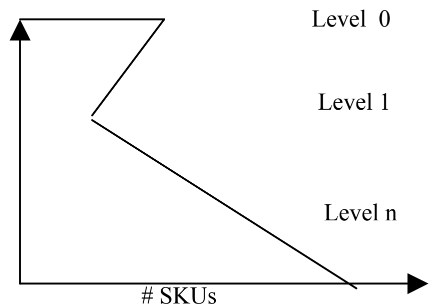
The indented provides more information but the single level BOM provides the final assemblers all the information that they need to know.

Within the MRP family, finished goods are called Level 0 products. The next level upstream, the components that are used in the final assembly process, are called Level 1 items. And so forth. In the above

BOM, the model 45BJ21 bicycle is a Level O item. All other models assembled would also be Level O items. The bicycle frame, its handlebars, wheel assemblies, and seats would be Level 1 items. The rims and spokes that are used to make the front wheel assembly are Level 2 items. Note also that the language of MRP is numbers. All parts are given alphanumerical names. Work is defined strictly in terms of units and amounts of resources used.

Exhibit 4

Number of SKUs by MRP Level



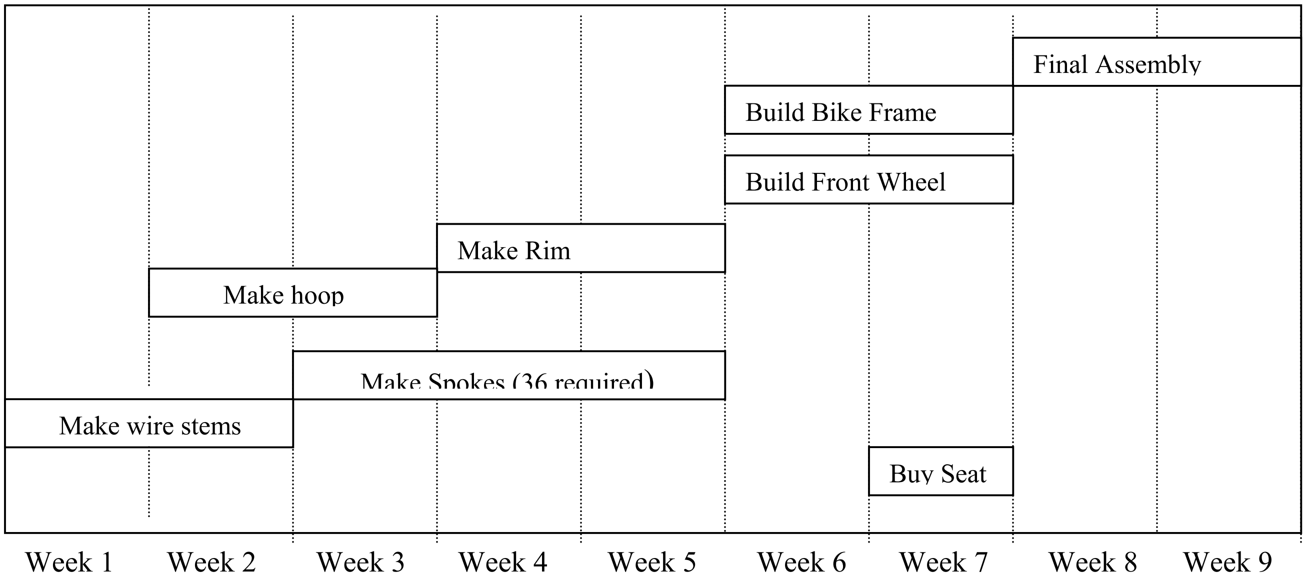
If the company wants to assemble customized bicycles, then it has two choices. It can create the capability of having each customized product have its own bill of material. This is feasible but it will greatly increase the difficulty of the master scheduler's task. Or it could do the master scheduling at a lower level, such as at Level 1, the sub-assembly level. If this is done, the master scheduler forecasts the usage of Level 1 items from past usage patterns, upcoming promotions, and the actual order file, when building the final assembly.

Knowing what you want to assemble and how many parts are needed to support each assembly tells us the total number of each part needed to support that plan. *But it does not tell you when they are needed*. In the pre-MRP era, it was not uncommon for firms to secure all parts needed to support a quarter's build schedule at the start of the quarter. The result, high inventory levels but production had the parts needed.

A major contribution of MRP is its use of *planned lead-times*. A planned lead-time is the time interval the planning system allows a department to perform a task, such as assembling a bicycle from Level 1 parts. Since the final assembly line has a number of bicycles to assemble, the planning system assigns it to a time block and tells that department, "Do this task any time within the allowed planned lead time but complete it by the end of this period." The supervisor of that department then might respond, "Fine, but make sure that all of the items that we need to assemble that unit are available at the start of my planned lead time." The time blocks in Exhibit 5 represent the planned lead-time for each operation. Note that each predecessor activity's time block is completed before the next stage's activities are started. If we want to make this order by the end of the ninth week, we need to start making the wire stems at the start of the first week.

. Gantt chart will exist for each units or batch of units in the master schedule. The MRP program will combine the requirements for each component and calculate how many are needed at the start of each time block to support the master production schedule

Exhibit 5
A Partial Gantt Chart of Bicycle Manufacturing



To explain how this is done, let us introduce the *MRP record*. A MRP record will exist for every part type—but not each order. If five bicycle models require the frame with part number 45BJ21, then the record will combine the *gross requirements* for this part number into one record.

Exhibit 6
A MRP Record

	Period								
	Late	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Item: Part 45BJ21									
Gross Requirements									
Scheduled Receipts									
Project available balance									
Net Requirements									
Planned order receipt									
Planned order release									

Lead time = ______ Lot size =

Let us define these terms in terms of our bicycle example.

- **Gross requirements**: this is the total amount of this item that is needed to support the master production schedule. For Level 0 items (end products), the planned final assembly numbers for each model are placed in weeks 1 through 8 in the above MRP record with an eight-week planning horizon. For items with higher-level numbers, the amount that appears in the gross requirements row will be calculated by the application package.
- **Scheduled receipts**: In MRP, this term has a special meaning. For purchased items, it includes only those planned orders for which a purchase order has been written. This is a legal commitment to buy these items. Do not place anticipated purchase orders in this row. These will go in the planned order rows shown below in Exhibit 6. For manufactured items, a scheduled receipt only includes items for which firm production orders have been released to the shop. While no legal commitment has been

made, MRP practitioners try not to change work assignments once they have been released to the factory. It is assumed that all scheduled receipts occur at the start of the period.

- **Projected available balance**: This is the planned beginning inventory for the item. The beginning inventory for an item at the start of week 1 equals last week's beginning inventory plus what we received from scheduled receipts and planned order receipts minus the items shipped/used in the prior period.
- **Net requirements**: These cells report the actual number of units that the process needs in each period. The net requirements indicate the amount by which demand (gross requirements) exceeds supply (projected available balance) in any period. If this amount is positive, we have a potential shortage in that period and we need to receive a shipment that equals at least the net requirements. If the net requirements is zero or negative, then we have sufficient supply to meet demand—provided no other action is taken in lower level MRP records to increase usage.
- **Planned order receipts**: These cells indicate the number of units of the component that the process will receive from internal or external suppliers at the beginning of each period. These differ from scheduled receipts in that no firm commitment has been made. We are planning here.
- **Planned order releases**: The cells in this row indicates that the number of units that the MRP system plans to order at the start of the period. When a number is entered in a cell, a like number should appear in the planned order receipt row L columns to the right—where L is the lead time. For example, if the planned lead-time is 2 weeks, a planned order of 100 units placed at the start of week 1 will arrive as a planned order receipt at the start of week 3.

The late column indicates a problem. A positive number in the late column of an item's MRP record indicates that insufficient inventory exists to assemble all items planned for in the master production schedule. It may still be possible to execute the plan, but some activities may need to be expedited. Expediting often means that we ask some downstream operation to perform a task in less than its planned lead-time. In effect, we are saying that it will receive an item late. If it is only slightly late and if there are not too many late jobs arriving at that department, then the downstream process normally can respond.

If the number and degree of lateness is severe, then this means that the master scheduling process needs to take steps that are designed either to relieve the factory from some of its work load or by increasing the amount of capacity within the factory. Often this is done through the use of overtime and/or by sub-contracting out some of the work.

At the bottom of the MRP record is an indication that we can use one of the independent inventory control decision rules within the materials requirements planning process. If economies of scale dictates that production occur in economic order quantities, then the EOQ for that item can be included within the MRP logic. Whenever the next requirements for that item goes positive, then an order of size Q is released sufficiently early to allow its delivery at the start of the project shortage. While Exhibit 6 does not show it, it is also possible to build safety stock into MRP's logic.

To illustrate the ways MRP records are linked within a production planning process, consider the case in which we need to make the 45BJ21 model in the following quantities over the next eight weeks.

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Gross requirements	0	10	0	40	40	0	30	0

In Exhibit 7 we show how Level 0 parts (the bicycle) is linked to its Level 1 part (the front wheel) which in turn is linked to its Level 2 part (the hub). Other parts have been omitted to preserve simplicity.

Exhibit 7
Partial MRP Records for the Model 45BJ21 Bicycle

	Late	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Item: Part 45BJ21									
Gross Requirements		0	10	0	40	40	0	30	0
Scheduled Receipts			50						
Project available balance	BI = 5	5	45	45	5	0	0	0	0
Net Requirements		0	0	0	0	35	0	30	0
Planned order receipt						35		30	
Planned order release				35		30			
Lead time = 2 weeks									Lot size = None

	Late	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Item: Front Wheel									
Gross Requirements				35		30			
Scheduled Receipts									
Project available balance	BI = 5	5	5	0	20	20	40	40	40
Net Requirements		0	0	30		10	0	0	0
Planned order receipt				50		50			
Planned order release		50		50					
Lead time = 2 week									Lot size = 50 units

	Late	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Item: Front Rim									
Gross Requirements		50		50					
Scheduled Receipts		50							
Project available balance	BI=15	15	15	0	45	45	45	45	45
Net Requirements				35					
Planned order receipt				80					
Planned order release		80							

Lead time = 2 weeks Lot size = 80 units

In Exhibit 7, you should note that the gross requirements of the middle MRP record is driven by the planned order release cell of its parent, which in this case was the 45BJ21 model bicycle. You should also have note that the use of economic lot sizes causes inventory to be carried into periods in which none was needed. To minimize inventory, many MRP practitioners use other types of ordering rules.

If setup costs are low, a lot-for-lot rule is used which simply orders sufficient quantities to keep the projected balance equal to zero in all periods. If manufacturing or purchasing economies of scale exist, "Order enough to cover our needs over the next four weeks." Or "Whenever the cumulative net requirements exceeds 100 units, order the cumulative requirement, i.e., if the net requirements over the next six weeks is 0, 40, 0, 70,0 and 60, we would order 110 units in time for their delivery at the start of week 2."

Resolving Problems

The purpose of operations planning is to assure that the people doing the work are given a doable amount of work and sufficient resources to allow them to do it. With MRP, the master production scheduler is able to detect problems of the following nature:

- Positive numbers in the late column: This indicates that the system either does not have or is not able to procure or make the goods needed to support the current master production schedule. Possible ways to eliminate this problem include:
  - If lateness is minor, negotiate with downstream departments to accept a shorter lead-time for the production of *that item*.
  - If some production is being scheduled to build finished goods inventory, consider delaying its production to a later time bucket or splitting the batch into two or more smaller batches.
  - If the lateness is significant, then the master scheduler needs to reconvene discussions with marketing and operations management to consider reducing the number of orders accepted and/or providing more factors of production to the plant.
  - Uneven production plans exist. One feature of most MRP systems is the ability to project the likely workload by department—usually in terms of hours of work. If the profile of the work load its uneven, then operations may request that the master schedule be changed in order to permit more efficient use of its productive resources.
  - If the production system is taking too long to produce goods, then the operations planning system has a structural problem. This can not be solved by MRP. Shortening the planned lead times will not produce beneficial results unless the capabilities of the departments is changed. This can be done, but it is a systems design issue—not an operations planning problem.

The goal of the master scheduling process is to produce a doable plan that will mutually satisfy the needs of marketing and operations. In many industrial environments, the master scheduling serves as an effective communication device both between marketing and operations and within the departments of the operations system. Marketing is able to gain a clearer assessment of the capabilities of an operating system. It is less likely to make promises to customers that cannot be satisfied in a timely manner. It also forces marketing to re-prioritize its orders so that its more important customers are well served.

Within operations, the morning MRP meeting provides an opportunity to alert the players to problems that they may encounter. Delays may not be eliminated, but the downstream departments can plan their work in order to minimize the adverse impact of them. If no major problems occur, then the morning meeting is a good time to build better relationships with your comrades.

Advantages of MRP Systems

Materials requirements planning systems are well suited for manufacturing environments that make end products comprised of a large number of component parts. One of its strengths is its ability to utilize BOM information—thereby reducing the need to forecast the demand/usage of a large number of parts. This is particularly helpful if the usage of a part is driven by a number of end products.

MRP systems are able to plan production to meet the needs of future demand better than independent inventory control systems. The master scheduler is building plans based on known and/or anticipated needs—not historical usage rates. If future demand has uneven patterns, such as lumpy, sporadic demand, these can be built into the master schedule. But most importantly, the master scheduler is able to focus his or her attention on the demand patterns of the vital few—not the thousands of component part demand.

JUST IN TIME MANUFACTURING

Just-in-time manufacturing is most associated with the Japanese manufacturing revolution in the post-WWII era. We could find instances of its earlier application, but American firms really did not take note until challenged in the marketplace by a superior manufacturing system. In the post-WII era, Toyota's Taiichi Ohno visited Henry Ford's River Rouge complex. This was *the* wonder of the industrial world. But Ohno noted two features of Ford's system that he felt would not work in Japan. The first was that Ford's highly specialized machines required long setup times, hence the resulting economies of scale called for long production runs. Secondly, he noted that the production rate of these highly specialized machines far exceeded the usage rate of the parts that were being produced. The result was high WIP inventories.

When Ohno returned to Japan, he started developing a unique style of manufacturing--one that was more suitable for the Japanese environment. What evolved became know as Just-in-Time manufacturing. Actually there are two JITs, Big JIT and Little JIT. Big JIT encompasses a set of organization-wide practices that collectively have as its goal the manufacturing of goods using the least amount of productive resources. It heavily is focused on eliminating wasteful practices. It defines waste as any activity that does not add value. Some of the areas in which Big JIT strives to eliminate waste are: product design, process design, worker education and training, equipment maintenance, capacity planning, and operations planning. Big JIT is the kissing cousin of Japan's TQM movement in that both work diligently to eliminate system variance.

The ways in which a firm responds to system variance varies. Prior to JIT, many firms sought to protect their operations from system variance through the use of buffering mechanisms, such as having higher levels of inventory or longer production lead times. JIT seeks to deal with system variance by eliminating as much as is possible to root causes of variance. In the materials management area, those programs can be categorized as seeking to:

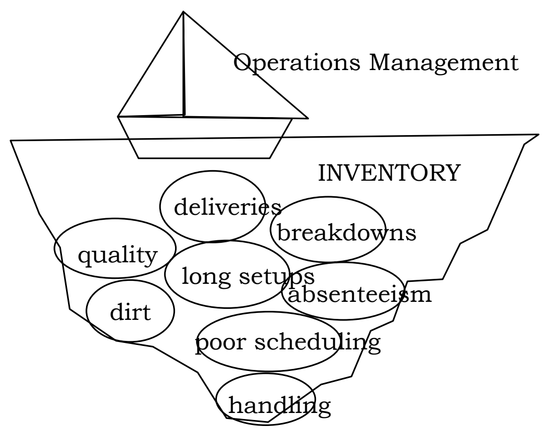
- *Eliminating economies of scale wherever possible*. The Japanese strive to eliminate or reduce production setup times in order to make the most economic lot size as close to one as possible. In the transportation area, they replace inbound truck load shipments either with a series of mini-shipments or truckload quantities of a blend of the needed components.
- *Eliminate factor of production unreliability*. Whether it be a machine, a person, or a product, the Japanese will not accept less than reliable performance. Workers are educated and trained to fully understand what is expected of them. Machines are treated to preventative maintenance and other tools

with the goal of continuously improving their reliability. Suppliers ***know*** not to ship products late and off-spec quality.

- *Eliminate factor of production waste*. Waste is any activity that does not add value. Thus the flow of materials through a JIT business environment seeks to have parts arriving immediately before they are to be used, in the quantities needed, and without anything that will cause delay. JIT's waste seeking practices include needless paperwork. If you need a computer to do it, it may be more complicated than need be.

JIT is an incremental approach. Whereas some Americans always seek a silver bullet to restore their firms to world-class status, practitioners of JIT recognize that it is a journey. Perhaps the best way to think of this JIT philosophy is to use its boat in a rock-filled lake analogy.

Exhibit 8:
The JIT Sailboat



This lake did not get filled with rocks overnight. It is the challenge of JIT practitioners to systematically lower the level of inventory that hides these problems. As they surface, the rocks are eliminated and the continuous improvement process can continue.

Little JIT refers to the pull system just-in-time uses to coordinate the flow of materials within the factory. The key instrument for this program is something called a kanban. Kanbans are cards that tell upstream departments that item has been used and it is okay to make a like amount. You might consider the way in which your mom purchased eggs. As you recall, eggs come in cartons of twelve. When the last egg has been removed, your recycling-oriented mom takes the empty carton to the hen-house to have it filled with fresh eggs. To be truly Japanese, your mom would need to find a quick response set of hens, i.e., ones that will produce eggs on demand.

As simple as this mechanism seems, it can not be implemented without ridding the system of much of the causes of system variance. The party filling the kanban card request ideally should be able and willing to ship small amounts of goods, quickly, reliability, and on-spec. While it is not essential, it is helpful if that supplier be close since delivery speed and transportation economics will be enhanced.

The number of kanbans that are needed to support an operation can be approximated by:

# of Kanbans needed = [(lead time x average usage rate) x (1+α)] / kanban card capacity

The first part of this equation is no different than we used to calculate the reorder point in the constant demand case. The (1+α) term is nothing more than a safety stock generating fudge factor. Set $\alpha = 0$ and you will get a system with little or no inventory.

In order for this system to work well, it is necessary for the lead time to be relatively constant. To help achieve this, all incoming kanban orders should be done on a first come, first served basis. Lead time variance will also be reduced if the workload is stable. Hence another key feature of effective JIT systems is level shop loading, i.e., the amount and mix of work being asked of the plant should be such that an even flow of work arrives at each work center. It also helps to have work centers that can quickly switch from one job to the next without an undue amount of effort. Flexibility and reliability are a must.

Advantages of Just-in-Time Manufacturing

The benefits of just in time fall into two categories. The first is the elimination of waste that results from an organization-wide effort to adopt Big JIT. What organization would not benefit from having all of its employees always seeking to eliminate waste? The second benefit results from having your organization produce goods in a pattern that mirrors demand. When sales goes up, so too does product quite quickly. When sales decline, fewer kanban cards are released--hence inventory levels also will decline. And it all is done without the use of expensive computer systems.

On the down side, JIT does not do well in Lexus-lane companies. Its desire to achieve minimum system variance makes it well suited for olive trees. Changing product design often is not well received.

SUMMARY

We started this shell with a description of a world-class factory that effectively used information technology and multi-plant collaboration to schedule the flow of goods through the plant. We used this example to illustrate how one firm is going about to achieve the goal of inventory management, i.e., to direct the flow of the right materials through the right processes so as to have product delivered to the right customers in a timely, cost-effective manner. This prospective should not be lost.

We then introduced a taxonomy of the varying roles inventories play both within a supply chain and within the operations management function. Like underwear, one size does not fit all, so we introduced the three basic types of tools operations managers use to manage the flow of inventories within the supply chain. Each works well in certain situations, each will need to change as the expectations of customers and supply chain players change. But the need to use any of these approaches is reduced whenever one can dissolve the problem with use of collaboration.

End Notes

1. Ford W. Harris, "How Many Parts to Make at Once," Factory, the Magazine of Management, Vol.10. No. 2, 1913.
2. R. G. Brown, *Decision Rules for Inventory Management,* Holt Rinehart and Winston*, 1967.*

References

1. Fogarty, D.W., and J. H. Blackstone, and T. R. Hoffman, *Production and Inventory Management*, 2nd ed., South-Western, Cincinnati, Ohio, 1991
2. Hadley, G. and T.M Whiten, *An Analysis of Inventory Systems*, Prentice-Hall, Englewood Cliffs, N.J., 1963.
3. Imai, M., Kaizan: *The Key to Japan's Competitive Success*, Random House, New York, 1986.
4. Orlicky, Joseph, *Materials Requirements Planning*, McGraw-Hill, New York, 1975.
5. Vollman, T.E., W.L. Berry, and D. C. Whybark, *Manufacturing Planning and Control Systems*, Irwin, Homewood, Ill, 1998.

Expected Learning Competencies

Before putting Shell Thirteen down, you should ask yourself the following questions. Am I able to explain:

1. What inventory is and the roles it plays in each market orientation and each process choice.
2. How inventory control theory evolved from the early days of applied mathematics and computers to what we call modern IT-based inventory management systems.
3. How pull inventory such as, such as using kanbans, works and how they differ push-type inventory systems.
4. The five major inputs to MRP systems and how each is represented in the MRP record. Then be able to explain how MRP records relate to each other.
5. How a master scheduler might use MRP to come to get marketing and operations to agree on what can and should be made. How does the scheduler resolved conflicts and/or infeasibilities/
6. Understand how independent demand forms of inventory management are used and why they still have uses today.
7. What your instructor added to this shell and why he or she thought that it was important enough to warrant its inclusion.

Frequently Asked Questions

Instructors have been known to ask questions similar to the following:

1. Describe the three basic ways the flow of inventories within supply chains are managed.
2. Explain how quick response suppliers have altered the way inventories are managed today.
3. Describe the roles inventory plays when each of the five classic process choices are present.
4. Describe the roles of inventory with each of the four market orientations are present.
5. Describe who makes inventory decisions within a:
   a. Retailer
   b. A wholesaler
   c. A job shop
   d. An assembly line
6. The 2 in the classic economic order quantity formula occurs because:
   a. We are calculating the tradeoffs between two variables
   b. We assume that inventory costs are twice the holding costs
   c. We assume that inventory costs are a function of the average level of inventory
8. A scheduled receipt tells the master scheduler when when we plan to get inventory.
9. The longer the replen   ishment lead-time the more kanbans will be needed.
10. The R in an R,Q system refers to the replenishment rate.

Shell 14
Scheduling Work

A Day in the Life of a Scheduler

By 6:30 AM Bill Taylor has already been at work for a half-hour. He will spend ten hours answering phones, handling crises, talking with dozens of people, and making sure that what must be done gets done. Each day he schedules 247 people around like the pieces of a large jigsaw puzzle. As the scheduler for the tool room at the Powertrain Division at GM's Lansing plant, he is responsible for assigning the right people to the right jobs on the right equipment at the right time in the right order, as well as dealing with emergencies. Taylor arrives at the tool room each day before 6 AM to plan skilled craft workers' schedules around 24 different work centers. Each work center consists of one or more similar machines grouped together, such as lathes or grinders. All these work centers depend on Taylor's decisions to convert drawings to tools and parts.

Each morning, Taylor looks over that day's work orders, assigns priorities, and determines which orders should be released to the shop floor. Some of his staff already knows their assignments. But Taylor must initiate plans for new projects using engineer estimates, the availability of resources, and each job's promised due date. Some of the work is repeat business, i.e., orders for standard jigs that are kept in inventory. Some of the work load is to support new projects which might last several months while the typical crib job usually takes only a week or two.

After fielding phone calls to deal with questions and problems, Taylor tours the shop floor to track progress. He looks for bottlenecks and possible safety hazards. He also notes when some key craftspeople are absent. Although Taylor has been told about most of his shop's work way ahead of time, he also knows he might get hit with some surprises. He hopes they don't come while a key lathe operator is on vacation.

Sure enough, just as Taylor is starting to relax, someone runs in with a rush job. A machine on the plant floor is down. Unless the tool room can make a replacement part, the plant will lose thousands of dollars. Taylor quickly writes out the specifications and hand delivers it to the shop floor. Machinists are told to stop whatever they're doing in order to do this urgent job.

Taylor looks at his watch as the rush job progresses from machine to machine. The replacement part is hurried out the door in about six hours--not bad. It's almost 4 p.m. now and time for Taylor to head home, but first he gives the afternoon shift its schedule for the next eight hours.

By prioritizing orders, deciding when to start work on them, and tracking their progress, Taylor is a one-man shop floor control system. He is both planner and executioner within his realm. And by 4 PM each day, he is a very tired man, indeed.

Source: The unpublished 2nd edition of Melnyk & Denzler *Operations Management: A Value Driven Approach*

Shell Fourteen

Scheduling Work

Table of Contents

Learning Objectives for Shell Fourteen

After reading this shell and thinking about its content, you should be able to:

1. Understand how the scheduling activity meshes with short term planning activities.
2. Understand the difference between detailed scheduling and the use of local decision rules.
3. Understand the role of due dates and due date setting practices used with each market orientation.
4. Schedule a simple problem using the Gantt chart.
5. Understand each of the following terms and their use in scheduling:
   a. Operational due dates
   b. Forward and Backward scheduling
   c. ‘Push and pull systems

INTRODUCTION

Every activity in an OM system either formulates or executes a plan. Planning answers several questions:

- *Who* bears responsibility for what work the operations function should accomplish? The answer determines the outputs the system should provide.
- *When* should the operations function generate those outputs? The answer specifies activities to take place immediately and those to defer for later action. It separates essentially short-term activities from those that continue over mid-to-long term planning horizons.
- *Where* should people perform these activities? The answer assigns jobs to particular facilities.
- *How* should operations complete planned activities? The answer specifies processing steps and allots organizational resources to individual jobs.
- *What* information should the OM system provide to support ongoing operations planning activities, including performance metrics.

Earlier, we referred to the first four as the WWWH questions. The last question is part of the DIS process.

Since planning must precede execution, managers often refer to planning systems as the upstream system. These planning processes combine inputs from multiple business processes to project appropriate OM system activities over time. To execute plans, operations managers rank jobs by priority and assign resources such as labor, equipment, materials, and tools based on those rankings. The outputs of these activities become inputs to the execution part of the operations function.

The manner in which jobs are prioritized and done should be driven by the performance standards established by the strategic planning processes. At one end of the control spectrum, operations managers receive detailed marching orders that specify answers to the WWWH questions. For simple systems, detailed schedules can be crafted using the analytical capabilities inherent in most human resources. When done right, these detailed schedules serve the customers well and observe the constraints imposed on the system.

The level of difficulty associated with answering the WWWH questions increases as the sequencing and scheduling of work becomes more complex. Scheduling complexity is increased by the following attributes:

- A larger number of stages of work.
- Strict precedence relationships associated with each job, i.e. less work sequencing flexibility.
- System inflexibility, i.e., restrictions on the type of activities humans and process equipment can do.
- Product mix variety --this may make the load within the system uneven over time—even lumpy.
- Tight delivery date requirements i.e., a more hurried work environment.
- System uncertainty, i.e., operation times, machine breakdowns, supply chain deliveries, etc.

When organizations are confronted with complex work sequencing and scheduling environments, they either seek to *resolve* the problem by dividing the task into smaller, disjointed scheduling tasks, or resort to complex, computer-assisted approaches that seek good, feasible, system-wide schedules.

Dialogue Driver*:*
Cynics often claim that ***Murphy is alive and well and lives on the shop floor.*** To what extent can we systematically use some of the tools in the OMToolkit to document the occurrence of scheduling snafus and then seek to rid the system of bad thinks happening?

To those of you who are unfamiliar with Murphy's Law it declares that "Everything that could go wrong, will."

Scheduling in Service Operations

Scheduling within service organizations often has attributes that make it slightly different from that normally found in a manufacturing environment. The task is more challenging because:

- the intangible nature of services makes it impossible to be inventory product,
- the work that needs to be performed is uncertain due to the heterogeneous nature of services, and
- service demand often cannot be postponed.

The nature of services demands that the system have the right, well-trained personnel in the right place at the right time. The extent to which service can be delayed or denied is something that should be defined by the capability specifications, which in turn is defined by the strategic planning process.

Scheduling services can be easier when the number of stages of the service delivery process is small. Many services are one stage processes. Also, many service-providers have sufficient resource flexibility to respond to service demand idiosyncrasies. For example, supermarkets train personnel to perform multiple tasks so they can be reassigned quickly to respond to surges and lulls in service demand.

Two variants of service scheduling exist. The first is called *resource-dominant service system* because it tries to fit service demand to the known capacities of the service system. Many professional service systems, such as medical clinics, use this approach to maximize the utilization of their high cost resources. The loss of convenience to the customer ma*y* be partially offset by better service once they do arrive. Variations of the resourced driven approach are the demand management schemes used to influence demand. Since demand management has been discussed in an earlier shell, we will not discuss it again.

A second variant of service scheduling is called a *demand-dominant service system* because it accepts demand as given and then goes about trying to secure the resources needed to satisfy customers. This system is desirable when customers have high service expectations and when it is possible to secure the needed resources quickly. How would you react if your local supermarket asked you to make an appointment?

The Order Management Process

O*rder management* becomes more important whenever the request for service is not immediately fulfilled. After an order is placed, the work created by each order must be scheduled to ensure the level of service delivery promised. For example, many restaurant hostesses assign tables to customers in the order of their arrival. Others recognize that some customers are more important than others either because they have made a reservation or because they possess "preferred customer" status.

Some organizations develop *priority rules* to separate critical service requests from less urgent ones. For example, a 911 emergency-response system prioritize incoming calls. Hospitals create two-queue systems to direct emergency orders to one queue and routine orders to a more leisurely service process. Customers waiting in each queue receive priorities based on a first come-first served dispatching rule.

Dialogue Driver:
How can a system designer defend the use of priority rules that discriminate against a class of customers – especially a charge that a downtrodden class is receiving inferior service?

* To better understand the role IT plays in customer service, read "Why Service Stinks," *Business Week*, October 23, 2000.

SCHEDULING SERVICE EMPLOYEES

Service managers must make critical decisions about scheduling employees whenever the capability specifications call for the firm to marshal resources to meet real or anticipated demand. Often, they begin by setting an overall staff level using demand forecasts and actual orders. They then proceed to determine an employee mix, shift schedules, and individual job assignments.

Staff Level: The staff level decision determines the capacity of a service-delivery system by setting the numbers of shifts and the employees per shift. Two key inputs are an understanding of the system's *demonstrated capacity* and firm's customer service strategy. These determine whether the firm maintains a level capacity or varies its capacity in response to changes in demand. It determines how to responds to unexpected demand. For example, a restaurant manager might intentionally over-staff to have sufficient capacity to meet unexpected demand. This suits firms whose value equation emphasizes speedy service.

Employee Mix: When choosing specific employees to staff a shift, operations managers must weigh considerations such as: skill levels, the extent of any cross-training, and the ratio of part-time to full-time employees. These issues affect the overall flexibility of the firm's labor pool and the investments that it must make to train the needed employees.

Shift Schedule: Operations managers must resolve very detailed questions to schedule employees for specific shifts. The scheduler decides who works when. Bar charts, such as the one shown in Exhibit One help to visualize schedules. For simple shift scheduling problems, one heuristic to resolve this problem is:

1. Determine the number of employees needed to provide the desired level of service each day. This determines the number of work shifts that must be scheduled. Fractional shifts are rounded up unless you can use part time workers.
2. Using a bar chart, assign shifts to the schedule. This often is done using the two-consecutive-days-off rule since most workers seemingly prefer this. This defines when the yet unnamed workers will work and when that person has a day off. For small problems, this can be done manually or with as simple Excel program.
3. Assign specific individuals to the schedule created above. Managers often use a "fair" criterion such as seniority or stated preferences. Some managers rotate assignments among workers.

The greater demand uncertainty is, the greater the need for buffer service capacity or planned unrequited service demand. Over-staffing costs money, while under-staffing can result in bad service and lost customers. Flexible workers may warrant premium pay if they allow the firm to meet desired customer service levels by being available or "on call."

An Example of a Shift Scheduling Problem: Let us go back to see how Bill Taylor develop work schedules for his employees. Although this task occurs within a factory, it really represents a service task, i.e., one in which service orders from the factory must be completed in a manner that serves the needs of the plant.

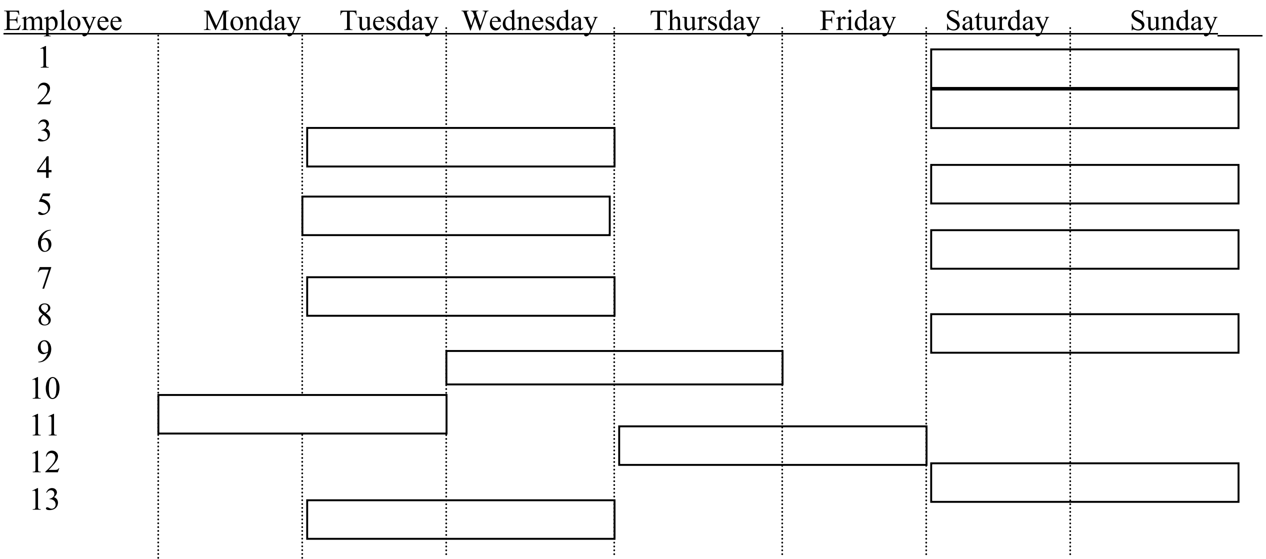
For example, consider the situation where Bill Taylor expects that the number of employees needed to work in the tool room during the coming week.

Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
11	8	8	11	12	6	6

He might have based these estimates on gut feel, past trends, or customer input. He has adjusted the results anticipating traditionally high demand on Mondays, Thursdays and on Fridays as people try to get orders in before the weekend. Summing up the requirements, Bill Taylor determines that he needs 62 work shifts for the week. If each employee works 40 hours per week, then Bill needs at least 62/5 = 12.4 or 13 employees.

He determines days off for each employee as illustrated below. For the first days-off slot, Saturday and Sunday carry the lowest demand, so they become one person's off days. Bill Taylor reduces the need for workers on the weekday shifts by 1. The second most-senior employee could be assigned the same schedule. Again, the scheduler adjusts the need for workers on weekdays by one. This process is repeated until it specifies a pair of off days for each employee, indicated by horizontal boxes. The resulting schedule is:

Exhibit One
Scheduling Employees' Days Off



	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
# Workers	12	8	8	11	12	7	7
# Needed	11	8	8	11	12	6	6

Notice that the tool room needs the 13th employee only to cover extra demand on Thursday and Friday. Judgment and knowledge of the workers' needs and capabilities often dominates these detailed assignments.

SCHEDULING WORK IN MANUFACTURING OPERATIONS*

Before proceeding, let's define what we have been calling *an order*. In the simplest terms, an order authorizes the operations system to assign people, materials, tools, and equipment to build a predetermined quantity of a specific item. Orders transmit important information such as a quantity, a due date for required outputs, a statement of urgency or priority in relation to other orders, and acceptable product quality. Some are simple while others give detailed schedules that list all shipments that the system must make over time. OM deals with orders in many forms. Their form can be: written, verbal, fax, email, or received via the formal IT system. Caution*: undocumented orders are a root cause for chaos*.

The Goals of Shop Floor Control Systems

Three goals drive the scheduling process for manufacturing systems. First, it seeks to ensure that operations complete orders as promised. The OM system tries to accomplish this objective by linking the shop floor control system to the production planning system through the *order due-date setting process*. The planning system sets a due-date to inform the SFC system when it must deliver an order. Meeting order due dates is a primary performance metric since it affects the firm's *effectiveness* at satisfying its customers.

A second goal of scheduling is to enhance the overall *efficiency* on the shop floor. At a minimum, the planning system should generate feasible plans. However, the general information in these plans does not automatically equate to the most efficient schedule. *Real efficiency comes when managers apply their insights and knowledge to arrange orders and schedules*. For example, one tactic for improving operational efficiency is to group orders that share similar components, processing activities, or setup. Likewise, many shops have to make the same item for more than one customer. Groups of orders with process similarities also allow workers to perform tasks faster and with less setup time. Efficiency benefits when the scheduler matches individuals with the types of orders that suit them.

The third goal of scheduling seeks to *reduce manufacturing lead-time variability*, i.e., how long it takes to process orders through the shop. If process flow time varies widely, production planners do not know how long a job will take. In order to minimize the risk of an order being late, there is a tendency to either quote later due dates or release the order too early to the shop—thereby increasing shop congestion.

An unfavorable consequence of process uncertainty is excess expediting. There are a number of tactics used to reduce manufacturing lead-time variance. These include:

- Doing a better job managing the flow of work/orders released to the shop,
- Having better time standards, i.e., better estimates of how long each task will take,
- Enhancing the skills and the flexibilities of both machines and workers, and
- Reducing unplanned resource shortfalls, i.e., reduced absenteeism and equipment breakdowns.

Since each can reduce process uncertainty, most effective operations managers strive to achieve them.

The SFC process is responsible for making the detailed and final allocation of labor, machine, capacity, tools, and materials to the various competing orders. It collects data on the activities taking place within the operations management system involving the progress of various orders and the status of resources and makes the information available to marketing and the planning system. SFC involves *four major themes*.

1. <u>Customer orders of some type drive operations scheduling decisions</u>. With a pure MTS market orientation, orders reflect a decision the firm has made on how best to invest a part of its financial resources into inventory. With the do-to-order market orientations, the scheduling process responds to specific customer orders or a mix of actual orders and stock replenishment orders.
2. <u>That operations scheduling often seeks to effectively manage the use of multiple resources efficiently</u>. Schedulers realize that their realm involves employees with specific skills and needs, inventories, customers with different priorities, and equipment with varying capabilities. Unlike MRP, they can not reduce their world to units and hours of capacity.
3. <u>The responsibilities of the operations scheduling systems extends beyond the operations function</u>. Scheduling involves interaction with the other business processes within the firm to ensure that OM activities complete orders as planned.
4. <u>In some cases, the operations scheduling process manages an order only after it has been released by some other business process</u>. The intent of this action may be that some product engineering issue has not be resolved or it may be done to avoid clogging the plant

Dialogue Driver:
To what extent should a firm allow its customers to see the status of its orders in your operating system?
Would your answer be different if you were in a full-blown partner relationship?

THE RESOURCES MANAGED BY THE SHOP-FLOOR CONTROL SYSTEM

To transform an order from a concept to a real product, the operations scheduler draws on five major resources. Of these five resources, the first three define the overall capacity of the system.

- <u>Materials</u>: A system's total stock of raw materials, processed materials, and components form part of the resources that its shop-floor control system allocates to complete an order. Materials requirements planning and other methods help operations managers to project needs for these resources.
- <u>People</u>: The human resources subject to shop-floor control include all people that the OM system needs to plan, process, or handle an order. This category covers overtime, employees transferred from other areas or locations, part-time help, multiple-shift operations, and people working flex-time schedules. SFC systems must account for both direct and indirect labor.
- <u>Equipment Capacity</u>: This resource reflects the total productive capacity offered by the equipment within the OM system. A shop's tool room, for example, includes machine capacity like drills, lathes, grinders, saws, and numerically controlled machines.
- <u>Tools</u>: This resource includes all of the special fixtures needed to set up and complete an order.
- <u>Information</u>: For each order, this resource includes a route that states needed processing steps and the sequence, time standards, a bill of materials, a due date, a quantity, and the customer's name. Also, a bill of labor and capacity lays out the needed capacities and their amounts.

These resources link the operations scheduling system to the planning system. Since the planning system defines a plant's effective capacity by determining resource levels, planners bear ultimate responsibility for the feasibility of any plan released to the shop floor. The operations scheduling system is accountable for applying resources efficiently to carry out the plans.

MAJOR BUSINESS PROCESSES USED BY OPERATIONS SCHEDULING

<u>Order review/release</u>: In simpler systems, this process evaluates system load and directs the arriving order to a work center or to a queue. In a job shop, the order review/release process evaluates inputs from the planning system and prepares them for production by the transformation process. Through this activity, the shop-floor control system ensures that it releases only doable orders to the floor and that it releases them in a sequence that helps the OM process to complete them on time in the correct quantities without creating unnecessary shop-level congestion. The order review and release process includes the following activities:
<u>Order Documentation</u>: Order documentation adds information to orders received from the planning system to provide additional detail that will guide the transformation process. Typically, documentation specifies several important characteristics of an order:

- *Order identification*: The documentation step assigns a number or code to uniquely identify an order and allow subsequent tracking.
- *Routing: Documentation* also defines the operations that an order have done to it and their sequence. An order's route helps to determine its resource requirements.
- *Time standards*: The time standards information identifies the expected amount of resources (machine and labor) that it requires at each stage. This information is useful for monitoring, scheduling, and capacity management.
- *Material requirements*: This information identifies the amount of components and other materials that the OM process will need to process an order.
- *Other*: Documentation may also state tool requirements, due dates for specific processing activities, anticipated levels of scrap, and special handling requirements.

This information becomes part of a packet that accompanies the order as it moves through processing steps. This packet can consist of a bundle of papers attached to the order sheet or a set of computer files that workers can call up by entering the order number or scanning a bar code.

Material Checking: The order review/release activity allows an order to proceed only when the OM process can draw the components and materials it needs to complete processing. The material-checking step verifies this condition, perhaps by physically examining storage locations or by checking inventory status in a computerized materials requirements planning system. If the process lacks needed materials, this step orders them. The order waits in a file until the materials arrive.

Capacity Evaluation: Besides essential materials, an OM process needs adequate available capacity to complete an order. The capacity-evaluation step of the order review/release activity compares the capacity requirements for an order with process capacity not currently occupied by other orders. If this analysis finds enough capacity, the activity can proceed with the next step, load leveling. If not, the release of the order may wait until the necessary capacity becomes available.

This step provides important protection against overloading the transformation system by releasing more work than it can complete. Without this safeguard, overloaded capacity would stretch lead times and make them more variable. Confusion would plague the transformation process as people wondered which orders they could fill and which they could not because of insufficient capacity.

Load Leveling: Many SFC systems regularly accumulate or backlog pending orders briefly, releasing them to the shop floor at a controlled rate to level the resulting load on the transformation process. This control reduces the peaks and raises the valleys of the load on capacity. At peaks, a process has too much work so it suffers from long queues and lead times. At valleys, activities in the same process might sit idle, waiting for new work. Together, peaks and valleys create excessive variance in a process. Load leveling works to reduce this variance by rearranging work loads to move excess demand from the peaks to keep the shop busy during valleys.

Detailed scheduling: One of the most visible and action-oriented operations scheduling activities within some systems is detailed scheduling. It is called detailed scheduling because it is, i.e., it assigns specific resources at specific times to individual orders based on their priorities. In services and in certain manufacturing systems, the detailed scheduling activity results in an appointment schedule or a final build schedule. The result is an understanding between operations and its customers exactly when and who will do the required activities.

In more complex operational environments, detailed scheduling seeks to match demands on the transformation process with its resources. This matching process results in extremely detailed scheduling decisions, beginning with assignments of order priorities. To identify the exact sequence, the process that generates the detailed schedule must weigh: the urgency of each order relative to others, the relative importance of each customer, the amount of processing that each order requires, the time remaining before each order's due date, and the reliability of due dates. Detailed scheduling divides all of these allocations into three major categories: order sequencing/dispatching, scheduled maintenance, and other assignments.

Order Sequencing/Dispatching: This process normally applies heuristic decision rules to determine the specific sequence in which a facility will process a number of different orders. This process's output is the assignment of workers, tools, and materials to selected jobs. These important decisions must support the predetermined goals of the SFC system and the vision of value that drives the OM system. Based on decision guidelines commonly called dispatching rules or priority rules, the SFC system ranks orders from the most to the least important. A daily dispatch list typically communicates these priorities to employees on the shop floor, displaying all of the orders waiting for processing by a given machine or work center in rank order. This information guides the operator's choice of which order to fill next.

Scheduled Maintenance: Preventive maintenance is an important countermeasure against daily wear and tear on tools and equipment. Mechanical breakdowns temporarily eliminate the productive capabilities, usually when the process has the most urgent need for its machines and tools, according to some operations managers. Scheduled maintenance reduces the risk of machine breakdowns through routine lubrication and inspections of equipment along with periodic overhauls. Detailed schedule faciliate preventive maintenance by ensuring that sufficient time is allocated to get it done.

<u>Data collection/monitoring</u>**:** Bi-directional information flows link the planning system to the operations scheduling system. The planning system continuously updates the information system about any changes in requirements (e.g., cancellations, additional orders, requests for changes in order due dates). In return, the operations function reports on a regular basis to planners about the progress of all orders in process.
In many systems, the operations scheduling system collects and maintains this information flow through its data collection/monitoring activities. The first of these two interrelated activities, data collection, records information from shop-floor activities. It typically tracks the current locations of orders and their states of completion, actual consumption of resources by process activities, and any unplanned delays.

The monitoring activity then analyzes this accumulated information, often by comparing actual progress with planned progress. Operations can measure the progress of any order in several different ways: stage of processing, costs incurred to date, or time remaining until the due date. This analysis often includes comparisons against standards generated by people in engineering or accounting, records of past performance, or management expectations. Ultimately, monitoring works to identify the orders with the largest gaps between actual and desired performance. These orders become the targets for special attention from either operating employees or managers.

<u>Control/feedback</u>: Every OM activity exhibits some variability. Operations managers tolerate this variability so long as it does not create problems and cause some other part of operations to lose effectiveness. To continue performing effectively, the system must reestablish control through direct intervention. The control/feedback activity circulates information to others within the system to alert them of current conditions. Many OM systems separate this activity into two linked procedures: control and feedback.

Out-of-control processes require short-term adjustments that make changes in capacity. A firm that competes by achieving reliable delivery performance must respond quickly when an order falls behind schedule. As one response, a firm may call in subcontractors to help it handle excess work. Often, the SFC system allocates more resources to a problem area by scheduling overtime, part-time labor, or a second shift.

In addition to allocating additional capacity in some form, the SFC system can try to reestablish control by directing an order along an alternate process route. Usually, some routine or preferred sequence of activities provides either: the lowest cost, the fastest processing, or the best quality. Alternate routes expose the system to some unusual costs, such as: longer setup times, lower production rates or higher scrap rates.

An undesirable method of reestablishing control involves *expediting,* in which someone "bugs" operations get a certain job "moving." Expediting frequently ties up a person to carry the critical order from machine to machine, pushing it through the process as quickly as possible. In general, expediting fails to add value, or it can even create waste, for several reasons. First, it represents a reactive response that occurs only after an order is out of control rather than a proactive measure to maintain control. Second, expediting disrupts the progress of other jobs waiting in work-center queues. Expediting one job, delays other orders. Finally, expediting corrects symptoms rather than the causes that send orders out of control in the first place

Feedback transmits information about the progress of orders on the shop floor back to the planning system. This link informs planners about events within the transformation process. It also identifies seriously troubled orders for which the SFC system cannot make sufficient capacity adjustments to restore control. The planning system may respond to feedback about orders too far behind schedule by taking one or more remedial actions:

- Changing the due date for the order, usually by pushing it further into the future
- Canceling the order
- Expediting the order

Some of the measures that SFC systems use to resolve scheduling problem is t intervene by:

- Lot splitting orders that are slowing down the flow of work
- Reducing the system's incoming load
- Reducing the order quantity, especially if it is a restocking order

Control/feedback rely on *management by exception* practices. Typically, this information involves critical or problem jobs. Exception reporting ignores non-critical jobs.

***Order** Disposition*: The last activity within shop-floor control, order disposition, pursues two major objectives: to relieve the transformation system of responsibility for the order and to provide the rest of the firm with information to evaluate the performance of the transformation process and the recently completed order. At the completion of order disposition, operations managers and accounting can evaluate the performance of the transformation process against standards for several important measures:

- Resources used (perhaps measured in labor hours or machine hours)
- Materials consumed
- Hours of setup time
- Tools used
- Completion date
- Rework or scrap generated
- Units completed versus the number started

Finally, order disposition gives everyone a last chance to examine orders and to understand exactly what happened to them. People tend to forget quickly about completed orders, Timely review of all performance fosters learning because it creates an opportunity to study problems and their causes. Such a postmortem investigation may provide valuable information to support continuous-improvement activities. World-class firms routinely contact their customers to see if they are satisfied.

Individually, each of the above activities gives operations managers a fundamental understanding of what is happening at the shop floor level. When all is going according to plan, there is little to do. Minor deviations from plan normally can be handled at the SFC level. Major variations may necessitate consultations with the other functional areas. *In an era in which top management hates performance surprises, it is imperative that bosses be alerted so that corrective actions can be done as needed.*

Dialogue Driver:
One element of product architecture was to decide how much reserve capacity a good should have.
From a scheduler’s standpoint, would it be nice to have some slack reserved into a system?
How might that be accomplished?

SCHEDULING CONCEPTS

Understanding general scheduling principles requires a basic understanding of some of the concepts and terms used by operations management practitioners. In this section, we will discuss these in greater detail.

While physical flow of product dominates scheduling decisions, and they often divert attention away from critical information flows used to make them. The process draws on information from a variety of sources, including dispatch lists, input/output reports, order-status reports, and various exception reports.

The first major term used in scheduling is the *order due date*. This is a promise made to a customer telling them when they should expect delivery of the product. In addition to the quality of the product, fulfilling your promises is a major determinate of customer satisfaction. Thus it is important to understand how this key business process works.

The Order Due Date: The inputs to the order due date process can be internal or external. *Internally* driven processes use "normal" production lead times to set the earliest delivery date. Humans normally deliver newborns nine months from conception. Likewise, factories have a typical product-gestation interval. Parents and customers learn how long this take and plan their actions accordingly.

Shop-floor control systems begin the order setting process begins by calculating the planned or estimated lead time for each new order in one of two ways. This calculation may apply a *standard lead-time allowance*. If standards call for a 3-week lead time for every order, then an order dated May 9 gets a due date 21 days later. Alternatively, the scheduler or dispatcher might determine the number of operations needed to complete the order and the *estimated time per operation*. After adjustment for the current shop load, the sum of operation times determines the earliest possible order due date. A customer can then approve or reject it.

Such a system may calculate variable lead times from formulas like the total work content rule, or TWK rule. This rule estimates lead time based on the amount of processing time needed for a specific job (setups plus operation or run times) adjusted for delays like time spent waiting in queues for equipment and transportation. Mathematically, TWK equals:

TWK = k times the Sum of the Setup Times and Operations Times

where k is multiplier which serves as a fudge factor.

To illustrate how the total work content is calculated, consider the following problem:

Operation	Description	Setup (hours)	Run Time per Piece (hours)
10	Rough turn	1.5	0.030
20	Finish turn	3.3	0.048
30	Mill face	1.8	0.025
40	Mill slots	0.6	0.010
Order quantity:	300 units	7.2	0.113

Summing the setup time and the total run time from the exhibit gives a total work content of 41.1 hours. Then

$$TWK = k\ (7.2 + 300 \times 0.113) = k \times 41.1$$

Suppose past experience suggests that k from the TWK equation equals 10, which means that the total lead time for processing an order tends average 10 times the length of the processing time. This multiple reflects waiting time and time consumed by transportation and other activities such as inspections. The equation gives a total planned lead time for the order of 411 hours, which can use this value to set the order due date.

Externally set due dates receive their inputs from outside the operations function. A customer may express a date they need their order has to be received. This may be an unrealistic date but it is up to marketing and the master scheduler to decide if the firm should make the commitment. Once the commitment has been made, it is the responsibility of the shop floor control system to make every effort to get the job done on time.

Due dates may be influenced by other functions with the firm. Top management may have informed

Wall Street analysts that sales for the current quarter will be so much. Or sales personnel may have their bonuses influence by end-of-quarter shipments. This may not be "right" but often it is so.

Finally, customers and representatives of the shop-floor control system can negotiate order due dates through some combination of the previous methods. When a customer wants a different due date than the SFC system offers, they can seek a mutually acceptable compromise date. The customer may have to accept a later due date while the SFC system may have to reschedule some work to improve its original estimate.

The due date setting process described above tells the customer when to expect the process, but it does not provide much help to the work centers within a factory. If an order entails work being done in seven different work centers, when should each start their part of the job? "Thus there is a need to establish some milestones to provide each work station due dates for their part of the job. These are called *operation due dates.*

The Operation Due Date Setting Process sets a completion time for every activity in the processing sequence for an order. Workers handling the order in Exhibit 2 would need four separate operation due dates for Operations 10, 20, 30, and 40. By meeting each one, the process would also meet the order's due date. In many SFC systems, the operation due date for the last operation matches the overall order due date. Suppose we promised our customer that the part would be delivered 400 hours from NOW. One simple way to create operational due dates for each workstation would be to divide the 400 hours by the number of operations.

Exhibit 2
Establishing Operation Due Dates

Operation	Description	Setup	Run Time per Piece	Operational Due Date
10	Rough turn	1.5	0.030	NOW + 100
20	Finish turn	3.3	0.048	NOW + 200
30	Mill face	1.8	0.025	NOW + 300
40	Mill slots	0.6	0.010	NOW + 400

If we elect not to release the order immediately, then the order's due date would have to be adjusted.

Prior to the advent of the computer, the use of the Julian calendar created problems for shop floor level schedulers. When is 400 hours from now? That depends on the number of hours worked per day, the weekend days off, national holidays. In order to minimize confusion, some operations planning systems use scheduling *calendars*. Scheduling calendars can be expressed by day and week, it is due Tuesday of Week 24, or by the number of days into the planning year, it is due on day114.

To apply the concepts of order due dates, operation due dates, and scheduling calendars to a practical situation, operations managers must make two choices. They must decide between forward and backward scheduling methods in determining how to generate due dates and release dates.

<u>*Forward vs. Backward Scheduling*</u>*: Forward Scheduling* starts with the earliest date on which a process can begin working on an order. It adds lead times for individual activities needed to complete the order to find successive operation due dates. When the process reaches the last operation, its due date becomes the overall order due date. SFC systems typically employ forward scheduling methods to set due dates.

In contrast, *backward scheduling* starts with an order due date and works backward through the sequence of OM process activities, starting with the last operation and ending with the first. It subtracts successive activity lead times to determine individual operation due dates and ultimately the latest possible order start date. Customers and planning systems typically conduct this kind of analysis to evaluate the feasibility of desired due dates. An infeasible order due date occurs when the order is given a first operation start date before the current date. Exhibit 3 describes the difference between forward and backward scheduling. This example assumes that the shop uses a day calendar and that it operates only one shift per day. The exhibit lists setup times, run times, numbers of operations, queue times, and transit times for each activities. NOW is day 271 and an order due date of day 320. The order is for 300 units. The following exhibit shows the operation due dates for the order determined by both forward scheduling and backward scheduling.

Exhibit 3
Forward and Backward Scheduling

Operation	Setup (hrs)	Run (hrs)	Operations (Days)	Queue	Transit
10			01		
20	1.5	0.030		02	01
30			05	02	01
40	3.3	0.048		02	01
50	1.8	0.025		02	01
60	0.6	0.010		02	01
95			03		
99			01		
Total	7.2	0.113	10	09	05

Order quantity: 300 Due date: 320 Current date: 271

			Forward Scheduling		Backward Scheduling	
Operation	Hours	Days	Start	Opn. Due Date	Start	Opn. Due Date
10		01	271	272	288	289
20	10.5	04	273	277	290	294
30		07	278	285	295	302
40	17.7	05	286	291	303	308
50	9.3	04	292	296	309	313
60	3.6	02	297	299	314	316
95		03	299	302	317	319
99		01	303	303	320	320
Total hours	41.1					

The results with forward scheduling show a lead-time for Operation 20 of 4 days; this gives the sum of processing time for the activity (10.5 hours, or 2 days) and queue time (another 2 days). Also, the start date for Operation 20 reflects a 1-day delay after the due date of Operation 10 (day 272) due to the 1-day transit time. Finally, notice that the operation due dates could slip by up to 17 extra days without compromising the final order due date of day 320. The backward-scheduling information indicates the latest possible operation due dates as well as the latest possible start date (Day 288) for the entire order. Both scheduling methods indicate a feasible order due date and processing sequence.

The two dates help the SFC manager understand how much slack there is and how it can be used. Using both procedures can show when is the latest start date and when is the earliest process date. The latest start date is important because the shop floor may be congested at the time of the required release date. Holding back the order can reduce the load at that time and ensure that the job is released when it can be done. To determine the slack (how long before the order must be released to meet its due date), backward scheduling can be used to calculate the latest start date. However, the customer may be willing to take an order completed early, and there may be excess capacity available on the shop floor. In this situation, forward scheduling can be used to determine when the order will be completed and the acceptability of this early completion. Forward and backward scheduling are not as much substitutes as they are complements.

Push vs. Pull Systems: The fourth concept involves the way execution actions are triggered. Do production activities result from management's plan or does a customer action trigger action. As a household shopper, do you buy groceries based on what you plan to eat or are you replacing what was just consumed. In operations, the plan driven approach is called a *push system* and the consumption driven approach is called a *pull system*. .*Pull Systems pull orders* through the system. The trigger to make something is predicated on a kanban card's arrival signifies a need to replenish a part or a number of parts that has been used. Pull scheduling provides several very attractive benefits. It simplifies scheduling because each activity builds just what an internal customer has used. This works well when there is high likelihood that similar usage will occur in the near future. Only real demand drives orders from downstream activities, so unneeded inventory doesn't accumulate. Problems are immediately apparent. A breakdown at Work Center C quickly idles Work Centers A and B, drawing the attention of workers to correct the problem. Pull scheduling automatically prevents additional load from piling up extra work at the bottleneck in the event of some problem.

In contrast, *push scheduling* moves an order to the next operation or work center in its route immediately on completion of the current activity whether or not that work center can begin processing it. As Work Center A pushes completed jobs to Work Center B, a large queue of work may accumulate. Despite this potential drawback, push scheduling does offer benefits. First, implementation is relatively simple when a worker completes an order, it moves to the next work center and the worker proceeds with the next order on the priority list. This reduces the need for coordination of flows between work centers, and it eases requirements on both the planning system and the shop-floor layout. Push scheduling relaxes the connections between activities, so an order can move to a number of different operations from any point in the process. This enhances flexibility to deal with widely varying loads on different work centers. Finally, push scheduling keeps each work center busy as long as work remains in its queue.

Push scheduling does suffer from several important problems, as well. As described earlier, work-in-process inventory can build up as orders flow in while a work center processes current orders. Also, push scheduling makes a process prone to quality problems. If the processing steps at Work Center A go out of control, it may continue to produce defective parts until personnel at Work Center B notice the errors and inform others. This gives Work Center A a lot of time to produce defects. Also, a breakdown causes work to build up at the disabled work center. When it returns to production, workers may feel pressure to rush the activity to clear the waiting work, creating opportunities for quality problems. These queues also stretch lead times.

Furthermore, push scheduling tends to hide processing problems. Trouble in one part of the transformation system leaves other parts to function as normal. This creates an appearance of activity that can mask problems. Finally, push scheduling requires some form of dispatching rule to tell workers which orders to process next.

Both pull scheduling and push scheduling bring important trade-offs. The SFC system should resolve these trade-offs in a way that enhances the firm's ability to add value for customers. It must also choose specific techniques and procedures for developing schedules that suit both customer needs and process characteristics.

Dialogue Driver:
To what extent to push and pull systems rely on knowing how long it will take to perform a task and the reliability of these duration estimates? How can a firm minimize these risks?

SCHEDULING TOOLS AND TECHNIQUES

Scheduling difficulty increases in complexity with the number of jobs being managed and the number of work centers increases. As is the case with all operations problems, firms can take one of three approaches:

1. *Solving the scheduling problem* with the use of a computer assisted model. These often result in detailed production schedules that tell each operator what job to do next.
2. *Resolve the problem* by creating a work-scheduling environment characterized by local decision rules and ample job scheduling slack.
3. *Dissolve the problem* by simplifying the processes and reducing the scope of the plant's operations.

In the following section, we briefly discuss each of these approaches.

A major facet of the scheduling task is to decide the order in which work is to be done. The means used to accomplish that is range from the fair and simple, First Come First Serve dispatching rule to more complex priority based rules. Scheduling priorities should be based on what the strategic planning process decided when it set performance metrics for the system.

While no two systems are alike, there are five general categories of scheduling procedures:

- General-purpose procedures: Some scheduling methods suit widely varying manufacturing settings, including short-interval scheduling, Gantt charts, and simulation.
- Job-shop scheduling methods: Dispatching rules and some other procedures suit the low volume and high variability of job shops.
- Scheduling for bottlenecks: A relatively new procedure called optimizing production technology (OPT) helps to identify and schedule bottleneck operations.
- Production-line scheduling procedures: Some methods prove especially suitable for high-volume processing and assembly lines.

In this section, we look at the following scheduling procedures.

General-Purpose Procedures are highly adaptable tools that support to schedule decisions making in a wide variety of settings' factories, warehouses, department stores, and offices among others. These include short-interval scheduling, Gantt charts, and simulation methods.

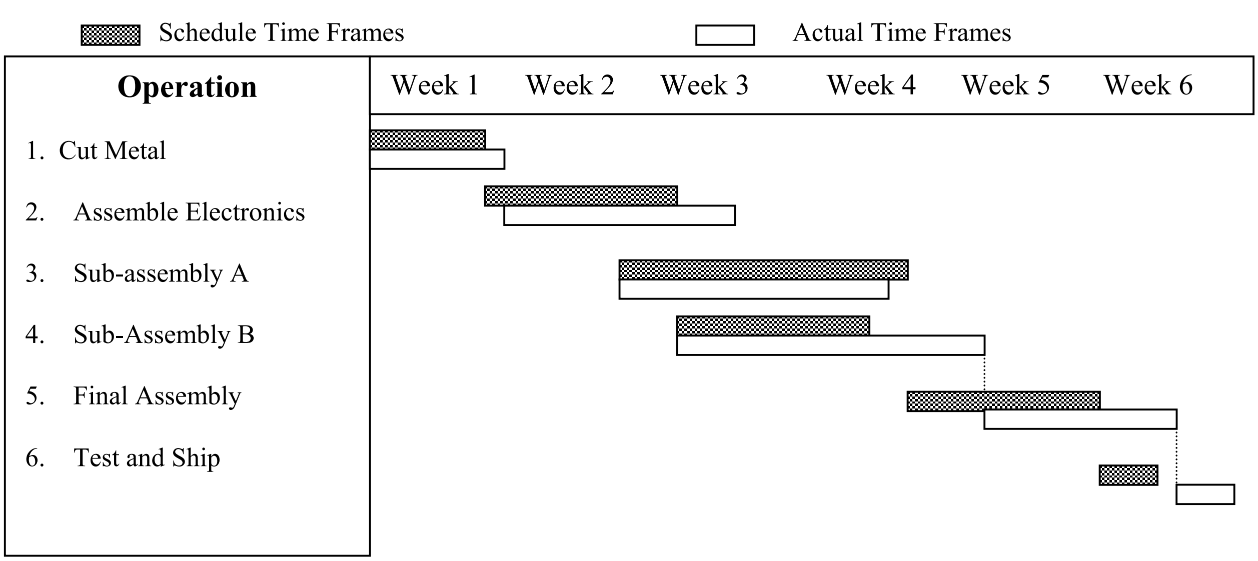
Short-Interval Scheduling (SIS) guides scheduling decisions by a simple, straightforward principle: *a company can improve its overall efficiency by controlling how it uses each hour of the workday.* In practice, SIS breaks down the capacity of a transformation system into small time units, usually 60 minutes or less. It then releases orders designed to take no more than the maximum size of the time unit.

A schedule specifies a "to do" matrix which defines the work each work center can complete within the interval, considering all demands of that work such as learning, setup time, and order quantity. The operator schedules jobs to complete all tasks on his to-do sheet within the hour. At the end of the hour, the department supervisor and the dispatcher receive reports on the status of all jobs (completed or in-progress) and the efficiency of each center and operator.

Gantt Charts display work schedules using horizontal bars to depict the start and completion of tasks. This chart helps operations managers monitor the progress of each order through the process and the load on each work center in relation to available capacity. In conjunction with larger-scale scheduling techniques like critical path management (CPM) and the project evaluation and review technique (PERT), it also helps to evaluate the progress of an overall project. In each of these three tasks, the Gantt chart provides the user with a quick, visual indicator of the actual status of each order and its anticipated or planned status.

Consider the Gantt chart that spans six operations that is shown in Exhibit Each row represents an operation, while each column represents 1 week of the order's overall estimated lead time. The inverted triangle indicates the current time (the beginning of Week 4). The light horizontal lines indicate the planned lead times for individual operations, while the heavy horizontal lines indicate actual progress. The first operation, cut metal, proceeded without any problems, but the second began and ended behind schedule.

Exhibit 4
A Gantt Chart



The Gantt chart provides valuable and easily understood information about the progress of an order in relation to the schedule at every stage of the OM process. Gantt charts continue in widespread use due to their many advantages. They provide useful information in a format that is simple to develop and interpret. Schedulers can easily incorporate changes in timing, machine loads, and current status. Some common changes can make Gantt charts fairly flexible to apply

We can augment a Gantt chart by having its bars map resource usage as each task is performed. This is useful because many manufacturing system simultaneously are working on many orders, each with its own resource use profile. By mapping the planned resource usage for all products, it then its possible to anticipate bottlenecks. Management intervention then must follow. It also identifies the locations of any current problems. It shows how Gantt charts can help schedulers to control machine loads by comparing the anticipated demands on work centers or machines with actual demands.

Simulations: A simulation develops and implements a computer model of an actual system to evaluate alternative policies, schedules, or solutions. The simulation can model all kinds of arrangements like different dispatching rules, processing procedures, or assignments of orders to work stations. It proves especially valuable for projecting the impacts of changes in the amounts and timing of workloads. This powerful analytical method becomes even more popular as new computer software simplifies the work.

Scheduling Rules for Job Shops tend to rely on *local decision rules*. Keeping track of the large number of jobs found within medium and large jobs shops has made the divide and resolve approach to job shop scheduling. A key input has been the use of operation due dates since it help allocate slack in a manner that gives each work center the necessary degree of freedom to sequence work within their realms.

The way in which orders progress through as job shop is as follows. As orders arrive at the gateway work center, they are placed in a queue of jobs competing for access to that center's equipment. A local dispatching rule sets priorities for these orders based on some formal logic. When the work center completes its current job, it selects as its next job the highest-priority order in the queue. In this way, dispatching becomes an iterative process that sets priorities for orders in the queue, picks the highest-priority job for processing, and then resets priorities in the queue to repeat the cycle.

The way in which orders are prioritized depends on how you want to run your plant. Do you want to be "fair" or do you want to take care of the customers and orders that matter the most. Some of the rules are:

First Come-First Served (FCFS) directs work centers to process orders in the exact sequence in which they arrive. This decision requires no computers or other technology; the system just records the times at which orders arrive, perhaps by placing cards at the end of a stack, and the operator pulls the orders in sequence from the front of the stack.

This rule brings benefits of simplicity in use, but it does suffer from a number of major shortcomings. It ignores important information like the order's due date, needed processing time, the relative importance of the customer, and any similarities in processing methods, setups, or components to other orders. As a result, this rule tends to perform poorly on all performance criteria.

In general, the first come-first served dispatching rule proves adequate only under certain important conditions. First, FCFS does effectively schedule essentially identical incoming orders. For example, McDonald's and similar service organizations rely on this principle, as do movie or theater box offices. In a homogeneous process, FCFS fairly distributes services among customers. FCFS can also function well with extremely short work queues, especially in just-in-time manufacturing systems.

*Shortest Processing Time (*SPT) sets priorities for orders based on their processing time requirement (setup plus operation time). Small orders get the highest priority while the largest gets the lowest.

This rule offers some important advantages. First, it effectively completes large numbers of jobs within relatively short periods of time. It also results in the smallest average time between due date and completion date. When a schedule sets either infeasible or highly suspicious due dates, SPT generally gives the most appropriate priority ranks. Despite these potential benefits, SPT is generally not recommended for several reasons. First, the method discourages fast processing of large jobs, leaving them to wait until the system finishes small jobs. Second, SPT ignores due dates when it sets priorities, so it does not support a goal of generating value by meeting due dates in a timely fashion. Finally, research has found that SPT adds variance to systems with little variability, reducing overall system predictability.

Earliest Due Date (EDD): This rule answers some criticisms of SPT by ranking orders by their overall completion dates. It sets the highest priority on the order with the earliest completion date, and it gives the lowest priority to the order with the latest overall due date. EDD supports any system that creates value by meeting due dates such as MRP. In addition, EDD encourages the on-time delivery of orders. It helps minimize the time between due date and completion date for an order in the transformation process. EDD is appropriate when orders follow a single route through the process and when the remaining processing time after completion of an activity does not constitute a critical component of total lead-time.

However, EDD does have several limitations. First, to work effectively, it requires attainable, realistic due dates. It performs poorly when handling excessively tight order due dates (e.g., when an order needs 100 hours of additional processing and only 105 hours remain before the due date) or infeasible due dates (e.g., when only 80 hours remain to complete the order). Second, the EDD rule distorts the real urgency of an order because it fails to compare the need for additional processing time with the available time.

Slack Time Remaining (SLACK): This dispatching rule addresses the weakness uncovered in the discussion of EDD. It sets priorities to favor an order with relatively little slack, defined as the difference between the order due date and the current time adjusted for the amount of processing time remaining:

$$\begin{aligned}\text{SLACK} &= \text{Order due date} - (\text{Time now} - \text{Remaining processing time})\\ &= \text{ODD} - \text{TNOW} - \text{RPT}\end{aligned}$$

The SLACK rule provides several important strengths. First, it considers both due dates and remaining processing time. Second, it creates a dynamic procedure for calculating priorities. All terms of the equation remain constant except the current time. As this changes, schedulers must recalculate priorities to update priority rankings.

Like EDD, SLACK provides an appropriate dispatching rule for any system driven by due dates or for any system that seeks to generate value through reliable deliveries. Like EDD, SLACK depends on feasible and sufficiently distant order due dates. Because SLACK considers the amount of processing time remaining, it offers an improvement over EDD and a superior way to minimize the period between the due date and the order completion date for any order.

SLACK does present one important problem: it ignores the number of remaining operations. The following shows how this omission can distort priorities. Both orders have equivalent priorities under EDD, since they share a due date. SLACK would set a higher priority on the first order (SLACK=6) than on the second (SLACK = 7). Note an important difference between these two orders: the first has reached its last operation while two more operations remain for the second. The second order must, therefore, wait in two more queues and pass through two more handling steps giving it a greater chance of falling behind schedule. To prevent this problem, the second job should be scheduled before the first.

Work center: 123 Current date: 137 (M-day calendar)

Order Number	Order Due Date	Scheduled Work RPT (Days)	Remaining Operations (ROP)
13446CD	149	6	1
17882MI	149	7	3

Critical Ratio Rule (CRR) ranks jobs based on a critical ratio (CR). The critical ratio for each job equal to the time remaining until the due date divided by the remaining processing time or:

$$\text{CR} = (\text{Due date} - \text{NOW}) / \text{RPT}$$

The resulting ratio indicates whether the order is ahead of schedule (CR >1), on schedule (CR=1), or behind schedule (CR < 1). All orders receive priority ranks in decreasing order from smallest to largest, so the job with the smallest CR gets the highest priority.

	Queue Time	Move Time	Setup Time	Run Time
Operation	(days)	(days) (hours)	(hours)	
1	2	0	2	3
2	3	1	1	2
3	1	2	4	6
4	4	1	2	7
5	2	1	2	3
6	3	1	4	1

Due Date: 237 Current time: 210 Quantity: 10

Operation Due Dates/Operation Start Dates (ODD/OSD): This priority rule establishes a due date or start date for an individual operation for every order in a queue. It bases these dates on the backward or forward scheduling methods previously discussed. An order's OSD identifies the date on which it should begin processing at the work center. This date depends critically on the method for identifying the expected queue time for every operation in the order's route. Most expected queue times come from work center standards. A higher standard queue time indicates greater demand for a work center.

The following illustration assumes an 8-hour production day. For Operation 6, then, the sum of setup and run time translates into 1 shift (5 hours rounded up to 1 day); for Operation 4, the same calculation gives 9 hours or 2 days. Backward scheduling gives OSDs and ODDs for these operations, as shows.

Operation	Operation Start Date	Operation Due Date
1	213	214
2	215	216
3	219	221
4	226	228
5	231	232
6	236[a]	237[b]

[a]1 day of processing [b]This date also becomes the order due date.

For example, the OSD for Operation 6 equals the ODD minus the processing time in days (237- 1). To complete the order on time, the work center should start working on it no later than Day 236. The ODD for Operation 5 comes from subtracting the move time (1 day) and the queue time for Operation 6 (3 days) from the OSD for Operation 6, or Day 236 (236 - 1 -3 = 232). The gap between the ODD for Operation 5 and the OSD for Operation 6 reflects time spent moving and in the queue between them.

…..The OSD/ODD method is becoming common for several reasons. First, ODD/OSD meshes well with date-driven systems such as MRP. Second, this rule considers the impact of the various components of lead-time (run time, setup time, move time, queue time) on the appropriate timing for operations. Third, and most important, ODD/OSD states priorities in terms that prove meaningful for most people who work with the transformation process. If an order has an operation start date of 229 and it has not yet started processing on Day 231, then the order is 2 days behind schedule.

The selection of a dispatching rule depends on several considerations, but simplicity of use be a guiding principle. As a rule of thumb, if it takes more than 5 minutes to explain a rule, workers will ignore it.

THEORY OF CONSTRAINTS

Bottlenecks affect schedules in both job shops and process/assembly lines. They limit the OM system's ability to meet its value-based commitments for quality, lead-time, cost, and flexibility. Bottlenecks underlie any differences between what operation managers promise and what they deliver to customers. Earlier, you saw how a system could be modeled as a *maximum flow network problem*. A technique called, the theory of constraints, has extended this problem into a formulation capable of dealing with bottleneck problems.

Theory of Constraints (TOC) emphasizes the need to identify and manage constraints within the entire system. The TOC framework begins with the premise that any OM system functions primarily to make money by delivering value to customers in the form of time, quality, cost, and flexibility benefits. One can measure its success in meeting these requirements by evaluating the amount of money that it earns. An OM system that more effectively delivers value should make more money for its owner. TOC advocates attacking bottlenecks and constraints because they significantly limit the level of value that it can generate.

A second premise of TOC argues that variability occurs naturally in any process or system. Any attempt to balance shop loads will fail because it does nothing to balance workflows. Consider the situation where Activity A has an output rate that equals the average rate at which the Activity B uses A's output.. However, if A takes longer than expected to produce an order, then it can starve activity B. Rather than balancing load, TOC advocates balancing work flows in a way that accommodates unavoidable variance.

To do this, TOC directs management assigns all system resources to one of two categories: bottlenecks and non-bottlenecks. A bottleneck resource constrains workflows and limits system throughput. Downstream problems are amplified by problems that begin earlier. So improvements early in the system benefit the system as a whole. In contrast, non-bottleneck operations do not constrain production, so investments there waste organizational resources because they do not increase the overall output of the system. These principles lead operations managers to focus attention primarily on bottlenecks

Planning must set realistic production goals in light of capacity constraints. All planning should focus on bottleneck activities. If they create infeasible demands on bottleneck resources, then they create infeasible demands on the system. To carry out those plans, operations managers should manipulate workflows to encourage effective utilization of capacity constrained resources. The theory of constraints uses performance metrics that distinguishes utilization of a resource from mere activation. Maintaining high efficiency on a non-bottleneck activity may be creating waste and system congestion.

The goal is to achieve high utilization of capacity constrained resources. Managers must rethink current practices and focus on reducing nonproductive setups at bottlenecks. It can do this by running the largest possible lot sizes at bottlenecks and by running small batches at non-bottlenecks to fulfill their primary role of supporting continuous operations at the bottlenecks. TOC uses a series of operating guidelines:

- Balance flows, not capacity.
- An hour lost at a bottleneck is forever lost.
- Time at a non-bottleneck resource has a negligible marginal value.
- The level of utilization at a bottleneck depends on some other constraint(s) within the system.
- Bottlenecks govern throughput, inventory, and quality.
- Utilize resources--do not simply activate them.
- The size of a batch moving between work centers need not equal the size of the processing batch.
- Processing batch sizes may vary both along an order's route and over time.
- Schedules should simultaneously accommodate all constraints. Lead times result from scheduled sequences, so planners cannot determine them in advance.

Today, advanced scheduling software is being offer as firms seek to squeeze more value adding activities from a finite set of resources. However, at the other extreme are the firms that have dissolved their scheduling problem by flattening the organization through extensive outsourcing of most early stages of manufacturing. One company, Custom Craft, assembles business-specific personal computers in two waves each day. Scheduling has been made easy—just fetch the parts and assemble and test the units.

Dialogue Driver:
Is the value driven approaches to designing and managing an operating system consistent with the TOC approach?

SUMMARY

We began this shell by looking at the problems encountered by Bill Taylor in managing daily activities in a GM tool room. He must create and implement a scheduling system that introduces orders from the planning system to the tool room's work centers. His system manages the flow of work to produces finished goods in a timely and cost-effective manner while meeting its internal customers' quality requirements.

Whether or not one is scheduling services or goods operations, the tasks confronting the scheduler are:

1. To manage the flow of work from planning through execution to completion of products.
2. To execute work in a way that supports the firm's vision of delivered value.
3. To understand that service operations requires careful schedules for labor capacity through order scheduling and employee scheduling measures
4. Shop-floor control depends heavily on the planning system. Planners define the capacity that the SFC system controls. Without good planning, the SFC system cannot succeed.
5. To effectively perform the five major activities of SFC, i.e., order review/release, detailed scheduling, data collection/monitoring, control/feedback, and order disposition.
6. To remember that scheduling is also a human management process. Dispatchers, department supervisors, and equipment operators draw on their knowledge and insights to determine and improve schedules. People choose appropriate scheduling tools to suit recognized needs.
7. Order due dates play critical roles in prioritizing the order work is executed.
8. General-purpose scheduling procedures that suit most environments include short-interval scheduling, Gantt charts, and simulation.
9. To understand the role local decision rules, such as FCFC, SPT and critical ratio play in organizing the flow of work within job shops.
10. To understand the limits of local rules and MRP in eliminating bottlenecks and understand the potential of resources constraint oriented methods, such as theory of constraints.

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3. Goldratt, Eliyahu M. , *What is this thing called Theory of Constraints and how should it be implemented?*, New York, North River Press, 1990.
4. Melnyk, Steven A., and Phillip L. Carter. *Shop-Floor Control: Principles, Practices, and Case Studies*. Falls Church, Va.: American Production and Inventory Control Society, 1987.
5. Wight, Oliver W. *Production and Inventor0y Management in the Computer Age*. Boston, Mass.: Cahners Books, 1974.

Expected Learning Competencies

Before putting Shell Fourteen down, you should ask yourself the following questions. Am I able to explain:

1. The concept of scheduling and who normally performs this activity within the operations management arena.
2. The differences between forward and backward scheduling and push and pull systems.
3. What detailed scheduling is and the conditions that must exist before it can be effectively implemented.
4. The role of due dates in a build to order environment, and how operations managers use them to organize/prioritize its work.
5. The scheduling decision making hierarch and the role local decision rules play in prioritizing work..
6. The performance characteristics of local decision rules, especially with jobbing environments.
7. What your instructor added to this shell and why he or she thought that it was important enough to warrant its inclusion.

Frequently Asked Questions

Instructors have been known to ask questions similar to the following:

1. Describe how information and IT support the work scheduling business processes in:
   - Each of the four market orientation
   - Push and pulls systems
2. Assume that you are a shop level supervisor and your firm uses MRP to plan its production. What factors that go into your scheduling decision are not normally included in the MRP planning process? If the firm was considering cutting its planned lead times in half in order to reduce manufacturing lead time, what would you want to happen before agreeing to this change?
3. How does the solve/resolve/dissolve approach to dealing with scheduling problems apply at the shop floor level scheduling environment?
4. Describe the business processes that exist in each of the four basic manufacturing process choices.
5. Which local decision rule is most likely to result in the least part flow variance when applied within a job shop environment?
   a. First come first serve
   b. Shortest processing time
   c. The critical path rule
   d. Order due date rule
6. The theory of constraints approach to scheduling seeks to maximize the value produced by a system.
7. None of the local job shop scheduling rules discussed in this shell let the importance of the customer or the customer's order influence the priority of that order.
8. The use of the Gantt chart requires the scheduler to use backward scheduling.
9. Just in time is an example of pull scheduling.

Epilogue

Well, this is what I looked like at the start of this journey. During the past hundred or so pages, I have tried to share with you some experiential wisdom gained over the last fifty years. While I started out to design nuclear power systems, external forces led me to a career in manufacturing management. What I discovered was a functional area replete with challenge. There were many, but a few stand out worthy of my taking a moment to share them with you.

People Count: Right from the start, I could see the difference between an ordinary boss and a great one. Great bosses develop people by motivating them to try things that may seem weird and then coach you when you fail. They treat you as a resource – not just a cost. I would encourage all of you to read Jack Welch's books or watch the Charlie Rose interview with him to learn how a great manager did it.

Colleagues Count: Throughout your career you will experience ups and downs. Remember that you meet the same folks on the way down as you did on the way up. Never underestimate the value of friends you make as you form your network of associates. I owe my current state to two associates, Warren Boe and Bill Berry, who helped me return to academia. After twenty years in industry, they were willing to take a chance on an old academic colleague who had not read an academic journal since he left Purdue.

Customers Count: As a young man. I learned that good service meant good tips. If you have not figured this out by now, I encourage you to take a part time job as a service giver, i.e., as a food server, bartender, or retail clerk. Getting close to the customer remains one of the most valuable experiences a business manager can have. It is a learned habit and one well worth cultivating. If you cannot do this, read *Fish*.

Fads Come and Go: Throughout your career, you will experience many "in" initiatives. We recently experienced one called the dot.coms revolution. Being able to sift through the enthusiasm to see if there is a kernel of value will make you a manager with a future. Tire kicking is important but it has to be done with quiet diplomacy. It is just as easy to get a reputation for being negative as it is to get one as being naïve.

Family Matters: Most of all, no career is worth hurting the ones you love. Good employers value family. If your employer "does not get it," then start your search for a firm or an endeavor that will enable you to preserve the sanctity and vitality of your personal life.

Thank you for joining me on my beach and for reading the shells. I hope that what you have learned will help you in your search to find success in a world fraught with change and opportunities.

☺