

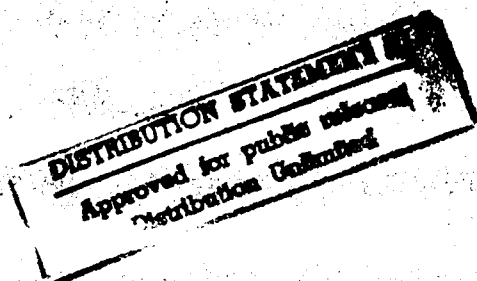
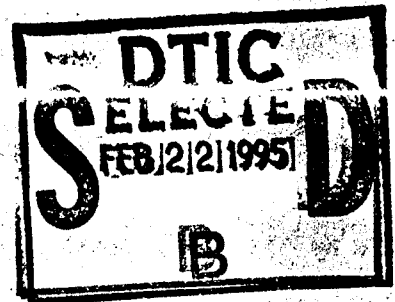
RAND

*The New Management
Paradigm*

*A Review of Principles
and Practices*

Arnold Levine, Jeff Luck

Project AIR FORCE



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Preface

A revolution is under way in private industry. In the 1950s and 1960s, a few innovative firms found ways to improve their performance markedly, putting pressure on their competitors to respond or lose market share. As firms in other industries observed the innovations under way, they began to adopt these new practices. Each innovation produced an innovative response. By the 1980s, the increasingly dynamic and unforgiving business environment began to look like something qualitatively new. The business literature began to fill with a body of "new business practices."

Mr. Grover Dunn, Air Force/Aircraft Missile and Support Division (AF/LGSW) on the Air Staff, suggested that RAND examine the implications of these new practices for Air Force logistics. Somewhat skeptical that the environment of private firms was similar enough to that of Air Force support activities to make any innovations transferable, we nonetheless initiated the business practices study under the leadership of Raymond A. Pyles. This literature survey began as the first analytic step in that study. Our initial insights from the business literature quickly evolved into an Air Force concept called "lean logistics," which seeks to use a variety of new business practices to make the Air Force logistics structure far more responsive to operational users who operate in an uncertain environment.

As our work on lean logistics proceeded, we continued to survey the business literature. This report is the end result of that survey effort. Although Air Force lean logistics grew directly from the work that started with this survey, we see the survey as an independent product with the potential for broad applicability in public agencies. From our work on lean logistics, we learned that it takes much effort to apply the principles developed here to particular policy contexts like Air Force logistics. That said, just as it provided a useful starting point for Air Force lean logistics, this survey is expected to provide a similarly useful starting point in other public policy contexts.

The survey should interest anyone studying new business practices and seeking to understand how to apply these practices in new settings. In particular, it helps impose a sense of order on the diverse range of experiments that private firms have tried, suggesting that many of these experiments share a great deal in

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common. Understanding these commonalities offers a solid jumping-off point for new applications of these practices.

This report was produced by the Logistics Project of the Resource Management and System Acquisition Program of Project AIR FORCE, the Air Force's federally funded research and development center. Comments and reactions should be directed to Frank Camm, the leader of the Logistics Project.

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Summary

Over the past 20 years, a new management paradigm has emerged that is the antithesis of mass production. Firms employing this new paradigm rely on an integrated set of principles and implementing practices. First, to get new products to market quickly, they integrate marketing, research and development, engineering, design, production, and distribution. Second, to respond quickly to shifting demand, they aim at producing small lot sizes, with minimal setup times—a practice known as lean production. Third, to make every aspect of production more visible, they work with fewer, more qualified suppliers and involve them in every phase of production, from product development on. Finally, they delegate much greater operational responsibility to those who design and manufacture the product.

The purpose of this report is to use an intensive survey of the literature to describe and analyze this new management paradigm. By providing a framework for understanding a very complicated subject, the report will serve as a resource for government managers and anyone else interested in those practices that are shaping manufacturing and service industries throughout the world.

The justification for organizing this report as a literature survey proceeds at several levels. A survey can summarize a vast amount of research and synthesize the experience of many executives and managers. Further, some of this literature shapes the context in which discussion of the new management paradigm occurs. Last, a literature review brings out the complexity of the practices and the different ways in which the authors evaluate their impacts.

This report recognizes the limitations of a literature that concentrates on implementation successes rather than failures, appears biased toward larger firms, often lacks methodological rigor, and may overstate the adoption of these practices in various industries. Nevertheless, an integrating study such as this may have substantial value, because it provides evidence that some companies in some industries have reorganized their operations in ways that dramatically improve the quality of their products, the speed with which they design and manufacture them, and the cost savings they pass on to their customers.

The New Management Paradigm

Since the mid-1970s, a new approach to manufacturing and service delivery has been superseding the traditional mass production model. New companies in a variety of manufacturing and service industries are far more responsive to the customer than traditional firms wedded to mass production. Their essential feature is that they have devised and perfected techniques that satisfy the shifting needs of heterogeneous markets.

New production systems and technology wedded to lean production have made this possible. Competitive firms can satisfy the customer because the amount of time needed to move products from design to point of sale has shrunk dramatically, and flexible manufacturing enables even small-scale producers to customize products, like automobiles, that were once fixed.

The new, integrated approach to product design and manufacture represents a shift in management paradigms. A paradigm is a norm that regulates theory and practice in a given area. The old mass production paradigm was grounded in the classical theories of organizations as rational systems whose main purpose is to address problems by reducing the immense number of possibilities that no one person could explore to a few clear-cut alternatives. It assumed that markets and customer demands were basically homogenous and stable and that products would change slowly.

The new management paradigm questions these assumptions. The environment in which firms wedded to lean production operate is neither stable nor certain. Because quality, cost, and speed interact, firms try to improve all simultaneously. Rather than optimizing a particular department or function, they optimize all departments and functions because they must work together to the desired end. Moreover, firms working within the new paradigm prefer to develop long-term relationships with fewer, but more qualified, suppliers.

Systems based on lean production require the restructuring of the producer organization. Firms that adopt lean production treat their employees as assets rather than variable costs, because they require workers to take initiative to, for example, stop the production line at any time. Both have a stake in the enterprise's successful operation, because both share the risks in running it.

Fundamental Principles Underlying New Management Paradigm

Although the routes by which companies adopt the new management paradigm vary greatly, the underlying principles of their operations are remarkably uniform and simple. Two principles underlie the management practices of the new paradigm: (1) customer satisfaction is central to the survival and prosperity of the firm, and (2) the firm is a *system of interdependent processes* that produces the products and services customers purchase.

Satisfying the Customer

Satisfying the customer depends on first identifying the different customers who potentially need the firms' products and services. Firms can do this by developing service strategies that allow them to segment the markets to be served, by researching their customers, and by concentrating on activities that provide a competitive advantage. By segmenting markets, firms can design products that meet the different needs of the different parts of the customer base. By researching this base, they can learn what customers really want and modify or change their products accordingly. By focusing on those activities that add value to their products and by contracting for items that others can produce more efficiently, companies can concentrate on their chosen markets better than their competitors can.

Because satisfying the customer is so demanding, the entire enterprise must be organized to achieving that end. Thus, senior executives committed to Total Quality Management (TQM) on behalf of the customer would probably restructure the organization around a set of goals directed to that end.

The Firm as a System of Interdependent Processes

Most activities in a firm are performed as part of one of three types of processes: manufacturing processes that transform physical objects, distribution processes that transport and store those objects, and business processes (such as accounting, order processing, and human resources) that act on electronic, paper, or spoken information.

Fragmentation of these processes across functional departments lengthens cycle times beyond the minimum needed to accomplish all of a process's value-added tasks. Moreover, managing such processes is difficult, costly, and almost unavoidably inefficient. Firms that address these problems by synchronizing

flows and decreasing batch sizes in their manufacturing, distribution, and business processes can achieve *simultaneous* improvements on the major dimensions of customer satisfaction, cost, quality, and speed.

Process Definition and Analysis. Process analyses—which use such tools as drawing flow charts of the progress of components, paperwork, and information through each step of the production cycle; measuring process times; and pinpointing bottlenecks—can quantify the effects of fragmenting processes across departments or sources of waste that are concealed by the structure of existing departments. Because these tools focus on the *flow* of objects or information, rather than the *structure* of existing departments, they can reveal how process fragmentation leads to lengthened cycle times, inefficiencies, and quality problems.

Process Redesign. Process analyses are inputs to process redesign efforts aimed at eliminating the waiting time and non-value-added effort that typically consume 95 percent of a process's total cycle time. During process redesign, machines may be rearranged, offices relocated, transportation routings changed, and mechanisms for controlling the flow of work revised. Such changes pave the way for establishing teams to perform processes previously spread over several departments. Such a fundamental redesign eliminates inbox waiting between departments and may permit a radical downsizing of many businesses processes that exist mostly to manage complexity. Because teams now handle processes that were fragmented among departments, workers are trained and empowered to manage the processes they help redesign.

Process redesign requires a high degree of cooperation among managers, workers, and suppliers. With minimal slack in the system, workers are kept alert by the knowledge that mistakes can quickly disrupt the entire process. Managers equip workers with the skills, information, and expert support they need to perform their tasks flawlessly. And firms help suppliers improve their processes and integrate them more closely with the firm's own.

Reengineering. Radical or fundamental process redesigns, such as eliminating regional warehouses in favor of rapid distribution from a single distribution center, are often referred to as *reengineering*. Because it often entails significant organizational modifications and expenditures, reengineering is often performed by a small team of experienced people, working closely with senior management.

Benchmarking. An important part of process redesign is *benchmarking* against similar processes, both within and outside a firm's own industry. Benchmarking against competitors establishes the standards against which process redesign efforts should aim to measure achievement. But while overall performance

information on competitors may be relatively easy to obtain, many firms will not allow competitors to study the details of how their processes operate.

Benchmarking of similar processes in other industries not only circumvents that problem, but also provides the opportunity to get fresh leads that may increase competitive advantage.

Quality Improvement. Improving processes to *prevent* defects, rather than reworking or scrapping items found to be defective during inspections, is highly cost-effective. Time and resources put into managing around defects can be freed up, and the products themselves are much less likely to fail in the field. Pursuit of quality through improved processes is not limited to manufacturing, since poor quality in business and distribution processes immediately affects customers and is expensive to correct.

Continuous Improvement. Firms that synchronize processes and prevent defects can devote more effort to improving their future competitive position. Rather than just reacting to events, managers and workers can spend more of their time anticipating problems, preventing more subtle defects, and further improving efficiency. This cycle of continuous incremental improvements has important long-term consequences. In some industries, continuous improvement is necessary just to keep pace with rising customer expectations. In addition, the cumulative effects of such improvements can be dramatic. Firms that neglect them in favor of "home run" innovations can be overtaken by competitors.

The long-run challenge for firms is how to achieve both continuous incremental improvements and the step-function improvements that come from designing new products and facilities and reengineering processes. Organizationally, it means periodically carrying out bold, strategic reengineering while nurturing steady, participative incremental improvements.

Catalog of Practices: Generating New Products

Because the two fundamental principles discussed above are embodied in a bewildering variety of institutional arrangements, it is more effective to discuss business practices in terms of the entire cycle through which a firm develops, manufactures, and distributes its products.

Learning What the Customer Wants

Lean production firms treat their customers as integral parts of product development and manufacturing. Such firms have many practices at their

disposal to determine what customers want. For example, they can collocate design engineers in the customer's plant, collaborate with a major customer in designing new products, support user groups that propose solutions to problems with existing systems, and create Joint Application Development teams of prospective users who can tell developers what features should be incorporated into a new product.

Three themes run through these practices: early involvement with the customer, integrating selling with product development and support, and the use of information both to learn about customers and to satisfy them. All of these are connected. Early involvement with customers enables suppliers to help them understand their real needs, while the integration of selling, product development, and support ensures in-depth involvement. Information generated by customer transactions enables retailers to restock automatically, salespeople to spot new market opportunities, and product developers to develop new products.

In the new business environment, firms have to go beyond traditional methods of test marketing products. Rather than the leisurely approach of introducing products and waiting a year or more for results, firms are compressing the marketing cycle. They pretest new products, use computer models to project sales for products comparable to existing lines, and introduce several products in a number of markets. For products that are genuinely new, firms may exploit technology they developed themselves or build on technologies developed elsewhere. Both cases require competitive intelligence or the ability to track market leaders for technology susceptible to improvement.

Research and Development

More rapidly than most U.S. firms, Japanese producers have scrapped the old model of basic research leading to exploratory development and culminating in some end product, which helps them bring innovative products to market better than many Western firms. Three complementary elements of Japanese R&D explain their superiority. First, Japanese firms intensively monitor developments outside their firms to introduce high-quality, lower-cost modifications to technologies developed elsewhere. The second element in Japanese R&D is a philosophy of managed evolution, which enables innovative firms to move from borrowing foreign technologies to operating at the technological frontiers. Third, Japanese firms apply R&D to the manufacturing process itself, developing new manufacturing methods in their own engineering laboratories and implementing them internally.

Multifunction Project Teams

Compared with ongoing manufacturing, distribution, and business processes, those that involve new products and facilities occur only infrequently. But their outcomes are vital to a firm's success, since they determine the products it offers and much of its fixed cost structure. The products developed must meet all relevant quality criteria, at a price customers are willing to pay, and reach market quickly, before customer preferences change or competitors introduce rival products. And the development process itself must be cost-efficient.

Project teams are a better vehicle for development processes than traditional departments. Drawing on experts from many functions, the team is staffed early and collocated, and individuals stay with the team throughout its life. These steps help build cross-functional communication and prevent team members from bringing their departmental myopia to the project. Suppliers are selected early and brought on as full members of the team.

Catalog of Practices: Building and Moving Products

Supplier Selection and Management

In the new management paradigm, the new emphasis is on lean production, which has two consequences for purchaser-vendor relations. First, the buying organization concentrates on those core functions that confer competitive advantage—provide potential access to a wide variety of markets, significantly contribute to customer satisfaction, and are difficult for competitors to imitate—and looks to outside sources for everything else. Second, large firms prefer long-term relationships with a small group of core suppliers for a number of reasons, including that the firms can achieve huge savings in transaction costs and that suppliers guaranteed a share of business are more motivated to work with their prime customers.

Production

Firms that master the new business practices integrate structured quality improvement programs with production. They first define what they mean by quality and, using that definition, improve processes by simplifying them and by eliminating waste.

Quality Improvement. Ensuring conformance to specification, or preventing defects, is the initial focus of most quality programs. Statistical Process Control (SPC) is based on the principle that, since the source of defects is variation in

processes, eliminating the root causes of variation is the best way to prevent them. In a manufacturing setting, SPC means that machine operators monitor and record key dimensions on parts as they are produced, rather than having inspectors check batches of parts to see whether any are out of tolerance. Operators can then adjust machine settings as necessary to ensure that they always operate within limits that prevent defective parts.

The highest leverage time for quality improvement is during process and product design. At that stage, firms can design processes to minimize variation by specifying machinery and tooling capable of very stable operation or designing component interfaces to minimize the chance of misassembly. They can also employ statistical techniques to render product designs insensitive to remaining process variations.

Synchronizing Small-Lot Manufacturing Process Flows

Some firms have improved all their manufacturing activities by synchronizing their production processes, thereby reducing costs, paring inventories, enhancing quality, and responding quickly to customer orders. The experience of successful firms suggests some recommendations for improving production processes: map processes to pinpoint work and waiting time that can be eliminated; organize equipment around families of similar components, not functional departments; reduce batch sizes; and reduce setup times.

Variability Reduction. Another essential production goal is reducing process variability. Several techniques exist: use quality improvement techniques like SPC, make work highly visible, ensure the accuracy of all information used by workers and schedulers, develop standardized work procedures and have all workers use them, institute preventive maintenance programs, balance capacity across subprocesses, standardize components and assembly sequences across models, reduce delivery time variability, and work with customers to reduce demand variability.

Production Control. All the preceding recommendations can be used with either a “push” production control system—production starts when raw materials are released to the plant’s farther upstream subprocesses and batches cascade from one subprocess to the next—or a “pull” system—an upstream subprocess does not begin production of a given batch until it receives a signal from a downstream process. In either case, reducing cycle times and their variability supports process synchronization and reduces scheduling horizons and order response times.

One approach to production control is Goldratt's Theory of Constraints, which focuses first on finding the relatively few bottleneck (constraint) subprocesses that limit the throughput capacity of an entire shop. The theory's strong points are its emphases on identifying and relieving bottlenecks and on reforming cost accounting systems to make them more relevant for managing production. On the other hand, it does not emphasize the benefits to be gained from eliminating waste and reducing variability in nonbottleneck processes or from training and empowering workers.

Flexibility. The dramatic reduction in setup times and manufacturing cycle times has allowed some firms to make production more flexible—not just making products to order, but customizing them to a degree never before feasible. Although investing in flexibility can be costly, the guidelines outlined in this section enable firms to achieve quantum increases in their ability to respond to variable demand. These measures carry relatively modest costs and set the stage for more sophisticated future investments, such as dedicated manufacturing cells for those products that make up the bulk of sales and maintaining some flexible, fast-response job shop capacity to meet for items with lower, but more variable, demand.

Shipping and Distribution

Lean production presupposes a network that links suppliers, producers, and carriers, because small quantities have to be shipped on frequent and rigid schedules. Integrated transportation and distribution systems are the concomitant of lean production, providing strategic weapons that enable firms to enhance customer service, cut distribution costs, and reduce the carrying costs of producers' inventories.

Integrated and Automated Distribution. The move toward integrated transportation and distribution has two principal features: unified distribution networks and communications among order processing, manufacturing, and distribution. Firms use electronic data interchange (EDI) to automate management reporting and rate-and-routing information, accept invoices from suppliers in standard formats and pay them electronically, and track shipment status and location. They can use EDI and comparable systems to gain control over costs and greater leverage in negotiating with carriers. They are also using warehouses, where they use them at all, more intelligently. By means of specialized hardware and software, warehouse managers can track all items and materials-handling equipment, thereby avoiding the logging, put away, and picking found in less advanced facilities.

New Carrier Relationships. As they move toward integrated distribution systems, many large shippers also reduce the number of carriers with whom they deal and strengthen relationships with those who remain. Long-term relationships with fewer, stronger carriers bring many advantages: access to specialized services and technologies, simplified communications channels, competitive rates, and lower administrative expenses. Some of these relationships have evolved into alliances involving manufacturers, carriers, and retailers that span the production-distribution spectrum. With most producers and retailers under intense competitive pressure, such alliances become strategic weapons.

Catalog of Processes: Supporting Business Practices

The “core” business processes described in the preceding section cannot stand alone. Production support systems are needed to assure more integrated information flows within the firm’s internal operations and may include a variety of “production-dependent” technologies. The management systems are important because of the need to maintain high levels of efficiency—ensuring that available resources are used most productively. Recent innovations in accounting theory and practice appear to identify the real costs of designing, manufacturing, and delivering products to consumers. Finally, new human resource policies accentuate the interdependence and control of the individual workers whose contributions determine the firm’s (or a product line’s) long-term success or failure. In addition, they seek to intensify the interdependence of the traditional functional departments.

Information Management

Although firms can use information technology to increase processing speeds and collapse the time between events and their consequences, they differ in their ability to use it in their operations. Organizations move through three stages in using information technology: (1) automate existing operations to wring paper out of the system and reduce the number of workers needed, (2) “informate” their operations to get new information as a byproduct of their activities and use it to generate leads for new products and services, and (3) use information technology to restructure the entire organization. Most organizations are still at the first stage. But automating existing processes rather than restructuring seldom changes the organization’s productivity; instead, it simply superimposes another layer on existing bureaucracies, which can usually find ways to defuse or neutralize the threat to things as they are.

Failure to link organizations and technology is behind the problems most organizations have in integrating new systems into the existing structure. Successful information system developments, like Otis Elevator's OTISLINE and Federal Express's COSMOS IIB, share certain features:

- Sponsors have a clear idea at the outset of what automated information systems can do to make the organization more productive.
- Modernizing a system offers significant benefits that justify the investment.
- Even where technological solutions are aggressive, they are well within proven technology.
- Solutions are data-driven.

For these and comparable firms, information systems are integral to their business strategies. They have shifted their attention from systems to information, from technology to the uses to which the technology can be put. At the same time, automation gives rise to two paradoxes that result from the availability of cheap, powerful technology. The first is that the more powerful the technology, the more harm it does when isolated within the organization. The other is that training becomes more necessary as technology becomes easier to use.

Management Accounting

Current accounting systems provide misleading information about internal costs of the firm, because the traditional allocation of indirect to direct product costs can lead to wrong assessments of true costs. The new accounting approach, which is an outgrowth of lean production's view of systems as integrated wholes is activity-based—virtually all costs can be broken down and then traced to groups of products and support activities. Activity-based costing makes it easier to identify expensive resources, resources whose consumption varies by product type, and resources where demand patterns do not correspond to traditional allocation measures. It also points to opportunities for increasing profits: it justifies new production systems by explaining how and why they are profitable and by quantifying their benefits. By unraveling the costs of producing an item, it enables executives to decide where to focus their investments.

Organizational Design, Human Resources, and Management

Several human resources policies support process redesign and enhance the efficiency of the redesigned processes.

Self-Managed Teams. For two reasons, teams of trained workers can manage the processes they operate. First, process improvements are specifically aimed at preventing the crises that managers in traditional organizations spend much of their time resolving. Second, recognizing the repetitive patterns in processes and setting up standard procedures to deal with the most common situations free managers from the need to make decisions whenever those situations change slightly. Their role becomes one of providing leadership and expertise in training or dealing with truly unique occurrences.

Changes in Human Resource Policies and Management Style. Self-managed teams, innovative human resource policies, and changes in management style appear to reinforce one another. Several conclusions follow from this. The first is that workers must be more broadly and systematically trained than they currently are. Another is that traditional evaluation and incentive programs that evaluate only individual performance should be modified in a team environment. Third, job security provisions are an especially important underpinning for virtually all the new management principles discussed in this report. Finally, managers and indirect staff in a team-based organization see their role as assisting workers in doing their jobs, rather than micromanaging them.

Organizational Structure Focused on Products and Processes. Hierarchical decisionmaking and coordination can impede the synchronization of processes by delaying upward and downward communications. Alternative approaches include empowering teams to make local decisions about their processes and using such horizontal communications mechanisms between teams as the *kanban* inventory control system found in Just-in-Time (JIT) factories. Firms can go even farther by structuring their organizations around products and processes, by establishing self-contained units for individual product lines. Each unit's leader has great operating autonomy but is also held accountable for the unit's performance. Within the unit, self-contained subprocesses run by self-managed teams are set up at as low a level as possible.

Firms organized around such teams can generate economies of coordination that may exceed the economies of scale derived from compartmentalizing skills in functional departments. The efficiencies deriving from synchronized process flows or from product designs optimized for manufacturability are examples of such coordinations. Nevertheless, such economies are consistent with the principle that efficiencies derive from the division of labor—by process rather than by functional skill.

Implementation Issues

Although this report relates many stories of firms that successfully adopted the new management paradigm, we have left important questions about implementation unaddressed:

- What fraction of firms has adopted the new paradigm?
- What performance benefits are to be expected from adopting it?
- What lessons can be gathered from the experience of firms that have either successfully adopted the new paradigm or tried to do so and failed.

How Extensive Is Adoption of the New Management Paradigm?

There are no rigorous, objective evaluations of the prevalence of new business practices we call the new management paradigm across the full range of firms and industries. Although researchers have used surveys and case studies to evaluate the adoption of innovative management practices, both are deficient in several respects. Surveys may be sent to a biased sample of firms, and firms that have adopted the new paradigm may be more likely to respond than firms that have not. Further, from published reports it is difficult to assess the degree of possible ambiguity or bias in the wording of questions or the analysis of data. Even a firm that has implemented a subset of the interrelated practices discussed in this report may not really have adopted a new paradigm.

Detailed cases studies are more effective than surveys for determining the depth and breadth of implementation of new practices by individual firms. Even here, the subjects of case studies usually are not chosen representatively, and implementation successes are probably reported more often than failures. On the evidence, U.S. firms in several industries seem to lag foreign competitors in implementing new business practices. More important, the rates of adoption of the new paradigm differ significantly across sectors of the economy—intensive in some industries, diffuse in many others, and scarcely begun in a few. The evidence suggests that implementation is most widespread in manufacturing and logistics-based firms, as well as financial services firms, such as banking and insurance. The extent to which other service industries adopt new business practices is less clear, either because their complex outputs are less easily defined or because they have large numbers of relatively independent workers interacting individually with clients.

What Are the Performance Benefits of Adopting the New Paradigm?

The large number of success stories cannot address this question, since failures are almost certainly less likely to be reported than successes. Even though anecdotal evidence suggests that failure rates are significant, we found no convincing, objective research in which they are estimated. And failure rates alone do not explain whether failures were caused by new practices that did not have the potential ascribed to them or by other factors external and internal to the firm.

The reception of TQM illustrates the difficulty of assessing benefits. Managers' perceptions of TQM, which vary widely, may be subjective or objective; most studies, however, concentrate on subjective measures and rarely consider TQM's impact on bottom-line performance.

Moreover, the impact of any new set of practices (including TQM) on performance is influenced by environmental factors. These may militate for or against success; thus a company like Harley-Davidson, which was committed to improving product quality and service, also depended on timely government protection from Japanese imports. Conversely, even highly efficient firms can be put at major disadvantage by currency fluctuations or subsidies from foreign competitors' home governments.

Internal factors can significantly affect the likelihood that a firm will implement new business practices. In particular, the nature of the implementation process itself is one of the most important internal success factors. Case studies of the introduction of information technology show that variables describing implementation—such as the amount of learning support the organization provided and the strengthening of the work group—were better predictors of success than those describing the technology itself or the organization in which it was inserted.

But even if a firm adopts practices that mesh with those of its suppliers and customers, it remains vulnerable to supplier and buyer disruptions. The organization is challenged to maintain its work group in the face of, for example, sudden drops in buyer orders. The first firms in an industry to reengineer themselves can often avoid layoffs by taking business from less innovative competitors. But once only reengineered firms remain, many fewer workers will be needed, unless total industry output increases significantly.

Implementation Lessons

This literature survey suggests three lessons that can be drawn from a study of new business practices. First, focus on changing what matters to customers. Implementing these practices will not work unless senior managers invest their time and resources in making them work. Given the scarcity of these resources, changes that do not affect core processes can be seen as failures, even if some short-term efficiency gains result. Firms can survey their customers, benchmark competitors' products, or adopt certain practices that are necessary just to survive in an industry—let alone create unique competitive advantage.

Second, the intervention of top management is essential for new business practices to succeed. Only top management has the authority to ensure that sufficient resources are allocated to implementation and to resolve those interdepartmental disagreements that can arise when cross-functional processes are redesigned.

Third, and related to the first two lessons, it falls to top management to choose the philosophy the organization needs to implement new processes and whether these changes should be radical and immediate or incremental and cumulative. There are many approaches to adopting the new management paradigm and texts to explain how best to incorporate it.

Yet none of these texts provides anything like a recipe for successfully implementing new business practices. The literature on which this report draws indicates clearly that transforming businesses and entire industries is lengthy and demanding and not assured of success. The incentive to change is not simply that adoption of certain practices can lead to better products and services. It is, rather, that firms losing competitiveness are more likely to risk the organizational pain that comes with adopting the paradigm. In fact, this may well be the most important conclusion to which a review of the management literature leads.

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Glossary of Organizational Improvement Philosophies

Just-in-Time (JIT)

A concept for organizing production that aims to streamline and synchronize sequential activities to minimize the waste of time and resources. Inventory is a form of waste that receives particular attention. Other key elements of JIT production are manufacturing cells, short setup times, SPC, and JIT deliveries from suppliers. First developed at Toyota Motor Co. in Japan.

Lean Production

A manufacturing system that integrates all functional activities in a firm (and its suppliers) to produce high-quality, affordable products tailored to individual customer demands. Contrasts with the variable quality and low-customization characteristic of mass production. Lean production employs JIT and TQM, as well as design teams. Term coined by the MIT International Motor Vehicle Project (IMVP).

Reengineering

The radical redesign of processes to achieve quantum leaps in performance. Information technology usually plays a large role in the process redesign. Term coined by Michael Hammer. Also known as **Process Innovation** (T. Davenport), **Business Process Redesign**, and **Core Process Redesign** (McKinsey & Co.).

Theory of Constraints (TOC)

A philosophy that aims to relieve bottlenecks (physical and organizational) that limit the output (called *throughput*) of products a firm sells to obtain revenue. Cuts through traditional cost accounting conventions that make it difficult to identify bottlenecks. Developed by Eliyahu Goldratt.

Time-Based Competition

A method that focuses on the time required to complete key processes. Redesigns processes to reduce that time, which requires quality improvements and reduces costs, and improves responsiveness to customers. Developed by the Boston Consulting Group.

Total Quality Management (TQM)

A philosophy that enlists all parts of an organization to improve the quality of products provided to customers. Emphasizes understanding of customer needs, definition of processes, and continuous, incremental improvements to those processes. A key set of process improvement tools is **Statistical Process Control (SPC)**, which uses basic statistical methods to control variation in processes and thus improve the quality of their outputs. Best known TQM proponents are W. Edwards Deming and J. M. Juran in the United States and Kaoru Ishikawa in Japan. Also known as **Total Quality Control (TQC)**.

Abbreviations

ABC	Activity-based costing
APICS	American Production and Inventory Control Society
ASQC	American Society for Quality Control
BOM	Bill of materials
CAD	Computer-aided design
CAM	Computer-aided manufacturing
CASE	Computer-aided software engineering
CEO	Chief executive officer
CONFER	Communications Network for Electronic Reinsurance
DOE	Design of Experiments
EDI	Electronic data interchange
EDS	Electronic data systems
EI	Employee involvement
FG	Finished goods
FMS	Flexible machining system
GE	General Electric
GM	General Motors
GT	Group technology
IMVP	International Motor Vehicle Project
IT	Information technology
JIT	Just-in-Time
MPS	Master production schedule
MRPII	Manufacturing Resource Planning
NMP	New management paradigm
NVA	Non-value-added
ODS	Operation Desert Shield
OODA	Observation, Orientation, Decision, Action
OPT	Optimized Production Technology
QC	Quality circle
QFD	Quality Function Deployment
QLF	Quality Loss Function
QWL	Quality of work life
R&D	Research and development
SPC	Statistical Process Control
TOC	Theory of Constraints
TQC	Total quality control

xxx

TQM	Total Quality Management
USAA	United Services Automobile Association
WIP	Work-in-progress

1. Introduction

Over the last 20 years, a series of far-reaching changes has transformed industries worldwide. Practices that originated among small Japanese automotive and electronics producers have gradually become the standard by which customers, shareholders, and analysts evaluate a firm's productivity. Using new commercial business practices, firms like Toyota, Wal-Mart, AMP, Hewlett-Packard, Xerox, and Federal Express rewrote the book on how successful businesses operate. Taken together, these practices arise from a new management paradigm that is superseding the classical system of mass production.

The new management paradigm is the antithesis of mass production. Where that system focused on internal efficiencies, sometimes at the expense of satisfying customer needs, firms that adopt new business practices actively search to identify user needs. And because user needs are diverse and constantly changing, these firms have changed their practices accordingly. First, to get new products to market quickly, they integrate marketing, research and development, engineering, design, production, and distribution. Instead of segregating these functions in divisions that seldom communicate with each other, executives at these firms insist that all of these units work together, from the design of new products to their delivery to the end user. Second, to respond quickly to shifting demand, these firms aim to combine flexibility with quality by producing small lot sizes, with minimal setup times; short setup times make rapid workload changes possible. This approach, which uses teams of multiskilled workers (and, often, flexible manufacturing equipment) to produce an enormous variety of products in different volumes with a minimum of equipment and materials, is also known as *lean production* (Womack, Jones, and Roos, 1990). As Womack notes, the production systems one finds in some Japanese and U.S. automotive and electronics companies are "lean" compared with mass production, because they require far less manufacturing space, fewer engineering hours to design new products, and less inventory on site.¹

Third, firms committed to lean production tend to work with fewer, more qualified suppliers and to involve them in every phase of production, from product development on. Working closely with fewer, more qualified suppliers

¹Womack, Jones, and Roos, 1990, p. 13.

benefits both parties. For a large assembler, using one or two qualified suppliers for a component can lead to huge savings in transaction costs and enables the buyer to tap into vendor technical expertise. For suppliers, such long-term contracts help to insulate them from marketplace uncertainties. Finally, top management delegates much greater operational responsibility to those who actually design and manufacture the product, because they are the ones who can spot problems as they arise and prevent the crises that managers in traditional organizations spend much of their time resolving.

Those firms that accept the new management paradigm have adopted an integrated set of principles and implementing practices, not discrete practices that they employ for some products but not others. Where firms have replaced mass production with lean production, they can serve a wider range of customers by supplying customized products to a larger number of smaller market segments and responding quickly to changing customer demands.

Purpose of This Report

Our purpose can be stated briefly. Basing our work on a survey of current management literature, we attempt to describe and analyze the new management paradigm sketched above. This report sets out to provide a framework for understanding a very complicated and often superficially discussed and understood subject. In so doing, we intend this report as a resource for managers within the Department of Defense faced with pressure to realize greater efficiencies with fewer resources, for civilian-agency managers faced with comparable challenges, and, more generally, for anyone interested in understanding those business practices that are shaping many manufacturing and service industries throughout the world.

We have organized our report as an intensive survey of the literature for several reasons. First, at its best this literature draws on and summarizes a vast amount of primary research, besides synthesizing the experience of numerous senior executives and managers—research far beyond the ability of any one study to replicate.² Second, a number of the works we cite go beyond describing these practices. They have, rather, shaped the context in which discussion of the new management paradigm occurs; in so doing, they have become a part of the

²In addition to numerous books and reports, this report is based on comprehensive surveys of the most recent two to five years of the following periodicals: *Academy of Management Journal*, *Academy of Management Review*, *Administrative Science Quarterly*, *Business Horizons*, *Business Week*, *The Economist*, *Forbes*, *Fortune*, *Harvard Business Review*, *The McKinsey Quarterly*, *Production & Inventory Management Journal*, *Quality Progress*, *Sloan Management Review*, and *Strategic Management Journal*.

business environment they describe and analyze. The very term "lean production" stems from the work of MIT's International Motor Vehicle Program that resulted in *The Machine That Changed the World* (Womack, Jones, and Roos, 1990), a comparative study of the Japanese and U. S. automotive industries that has relevance far beyond its ostensible subject. Third, a review of the literature reveals fruitful disagreements about the causes and effects of many of the practices discussed—disagreements that more superficial treatments ignore. Even where researchers agree that some companies have adopted lean production or the outsourcing of capabilities that are not "core" to the firm, they can still disagree about the origins and the implications of these practices.

In sum, this report is intended as much to digest as to survey an enormous and growing literature. Its primary purpose is less to describe everything written on the subject, which would be an impossible task, than to separate valuable insights and analyses about the new management paradigm from the mass of anecdotal reportage about new business practices.

We are also aware that, for all its richness, this literature has its limitations. We have found no rigorous, objective evaluations of the prevalence of the new paradigm across the full range of firms and industries. As the final section of this report explains, two popular research methods, surveys and case studies, are not well suited to answering this question, because neither is fully representative. They are more likely to report implementation successes than failures. In addition, the literature seems to be biased toward larger firms like Federal Express, Motorola, and the automotive companies, because they have the capital to reorganize, while small firms do not.

The literature also leaves open the question as to how deeply rooted these practices are, even in those industries that are most often cited. Even sincere implementation by a firm of only some of the interrelated practices discussed in this report is not equivalent to thorough adoption of a new paradigm. Especially in service industries and in the public sector, the path of adoption is difficult to project, because their complex outputs are not easily defined and because in the case of government organizations there may be no competitors for the services they provide.

Having conceded this much, we nonetheless believe that a study that integrates this literature has substantial value. In even the most conservative view, the literature provides substantial evidence that some companies in some industries have reorganized their operations in ways that dramatically improve the quality of their products, the speed with which they design and manufacture them, and the cost savings they pass on to their customers. Such improvements confer a

competitive advantage to those companies that adopt them. Once Toyota and Honda developed systems of lean production, their European and American competitors were no longer free to ignore them. To remain competitive, companies like General Motors and Ford had to develop comparable systems tailored to their customer base and product lines. Other industries, especially in retailing, electronics, capital goods, and financial services, had to undergo restructurings that were comparably difficult. This report describes what these restructurings entail and the dramatic changes in operations, product quality, and customer satisfaction that often (although not invariably) ensue.

Organization of the Report

Our review of new commercial business practices moves through a definite sequence. We go from defining the problem to outlining the principles that underlie the new paradigm. We then discuss the practices that arise from it, beginning with those that are part of the production life cycle and concluding with practices in information management, accounting, and human resources that are not limited to any one phase of that cycle. This sequence is not arbitrary, since we are not dealing with discrete practices taken in isolation. The assumptions underlying this report are that superior commercial enterprises link these practices into integrated systems and that practices and their implementation are "nested" within specific principles.

Section 2 considers the management environment that has made new business practices both possible and necessary and cites the Japanese automotive industry as exemplifying the transition from mass production to a regime of lean production. Section 3 moves from assumptions to a consideration of the two fundamental principles that drive new business practices: customer satisfaction and the organization as a system. Sections 4, 5, and 6 link principles to practice, with the first two sections considering practices that affect the product life cycle and the last reviewing major business processes, including information management, management accounting, and human resources policies that support all the commercial firm's activities. Section 7 considers some of the issues involved in implementing these practices in different commercial environments, as well as some limitations of the literature on implementation.

2. The New Management Paradigm

New Philosophy of Production

Since the mid-1970s a new approach to manufacturing and service delivery has been superseding the traditional mass production model. Whether in electronics, automobiles, specialty steels, or retailing, agile companies like Sony, Honda, Nucor, and Wal-Mart are far more responsive to the customer than more traditional firms. The essential feature of these companies is that they have devised and perfected techniques that satisfy the shifting needs of heterogeneous markets.

Satisfying customers would be easy if they were stable, inert, and monolithic, although in fact they are none of these. In the 1950s, U.S. auto companies, led by General Motors (GM), posited customers who traded up from budget to luxury cars every two or three years and were satisfied with minor annual stylistic changes to platforms that were basically fixed. The domestic steel industry was dominated by a few large vertically integrated firms that set prices and imposed their product lines on customers with few alternative sources of supply. In addition, large-scale retailing was parceled out between general-purpose department stores and discounters, each selling standardized products that changed slowly.

Whether as consumers or buyers of capital equipment, customers are now in the driver's seat. They can buy from their current suppliers or take their business elsewhere. New production systems and technology wedded to lean production enable firms that adopt the new management paradigm to speed up their rate of product innovation, divide their markets into smaller segments, and improve product quality. Competitive firms can satisfy the customer because (1) the amount of time needed to move products from design to point of sale has shrunk dramatically and (2) flexible manufacturing enables even small-scale producers to customize products like autos that were once fixed. The steel companies that once dominated their markets are now under severe pressure from minimills that use scrap metal as their raw material and specialty firms that make customized products. Customer demand is forcing firms in every business to respond to rapidly changing customer needs or go under.

For these companies, identifying one's customer base *always* involves strategic choices. One insurance company may sell primarily to military personnel, while

others sell to high-risk automobile drivers, reinsurers, or covered groups within an organization. The decision about the makeup of one's customer base is fundamental, since all other decisions about product design, suppliers, information technology, and the rest flow from this information. Because knowing the customer is essential to a firm's survival, some firms have adopted relationships that give them more information about the customer and, in turn, give the customer more information about their products. But unlike firms still wedded to traditional models of production and customer service, they have not focused only on their existing customer base. Rather, they have tried to reach all the customers that they could be serving but do not (Drucker, 1990).

Drucker's point is that firms find it easier to take their customers for granted than to face the painful, thoroughgoing restructuring that really serving them may entail. But the costs of not restructuring, as U.S. auto manufacturers learned, may be even more painful, whether measured in loss of market share, recalls of defective vehicles, or delays in bringing new models to market. These problems flowed from the companies' indifference to what their customers were telling them. What distinguishes successful firms from the others is that they do listen and respond accordingly. Indeed, they listen as closely to the customers they lose as to those they keep, because the former tell them exactly what parts of their business they need to improve (Reichheld and Sasser, 1990).

Changed Assumptions About Markets and Organizations

The mass production model was questioned first by the principles and practices developed by Japanese firms in response to the uncertain economic environment of postwar Japan. In terms of quality, price, and speed, the results eventually achieved by Japanese manufacturers went far beyond anything that companies wedded to existing production practices could match. The differences could not be explained merely by pointing to special features of Japanese society and culture; some Western firms—for example, Hewlett-Packard, AMP, 3M—successfully transferred the philosophy of lean production and continuous improvement to their own operations. These differences could not be explained by Japanese materials and technology, since Toyota and Honda used much the same as their U.S. and European rivals. The basic techniques for building a car have changed remarkably little since the turn of the century. Yet the resulting products were remarkably different, because firms like Toyota and Honda were better able than their U.S. and European competitors to differentiate among products and markets and to produce an enormous variety of products in any desired quantities. In particular, they could manufacture products on a small

scale—something that mass production systems could do only at great cost and only if demand was stable.

The new model of production represents a shift in management paradigms. The concept of a paradigm—that is, a norm that regulates theory and practice in a given area—was introduced to a nontechnical audience by Thomas Kuhn's *Structure of Scientific Revolutions*, first published in 1962.¹ This notion helps to define those features that differentiate one system of thought or practice from others. A paradigm provides the criteria for the problems the scientific community chooses to address by ordering an enormous mass of data more effectively than its rivals. The Copernican model of planetary motion explained the same data as the older Ptolemaic model, but it did so far more simply and elegantly.

Kuhn's work is relevant to the production systems described above, with the obvious difference that the system of mass production was not so much "refuted" as overtaken. On its own terms, mass production was a legitimate response to the economy it helped to create; indeed, GM ranks as the most successful company in the history of capitalism. Until the 1970s, mass production—especially as it developed in the automotive and steel industries—was extraordinarily successful, just as the Newtonian paradigm was the most successful scientific world view before Einstein incorporated it into a more comprehensive system. By the mid-1920s, GM, under chairman Alfred Sloan, had solved all the major organizational and managerial problems that instituting mass production entailed. Sloan's achievement rested on product diversification and standardization, and the decentralization of worldwide operations. GM's five-model product range accommodated buyers at every income level. Further, GM used dedicated production tools to produce standardized mechanical items that were common to all its product lines. Once it decentralized operations that were managed "by the numbers," GM could treat its domestic and foreign subsidiaries as free-standing enterprises that required very little direct supervision (Womack, Jones, and Roos, 1990).

Like a scientific theory, the mass production paradigm made specific assumptions about the nature of customers, the products they bought and the means for producing them, and the qualities that one desired in production workers. Whether in autos, metals, or nondurable consumer goods, customers could choose from a few basic product lines that were manufactured in long

¹Several other authors have also referred to the management practice and organizational structure changes described in this report in terms of a paradigm shift. They include Hill (1992), Dichter (1991), Schonberger (1990), Boyer (1991), Byrne (1992), Stewart (1993), and Barker (1992).

production runs. So long as these assumptions “worked,” they were not challenged. Kuhn notes that “as in manufacturing so in science—retooling is an extravagance to be reserved for the occasion that demands it. The significance of crises is the indication that an occasion for retooling has arrived” (Kuhn, 1970).

Table 2.1 contrasts the assumptions about markets, organizations, and workers characteristic of the classical, hierarchical organizational model with those of the new management paradigm.

The left-hand column embodies the assumptions found in the great classical theories of organizations as rational systems—theories that could equally explain the workings of industrial organizations and government bureaucracies. In fact, bureaucracy and mass production emerged at the same time and are being rejected at the same time. From F. W. Taylor and Max Weber early in this century (Bendix, 1960; Chandler, 1977) to the monumental study of organizations by March and Simon in the late 1950s (March and Simon, 1958), most theorists viewed organizations as systems for achieving relatively specific, stable goals. Although organizations served many secondary ends, their main purpose was to address problems by reducing the immense number of possibilities that no one person could explore to a few clear-cut alternatives (Bower, 1968).

Weber’s theory of bureaucracy was the clearest possible description of the “rational-legal” systems that dominated every aspect of life (Scott, 1987). According to Weber, bureaucracies shared these features:

- a fixed division of labor among participants
- a hierarchy of offices
- formal rules that govern performance

Table 2.1
Two Paradigms of Organizational Behavior

Organization as a Hierarchical System	New Management Paradigm
Stable environment	Unstable environment
Trade-offs among quality, cost, and speed	Simultaneous improvement in quality, cost, and speed
Optimizing individual departments	System optimization
Acceptable quality	Statistical process control
Inspection and rework	Quality through process improvement
Buffer system imperfections	Stress system to failure and improve it
Hierarchical coordination and communication	Horizontal coordination and communication
People viewed as variable costs	People viewed as assets
Owner/worker conflict	Owner/worker cooperation

- the separation of office from personal property
- selection of personnel on the basis of technical merit
- office viewed as a career by participants.

Bureaucracies the size of GM, the military services, and the Internal Revenue Service exemplified all these features. GM had divisions at every level: between salaried and hourly workers, between functional (accounting, strategic planning) and production divisions, and within production, between styling, manufacturing, and dealer relations. For each activity and at each division, there were detailed rules and procedures to be followed, leaving those involved just enough discretion to apply them to the organization's ends (Drucker, 1972). Many of these rules remained in place long after their reasons for being disappeared.

Large governmental organizations, like the Air Force and the Internal Revenue Service, were structured along similar lines. In both agencies, a body of extremely detailed regulations and policy documents could (at least in theory) generate preformed rules that covered most operations. For example, government- and agency-wide rules specified in minute detail how competitive procurements for products and services were to be structured, the criteria for evaluating bids and proposals, and the arrangements for administering contracts. All of these rules led to a system that was, in certain respects, more equitable than what it replaced but at considerable cost in the speed with which bidders were qualified and contracts awarded (Kelman, 1990).

One flaw in this and related models of the organization as hierarchical system is that they could not account well for change. In particular, Simon's theory of administrative behavior tends to treat the organization as a closed system on which the external environment scarcely impinges. The result is a static, ahistorical model in which senior executives make rational decisions based on clear-cut alternatives. In such a world, executives do not seek optimal results. Instead, they "satisfice," that is, they make do with results that are "good enough." Simon and March note that "most human decisionmaking, whether individual or organizational, is concerned with the discovery and selection of satisfactory alternatives; only in exceptional cases is it concerned with the discovery and selection of optimal alternatives" (March and Simon, 1958). Such models accept change only at the margins.

Writing in the early 1960s, Simon asserted that decisionmaking would become centralized, although the lines of demarcation among purchasing, manufacturing, engineering, and sales would probably fade as a result of

automation. Automation would replace rather than supplement semiskilled labor, while the workplace would become even more rational and impersonal. More than in the past, managers would deal with "a well-structured system whose problems have to be diagnosed and corrected objectively and analytically, and less with unpredictable and sometimes recalcitrant people who have to be persuaded, prodded, rewarded, and cajoled" (Simon, 1965). Such managers could "optimize" within the existing organization, because they understood the full range of options and outcomes within their environment.

The new management paradigm, as displayed in the right-hand column, questions all these assumptions. The environment in which firms now operate is neither stable nor certain. Because quality, cost, and speed interact, they try to improve all simultaneously; firms wedded to the new paradigm do not have to trade off better quality against higher cost and longer production schedules. Rather than optimizing a particular department or function, and thereby creating bottlenecks in less optimal departments and functions, these firms optimize all sectors because they must all work together to the desired end.

Continuous improvement represents an even greater departure from the mass production model. Although mass production techniques certainly had their successes—their "home runs"—they failed to produce consistently robust quality across product lines. New products tended to compete on price and styling, rather than on product quality. Instead of looking for isolated successes among generally mediocre products, the new commercial enterprise is committed to a host of small, cumulative changes: reducing defects, errors, and waste; increasing production yields; compressing delivery times; and continuously training all employees in techniques for improving quality. Improvement has to be continuous for two reasons: no single effort can lead to superior products, and an organization that is not improving continuously is moving backwards.

The new system also involves close relations with fewer, but better, suppliers. Under the old model, GM bought as much as two-thirds of its parts from captive in-house suppliers; the remainder came from outside suppliers who normally competed on price and were not assured of long-term contracts. Japanese auto manufacturers, in particular, did away with this approach. Instead of captive internal suppliers, companies like Toyota and Honda developed long-term relationships with smaller numbers of carefully chosen external suppliers—usually two for every part. Toyota and Honda executives believed that by using such vendors, they could lower their own production costs, avoid creating units that depended on them for continuing support, and tap the expertise and technology of outside suppliers. In contrast to American auto assemblers,

Japanese firms also involved their suppliers in the early design phases, rather than turning to them after the design was frozen.

Creating systems based on lean production and continuous improvement required restructuring the producer organization. As noted, the classical model of hierarchical decisionmaking worked in a steady-state environment, where organizations could adapt to gradual changes. Organizations that accommodate frequent structural changes as inevitable have to use a different approach. A top-down approach will not work, because senior executives cannot anticipate today what they will know only tomorrow. They must rely on the organizational units closer to the customer and the technology. To design, assemble, and sell products as complex as automobiles, they must coordinate the activities of those working at similar organizational levels, whether in research, design, production, marketing, or sales. In a system that requires workers to take the initiative, executives treat their employees as assets, not variable costs. They stress continuous training because workers must understand both the system and the roles they play in it. When workers can stop a production line at any time, they must know precisely when and why they can do so. The system demands cooperation between workers and owners, because both share the risks in running it.

Conclusion

Although it responded to specific local conditions, the production system that originated in Japan in the 1950s could be adapted to many environments. Once this integrated approach to product design, manufacturing, and distribution spread beyond Japan, few industries remained untouched. Competitors elsewhere began to notice changes that were not temporary, that required a fundamental rethinking of their operations, and that could not be reversed simply by cutting their own production costs. In many industries, once one firm introduced a system of lean production, other firms had to adopt it to survive.

But many larger firms, above all in the U.S. automotive industry, have found the changes required of them were so drastic that only a dramatic loss of market share could persuade them to make the effort. For GM, Ford, and Chrysler, moving from mass production to lean production entailed enormous pain. It required them to close many plants; develop altogether different kinds of relations with suppliers and dealers; consolidate the platforms around which cars are built; bring research centers, designers, and engineers closer; and train workers to understand the new production system that—if they were fortunate—would employ them. Their incentive to persevere was that if they did not move

to a new production system, they would fall even further behind, making products fewer people wanted. But before they could adopt this new system, they had to understand its basic principles. This subject is discussed in Section 3.

3. Fundamental Principles

Although the routes by which companies arrive at the new management paradigm vary greatly, the underlying principles of their operations are remarkably uniform and simple. All the management practices discussed in this report rest on two principles: (1) that customer satisfaction is central to the survival and prosperity of the firm and (2) that the firm is a system of interdependent processes that produces the products and services that customers purchase. But although these principles are easy to state, they are not easy to implement. Understanding who customers are and what they want is a never-ending task, while linking all the processes in a large organization may entail drastic changes that leave nothing untouched. This section discusses both principles, draws out their implications, and lays the groundwork for the more detailed analysis of specific practices contained in the following sections.

Satisfying the Customer

The goal of a profit-making enterprise is to survive. To do that, it needs to attract capital from those sources that have it: customers, shareholders, and banks.¹ If the first one dries up, so will the other two. This is why customer satisfaction is the corporation's goal and achieving it its greatest challenge.

It is essential, yet difficult, for an enterprise to determine what its customers need and want. It is essential because its survival depends on it. It is difficult because one *never* knows one's customer completely. There is always room to learn more and to improve a firm's understanding of its customers, because only they know what they want. An interesting tension runs through supplier-customer relations. If the customer wants something I do not produce, is he or she still a customer? Faced with that situation, a producer has a choice: produce it or eliminate the customer. Alternatively, producers can use their existing customer base to add value to their products by customizing them. Auto customizing, as found in Japan, only carries to extremes something found in the manufacture of printed circuit boards, application-specific circuitry, and specialty chemicals and steels (*Business Week*, 1991).

¹Note, however, that capital is only a *necessary*, but not a sufficient, condition for business success. Many firms fail, despite having considerable capital.

To identify their customers, firms develop service strategies that allow them to segment the markets to be served and research their customers.² It should be noted that these customers include not only end users but regulators concerned with safety, retailers concerned with displaying the product, vendors preoccupied with manufacturing product components, other units of the firm that use the product as input to their own operations, the mechanics who will service the latest production model (Main, 1992), and even (or perhaps especially) the worker doing the next step of a process on the production line.³ Thus, the job of the producer must be to strike an appropriate balance among all its customers—external and internal.

A customer-oriented enterprise tries to find out what really matters to its customers. This can be speedy delivery of expensive parts, defect-free products, or customizing a part for a specific application—or more likely, all of the above. At the same time, it will set quantitative performance standards to measure its own and its customers' expectations: for example, six sigma error rates (no more than three defects per million parts), package delivery by 10 a.m., or delivery of spare parts and service anywhere in the world within 24 hours.

In setting and publicizing such goals, the organization commits itself to satisfying the customer, even if the entire organization has to be revamped to meet the standard.⁴ Lean production companies make greater efforts to retain long-term customers because they generate greater profits than short-term customers do and because a customer who buys one product or service can be persuaded to buy others (Reichheld and Sasser, 1990). Long-term customers require less selling effort and provide referrals to other potential customers. They can be sold products with more value added (e.g., entire assemblies instead of just components), because the provider gains greater knowledge of their needs and can suggest enhanced products. Moreover, many of the things needed to attract them, like advertising and credit checking, need be done only once. It

²Electronic technology enables many firms to get information on their customers virtually in real time. Firms can use proprietary databases and point-of-sale tracking to find out what items are moving through the system, what needs to be back ordered, and how the volume of transactions (for example, at a bank's automated teller machines) changes over time. But there are other, equally effective means to determine and modify customer demand. By charging the full cost of operations to their internal customers, a corporate information manager can find out what his or her customers are prepared to pay for a given service.

³One justification for cellular manufacturing is that workers in repair cells get more immediate feedback on the quality of their work, because their "customer" is the worker doing the next step (Glass and Schwartz, 1988).

⁴The practices associated with satisfying the customer, not the goal itself, represent something new. General Motors, IBM, and Sears got in trouble not because they were indifferent to customer needs but because they did not develop practices to identify or respond to those needs as quickly and effectively as the new competitors who adopted lean production practices. These companies could accommodate their existing customer base only to the extent that it required no major restructuring of their existing organizations.

makes sense to invest in these customers rather than in those who may be here today and gone tomorrow; if certain types of customers do not stay long enough to become profitable, the company's investment is wasted. Commercial companies can virtually double profits by retaining only 5 percent more of their customers (Reichheld and Sasser, 1990).

Thus, successful companies adopting the new management paradigm do not merely respond to customer demands. They try to anticipate them. Indeed, the process of determining customer needs is a continuous-loop process; the more one knows about what their customers want *now*, the better positioned one is to develop new products and services for them. Given the ability of many enterprises to bring new products speedily to market, a firm that waits for demand to make itself known is already out of the game.

Satisfying demand is complex because, among other reasons, the visible product is only a fraction of what there is. Any new car model has thousands of refinements that, while inconspicuous, add up to total performance. Quality Function Deployment provides a way to assess and trade off design options against customer desires and needs. Design engineers can break a single feature like a car door into from 30 to more than 100 attributes: that it opens and closes easily, does not leak, looks attractive, and so on. Because not all preferences are equally important, it falls to these engineers to make the necessary, often difficult, trade-offs (Hauser and Clausing, 1988). But whatever the case, a company's products should all be susceptible to improvement and to having those improvements (if not the discrete changes that underlie them) explained to the customer (Chakravarty, 1991).

Satisfying the customer also involves ensuring that production and distribution are fully integrated. Whether they manufacture components or end products, most mass production style producers find that they have to work through distributors or retailers rather than directly with their customers. For example, Japanese auto companies have developed a "produce-to-order" system that offers customers products tailored to their needs. So there is no need for the huge dealer inventories, sales pressure, and rebates that prevail here.⁵

⁵Owing to the distance between Japanese plants and U.S. auto markets, those same firms have had to accept the U.S. dealership system, even as many U.S. dealers complain about the adversarial relations between themselves and the manufacturers. Evidence, however, shows that Japanese companies intend to make lean selling the final stage in the entire production system and develop a top-to-bottom manufacturing system in North America in the 1990s (Womack, Jones, and Roos, 1990). With cars built to order for speedy delivery, the Japanese will have a totally integrated system for design, manufacture, and distribution in place.

Because satisfying the customer is so demanding, the entire organization must be oriented to achieving that end. The close coupling of production and distribution processes helps lean production firms satisfy customer needs more quickly and relevantly than their mass production competitors. Management commitment, the insertion of advanced technology, the use of new accounting methodologies—all are means to that single end. The following subsection explains what the close coupling of business processes means, why it matters, and why the firm that accepts the new business paradigm can aim for nothing less.

The Firm as a System of Interlinked Processes

A firm that adopts the new management paradigm fundamentally redesigns itself around the goal of customer satisfaction. It eschews selective “magic bullet” solutions like technological fixes or concessions from workers, suppliers, and government authorities. Instead, it first defines and understands the fundamental *processes* that design, produce, and supply its products, and how they combine into an overall system. Then, it redesigns and continuously improves those processes to maximize customer satisfaction on all relevant criteria. This section describes the major types of processes and the principles that guide their improvement.

What Are Processes?

A process is an activity that transforms inputs into outputs, has definable interactions with other processes, and has measurable performance parameters. Major processes can be divided into subprocesses, which have parallel or sequential relationships to each other; many of these subprocesses may be carried out by suppliers. Users of a subprocess’s outputs are internal customers, whose needs can be understood and satisfied as rigorously as those of external customers. Similarly, providers of a process’s inputs are internal suppliers.

Types of Processes. Most processes can be conveniently grouped into three major categories.⁶ Manufacturing processes⁷ carry out transformations on physical objects. Distribution processes⁸ accomplish the transportation and

⁶Project-oriented activities, such as new product development, can also be treated as processes but are discussed separately in Section 4.

⁷Remanufacturing processes, such as the repair and overhaul of high-value reparable components like aircraft jet engines, are included in this category.

⁸The commercial literature often uses the term “logistics” processes to refer to these activities. We use the term “distribution” processes because “military logistics” covers such broad areas as

storage of objects. Business processes⁹ act on information in paper, electronic, or spoken form.

An illustrative manufacturing process (Figure 3.1) is the automobile assembly line (Womack, Jones, and Roos, 1990; Markillie, 1992). Some key measures of its performance are number of cars produced per hour, assembly hours per car, and defects per car. It consists of sequential subprocesses such as body fabrication, powertrain installation, and interior installation. In the body fabrication subprocess, people, presses, and welding and painting equipment convert sheet steel into car bodies; relevant performance measures might include cycle time to complete the subprocess, paint quality, percentage of defective welds, and unit cost. And this subprocess in turn is made up of subprocesses: sheet straightening, blanking, stamping, assembly, welding, and painting. Other manufacturing processes proceed in parallel with the assembly line and feed inputs to it at certain points. Engine production is such a process; so is making tires, even though it is usually done by a supplier.

Examples of distribution processes are incoming transportation from suppliers, inventory management, and outbound shipment to customers. The incoming transportation process, for example, may have components from suppliers, trucks, drivers, and scheduling information as inputs and supply its outputs to a manufacturing process. Performance measures might include transportation time, cost per item transported, and total pipeline inventory.

Business processes encompass a wide variety of activities, including accounting and finance, human resources, planning and resource allocation, and administrative aspects of manufacturing and distribution processes, such as processing and scheduling customer orders.¹⁰ For example, some accounting processes receive data from many other processes in the firm and then produce reports for internal and external customers. Appropriate performance measures might be time and cost to generate reports, and how useful those reports are to recipients. Firms may subcontract other accounting processes, such as payroll, to specialized suppliers.

purchasing (but not system acquisition), remanufacturing, transportation, warehousing, and the associated business processes.

⁹The commercial literature sometimes uses the term "business" processes to cover virtually all a firm's activities. We use the term in the narrower sense described in this section.

¹⁰Marketing and sales can be analyzed as business processes that not only transmit information from external customers to other processes, but also give external customers information about products, prices, delivery status, etc.

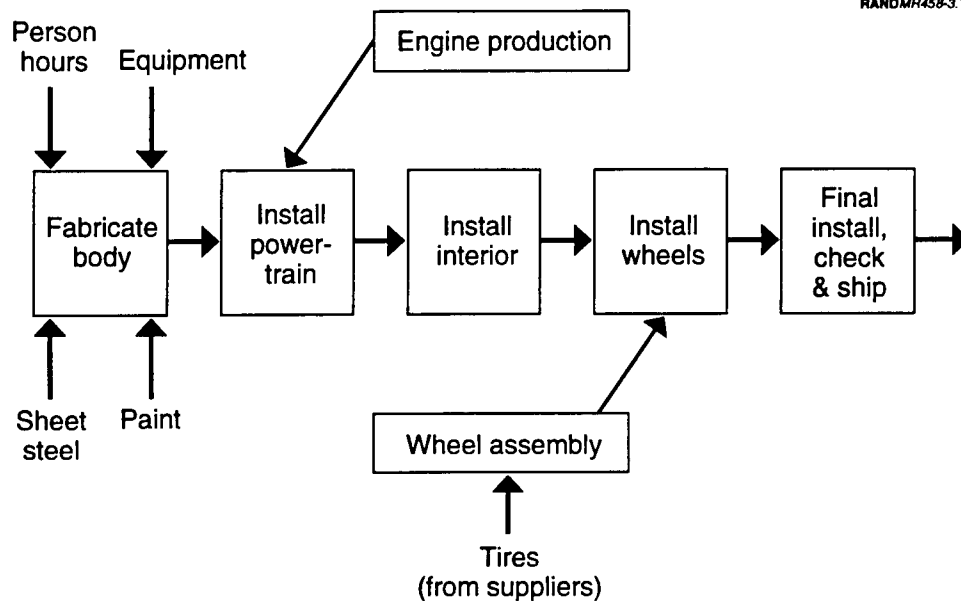


Figure 3.1—Automobile Assembly Process

Processes are not the same as traditional functional departments. But while the continuous flow of an assembly line makes its process nature apparent, processes fragmented across different departments are very often difficult to discern. In manufacturing, for example, a component may make several trips between different manufacturing departments as it progresses through its fabrication sequence. Multiple handoffs of products between storage areas, shippers, and distributors are common in distribution processes. Business processes that require the handling of one package of paperwork or information by multiple departments are probably all too familiar to the reader.

Linkages Between Processes. Even though processes are focused on the objects or information that flows through them, tight linkages between processes are key to the firm's overall performance in satisfying customers. For example, marketing and design processes work closely together to create designs that meet customer needs, the design process optimizes the manufacturability of that design, and purchasing and transportation processes ensure that manufacturing processes receive high-quality components on schedule.

Linkages are especially tight within the sequence of processes that constitute the firm's critical path for filling customer orders (Stalk and Hout, 1990; Shapiro et al., 1992). The total cycle time through this series of processes determines the order response time, i.e., the time customers must wait to have orders filled after placing them. A manufacturing firm's critical path may be through business

processes that gather customer orders and schedule production, then manufacturing processes, and finally distribution processes that transport the finished product to the customer.¹¹ In a service firm, one critical path may start with the submittal of a customer claim or application and continue through a sequence of checking, analysis, and approval subprocesses until eventual approval or rejection.

Synchronized Small-Lot Process Flows

Fragmentation of processes across departments lengthens cycle times beyond the minimum time needed to accomplish all of a process's value-added tasks. A common rule of thumb (the "95/5 rule") is that products, information, or paperwork spend only 5 percent (or less) of their total process cycle time having value added and the rest just sitting and waiting or being unnecessarily moved around (Stalk and Hout, 1990).¹²

Customer satisfaction criteria—speed, price, and quality—all suffer in this environment. Customers must wait through long critical path cycle times, or else manufacturers or distributors must carry large finished goods (FG) inventories to fill orders from stock.¹³ Large batch sizes and long total cycle times mean high work-in-progress (WIP) inventory as well. Financing, storing, tracking, handling, and accounting for these large inventories are costly. Quality suffers, even in business processes, because finding the cause of defects discovered during inspection of a batch produced days or weeks ago may be impossible.

Managing such fragmented processes is difficult, costly, and almost unavoidably inefficient. It requires much valuable managerial time, complex information systems, and staffs of accountants, schedulers, planners, and expeditors. Long critical path cycle times, as well as business processes that are slow in returning sales data to planners and schedulers, imply long forecast horizons. The inherent uncertainty of long-range forecasts means production plans based on them may be out of line with actual realized demand.

¹¹For a manufacturer, distributor, or retailer who fills customer orders from stock, the cycle time from an order to replenish stock to actual replenishment can become critical.

¹²Large batch sizes exacerbate this stretching of cycle times. In manufacturing processes, for example, a component must wait in front of a given operation until batches in front of it are finished, and then again while all other parts in its batch are being completed. Delays in distribution processes result from, say, holding components in storage until a full truckload is gathered. Batching is harder to see in business processes but nevertheless creates delays, as when a batch of orders is sent from sales to a warehouse only once per week.

¹³Even then, stockouts may occur on unexpectedly popular items and excess inventory of slow-selling ones.

Firms that address these problems by synchronizing flows (i.e., reducing the 95-percent waiting time) and decreasing batch sizes in their manufacturing, distribution, and business processes can achieve *simultaneous* improvements on the major dimensions of customer satisfaction—cost, quality, and speed (Schonberger, 1990). Critical path cycle times are sometimes shortened enough that a firm can make to order rather than to stock and thus cut FG inventories (Bower and Hout, 1988). Shortened cycle times and smaller batch sizes allow WIP inventory to be reduced as well. Information about defectives is rapidly fed back to the process that produced them, so that corrective action can be taken before large numbers of defectives are produced. Most of the indirect staff effort formerly required to manage process complexity and large inventories can be redirected or eliminated, resulting in significant overhead cost savings (Miller and Vollmann, 1985).¹⁴ And short cycle times allow shorter-term, more accurate forecasting and faster response to changes in demand level and demand mix.

Process Definition and Analysis. Defining and analyzing processes are the first step toward achieving synchronized small-lot process flows. The analysis tools used are deceptively simple: drawing flow charts of how products, paperwork, or information progresses through the steps of a process; measuring process cycle times; and pinpointing bottlenecks.

Because these process analysis tools focus on the *flow* of objects or information, rather than the *structure* of existing departments (Rummler and Brache, 1991), they can reveal how process fragmentation leads to lengthened cycle times, inefficiencies, and quality problems. One such source of performance degradation is suboptimization, where a department pursues narrow goals at the expense of overall process performance. For example, a transportation department may delay delivery of critical components to a manufacturing department until a full truckload is accumulated. A process analysis could quantify how this transportation policy imposes inefficiencies on the overall production system that far outweigh the transportation cost savings.

Overly strong departmental boundaries also foster an “over-the-wall” attitude, where departments give little consideration to the impact of their actions on downstream departments. Process analyses that explicitly define interactions between departments can strengthen the role of customer satisfaction criteria in departmental decisionmaking, bring essential information into focus so it can be efficiently communicated between departments, and, where applicable, foster the

¹⁴The impact of indirect cost reduction is highlighted by the fact that direct labor costs now account for 10 percent or less of the cost of most products (Berliner and Brimson, 1988).

smooth handoff of information and physical objects from one department to another.

Process analyses aim to uncover sources of waste, i.e., any effort or activity that can be eliminated during process redesign without affecting customer satisfaction (e.g., handing products or information back and forth between departments multiple times, requiring multiple approvals of minor decisions, maintaining excessive inventories within or between processes, producing reports no one reads, or producing defective items or information). These sorts of waste are also known as non-value-added (NVA) effort.

Worker participation in process definition and analysis is essential for several reasons. First, much of the detailed knowledge about how tasks are actually performed resides inside the heads of the operators of a process—it is not fully captured in the drawings, manuals, or procedures developed by managers and engineers. Second, process analyses benefit from having many people look at the same issue, not just an analyst or decisionmaker. Finally, workers who participate in process analyses are more likely to “buy in” to the changes eventually made to those processes.

Process Redesign. The results of process analyses are inputs to the redesign of those processes and to other changes necessary to support their smooth functioning. Instead of focusing exclusively on improving the efficiency of value-added tasks (the 5 percent), process redesign efforts also focus on eliminating the waiting time and NVA effort (the 95 percent) that hinder the smooth flow of processes. As a result, while at first many individual tasks may not change much in the redesigned process, machines may be rearranged, offices relocated, transportation routings modified, and mechanisms for controlling the flow of work revised. Longer-term changes in technology, information systems, and product designs can then be designed and implemented to serve the needs of the streamlined process.

A common type of manufacturing process redesign is transforming a factory to a cellular layout. In a traditional functional layout, components move back and forth in large batches from one department to another, spending much of their time being transported or sitting and waiting for batches in front of them to be finished. By contrast, a manufacturing cell contains all machines necessary to fabricate a certain type of component, and workers are crosstrained to operate all machines in their cell. Shortening setup times and reducing batch sizes allow a synchronized flow through the cell, which yields short cycle times, rapid feedback for quality control, and flexibility to respond to a variable demand mix.

Such cells can support a flexible assembly line, where different models alternate one after the other, rather than in large batches.¹⁵ Overall, products can then be tailored to customer orders in a much shorter time than before, sometimes enabling the firm to build to order rather than to stock.¹⁶

Distribution processes can also be redesigned to achieve synchronized flows. For example, a truck delivering components to a factory could pick up partial loads once a day from each of several suppliers, rather than a full load from each supplier once a week (Suzaki, 1987). Inside warehouses, dedicating areas to particular products minimizes handling and interdepartmental transfers. Deliveries and pickups can then be tightly scheduled to minimize the time a product being transshipped actually spends in the warehouse (Drucker, 1992a).

Some business process changes can be fairly simple, such as establishing explicit communications channels between departments or modifying forms to prevent common data entry errors. A more fundamental type of redesign, analogous to rearranging machines into cells, is to set up a team to perform a process previously spread over several departments. This eliminates inbox waiting between departments, and unusual issues or errors can be resolved immediately. The team can gather data to understand repetitive aspects of its tasks and then develop standard procedures to prevent errors or eliminate NVA tasks. Crosstraining prevents one person's absence from holding up the whole process. Going even further, the whole process could be redesigned so that one multiskilled person (a case manager) could perform all its steps, perhaps drawing on functional expertise to handle unique cases.

Reengineering. Radical or fundamental process redesigns, such as moving from a traditional multidepartment clerical process to a case manager system or eliminating regional warehouses in favor of rapid distribution from a single distribution center, are often referred to as *reengineering* (Davenport and Short, 1990; Hammer, 1990; Davenport, 1993b; Hammer and Champy, 1993). A well-known example is the redesign of Ford's accounts payable process, where most work was reconciling largely preventable discrepancies between purchase orders, shipping documents, and invoices. Instead of merely streamlining the flow of existing documents and redesigning procedures to prevent errors, Ford

¹⁵The redesign of manufacturing processes is discussed in detail in Section 5.

¹⁶Synchronized small-lot manufacturing is also effective in a job-shop environment, where reduced order response times, high-quality, and low-cost customization can confer a competitive advantage (Hall, 1987; Ashton and Cook, 1989; Stalk and Hout, 1990). Manufacturing cells can be set up around families of similar components, and basic designs and subcomponents standardized.

Redesigning processes for synchronized small-lot flows has also proven effective in repair and remanufacturing environments, for example, aircraft overhaul and jet engine maintenance (Glass and Schwartz, 1988; Taylor, Layton, and Taylor, 1992; Stewart, 1993).

developed a new information and communications system that replaced documents with electronic ordering, receiving, and payment transactions.

Because reengineering efforts often entail significant organizational modifications and expenditures of resources, they are often carried out by a small team of experienced people, working closely with senior management. Another reason for this type team (in contrast with the lower-level teams that can make less radical process changes) is that reengineering can greatly decrease the number of people required to perform a given process. Ford's accounts payable reengineering, for example, reduced the staff in that department by 75 percent.¹⁷

Benchmarking. An important part of process redesign is *benchmarking* against similar processes, both within and outside a firm's own industry (Camp, 1989). Benchmarking against competitors establishes the standards that process redesign efforts should aim to achieve (Sherman, 1993). For example, if a firm takes 60 days to fill customer orders while competitors can fill orders for comparable products in 30 days, a process redesign would strive for a 50-percent reduction in order fulfillment time. But while overall performance information on competitors may be relatively easy to obtain, many firms will not allow competitors to study the details of how their processes operate. Benchmarking of similar processes in other industries not only gets around that problem, but provides the opportunity to get fresh ideas that may lead to an advantage over competitors. For example, Xerox significantly improved its warehouse order picking processes by benchmarking similar processes at retailer L.L. Bean (Tucker, Zivan, and Camp, 1987).

Implications for Organizational Design and Management. Reaping the full benefits of process redesign may require profound organizational changes, so that cumbersome management structures do not vitiate improvements like faster response to customers, rapid feedback for quality control, and elimination of NVA work. In particular, teams of workers may be trained and empowered to manage the processes they helped redesign and the firm's overall organization restructured to emphasize major processes rather than functional departments. Top management support is essential for initiating and guiding such major changes.¹⁸

¹⁷Of course, business processes that exist mostly to manage complexity in manufacturing or distribution processes, such as inventory control, can be downsized dramatically just because the processes they support are redesigned (Blaxill and Hout, 1991).

¹⁸These organizational, management, and human resource changes are discussed in detail in Section 6.

Elimination of Slack. Activities in synchronized small-lot process flows are very tightly sequenced, and yet these processes intentionally operate with minimal slack to buffer against disruptions like machine breakdowns, defective components, or mistaken data (Womack, Jones, and Roos, 1990; MacDuffie and Krafcik, 1992). In fact, slack such as WIP inventory is deliberately taken out of the system *to make clear where process improvements are needed*. Managers do not blame workers or suppliers for problems that show up when the system is stressed like this but instead work with them to find and eliminate the causes of problems that could hinder the synchronized flow.

Maintaining process performance while minimizing slack, therefore, requires a high degree of trust and cooperation among managers, workers, and suppliers. Firms help suppliers improve their processes and integrate them more closely with the firm's own. Managers equip workers with the skills, information, authority, equipment, and expert support they need to carry out their job tasks flawlessly. And workers are kept alert by the knowledge that mistakes can quickly disrupt the entire process.

Quality Improvement

Firms that pursue quality mostly through inspection and rework see higher quality as something that costs money. However, the overall costs of poor quality (including scrapped items, inspection and rework costs, and warranty repairs, as well as downtime for interrupted processes) are estimated to be as high as 30 percent of total production costs (Juran, 1962; Garvin, 1984; Carr, 1992). And reliance mostly on inspection inevitably allows occasional out-of-specification components, inaccurate information, or deliveries of wrong items, any of which can disrupt synchronized processes.

Improving processes to *prevent* defects, rather than reworking or scrapping items found to be defective during inspections, is therefore highly cost-effective. (An influential management book even bears the title *Quality Is Free* [Crosby, 1979].) Both rework and final inspection can practically be eliminated, cutting costs and process cycle times. The time and resources formerly put into making scrapped items and managing around defects are freed up, yielding a virtually free increase in production capacity. In addition, defect prevention makes products much less likely to fail in the field, which reduces warranty costs and increases sales by enhancing the firm's quality reputation (Deming, 1986).

Pursuit of quality through improved processes is not limited only to manufacturing. Poor quality in business processes (e.g., surly customer service, mistaken data entries, or lost paperwork) is costly to inspect for and correct and

can alienate customers. Poor quality in distribution, such as late or lost shipments, can immediately impact customers as well as require considerable effort to correct. McKesson, a drug distributor, estimates that an incorrectly filled order costs the firm seven times more than a correct one (Magnet, 1992b).

The basic defect prevention technique, Statistical Process Control (SPC), statistically analyzes process performance measures to determine the underlying causes of defects. These causes are then eliminated, for example, by modifying procedures or work sequences, establishing strict standards for data consistency, or modifying equipment or tooling.¹⁹

A phenomenon known as the Pareto Principle (or "80/20 rule") gives high leverage to such process improvement efforts. This rule of thumb states that 80 percent of the problems with a given process are usually caused by only 20 percent of the root causes. Simple statistical analyses, therefore, help improvement efforts target the "vital few" areas for change and not get bogged down in the "trivial many" (Juran, 1962). A small number of changes can thus lead to greatly improved process performance.

In the long run, redesigning products and processes offers high leverage for quality improvement. Aspects of product assembly or tooling design that contribute to manufacturing defects can often be corrected only with new designs of products or manufacturing facilities. Similarly, steps like modifying information systems to preclude the occurrence of common errors may be feasible only in the context of a process reengineering effort.

Continuous Improvement

Firms that synchronize processes and prevent defects and problems can continue to make incremental process improvements²⁰ that will maintain or enhance their competitive position. Managers and workers can spend a larger fraction of their time anticipating problems, preventing more subtle defects, and further improving efficiency rather than just reacting to events (Sirkin and Stalk, 1990).²¹ They can also work more closely with customers or participate in new product development efforts.

Continuous improvement directly contradicts the traditional principle "If it ain't broke, don't fix it." It means always refining processes to approach nominal

¹⁹SPC and other process improvement tools are discussed in Section 5 and the appendix.

²⁰Often referred to by the Japanese word *kaizen*.

²¹Planned, progressive slack elimination to pinpoint problems is tied very closely to such continuous improvement efforts.

requirements, using ever finer scales of measurement, not just maintaining acceptable standards (Yoshida, 1989; Melcher et al., 1990). This approach keeps managers and workers from lapsing into complacency or backsliding to poorer performance. Continuous improvement also recognizes that improvement ideas build on each other, for example, when improvements to the outputs from one process then make it possible to improve downstream processes as well.

This cycle of continuing improvement of processes has powerful competitive consequences. In some industries, continuous improvement is necessary just to keep pace with rising customer expectations. For example, although U.S. automobile makers have approached their Japanese competitors' performance on the number of defects per car, the Japanese firms have continued to raise customer expectations in styling, technical innovations, and the sensory nuances of their cars (Reibstein and Washington, 1992).

The cumulative benefits of continuous incremental improvements can be dramatic; firms that neglect them in the search for "home run" innovations can be overtaken by competitors. Xerox became complacent about its manufacturing and product development processes because of the huge competitive lead it built on its invention of xerography. In the late 1970s, it was shocked to find that its Japanese competitors, while not changing fundamental copier technology, had learned how to produce copiers for one-third less than Xerox and could design a new model in half the time, with a staff half as large (Kearns and Nadler, 1992).

The long-run challenge for firms is how to achieve both continuous incremental improvements *and* the step-function improvements that come from designing new products and facilities and reengineering processes (Mansir and Schacht, 1989; Hsieh, 1992; Davenport, 1993b). Organizationally, it means periodically carrying out bold, strategic reengineering efforts while still nurturing steady, participative incremental improvement activities. For example, if a new production line is set up to manufacture a newly designed product, inevitably management and workers who operate that line will find ways to fine-tune it using approaches its designers had not envisioned; meanwhile, feedback from customers can be used to make incremental product design improvements. The same cycle of incremental improvements would apply to reengineered distribution or business processes.

4. Generating New Products

Introduction

The two principles outlined in Section 3 drive firms to find practices that either give them more information sooner about their customers' needs or help them integrate their operations to respond more accurately and quickly to those needs. Thus the first issue is to find out what the customer wants, and the second is to better integrate all the internal production-related operations of the firm. This section considers both issues in terms of the early stages of the product life cycle, those involving the design and introduction of new products. The following section examines how firms build and move those products in collaboration with carefully chosen suppliers. Finally, we discuss three sets of practices that fall outside any temporal sequence because they support them all: information management, management accounting, and human resources management.

Learning What the Customer Wants

Except for start-ups, firms do not really "begin" the product development and production cycle at some discrete point. Successful enterprises are involved in a closed-loop process: There is a constant give-and-take among themselves, their ultimate customers, and their suppliers. The very process of manufacturing and selling generates information and sales leads that feed into new products and services or the reformulation of existing lines.

How Firms Learn About Customers

For-profit firms have many ways of anticipating and responding to customer demand, such as

- collocating design engineers in the customer's plant (Womack, Jones, and Roos, 1990)
- collaborating with a major customer, like an auto assembler, in developing new products (DoD Technology Assessment Team, 1988; Womack, Jones, and Roos, 1990)
- assembling flexible sales teams to develop and sell new products, as Du Pont has done (Power, 1992)

- supporting user groups, as IBM and Microsoft do, that propose solutions to problems with existing and proposed systems¹
- creating Joint Application Development teams of prospective users who tell information system developers what features should be incorporated in new products
- selling cars door-to-door, as some Japanese firms do, and using the information collected from customers to forecast demand (Womack, Jones, and Roos, 1990)
- analyzing usage data, e.g., the number and kinds of transactions at automated teller machines or checkout counters, to improve existing products and services and develop new ones (Morton, 1991)²
- giving customers free hardware and/or software to link them more tightly to the supplier, as leading carriers do with their largest customers (Bowersox, Daugherty, and Droge, 1989)
- drafting industry product standards in advance of the technology they are intended to support (National Research Council, 1990).

Three themes run through these practices: early involvement with the customer, integrating selling with product development and support, and the use of information both to find out about customers and to satisfy them. Early involvement can include a component supplier working with capital equipment manufacturers, user groups telling software developers what they want in a new release, and design teams *within* a single firm working at specifying the features of a new product.³ To say that suppliers and producers favor early involvement because that is what their customers want only begs the question of why they want it. Although large manufacturers have many reasons to involve their suppliers in the design process, perhaps the most important is that the latter can help them understand what they really need (Burt, 1989).⁴

¹Aside from formal user groups, hardware and software manufacturers also use hot lines, mail-in cards shipped with the products, and user surveys to find out what customers want out of new releases of existing products or products introduced for the first time.

²This strategy is appropriate for a firm's internal customers as well. A computer systems center that charges back the full costs of processing to internal customers is getting data for making pricing and product decisions comparable to those bank ATMs or retail checkout counters collect from end users.

³One cause driving component manufacturers toward early involvement with assemblers is the movement of large producers to work with fewer, but better, suppliers discussed below. For example, AMP, the leading manufacturer of electronic connection devices, initiated early involvement programs that led to the development of a high-density connection system for Siemens telecommunications equipment, a wiring integration connector system for Boeing, and sealed connectors for a number of large automotive manufacturers (AMP, 1989).

⁴The customer here is both the manufacturing company that buys the subsystem and the end user who buys the assembled product. Components and subsystems vendors may possess the know-

Moreover, these themes, or practices, are connected. Involvement with the customer must begin early in the product development cycle, but it must be continuous to justify the customer's often sizable investment in the relationship. In addition, large sales to long-term customers often demand teams of experts in many disciplines. The sales force must first understand what it is selling to be able to explain the product or service to the customer. It may be called on to solve problems related to products the customer uses and it may have to do complex financial analyses to convince the customer that the product is worth buying. These conditions all dictate that making a sale is less of a one-shot, one-person deal than formerly. Increasingly, selling to the customer—particularly where multiyear, multimillion dollar contracts are at stake—is so complex and demanding that no one person can do it (Cespedes, Doyle, and Freedman, 1989).⁵

Customer Databases

Such relationships also demand systems that can provide information quickly and accurately. Not only retailers, but also manufacturers and distributors, have become adept at analyzing data generated by every customer transaction; many large retailers already use the data generated when products are electronically scanned at checkout to reorder automatically, or change the mix of products ordered. Armed with data about buying patterns, salespeople can alert management to new market opportunities (Morton, 1991). Some firms, both in the United States and Japan, are learning even more about their customers through huge, constantly updated databases. For example, Kao Corporation, Japan's largest soap and cosmetics corporation, can use point-of-sale information from more than 200 retailers to learn if a product will be successful within two weeks of introduction. Because Kao knows exactly who is buying and because it listens carefully to what its customers say, it can change products far more rapidly than its competitors (Stewart, 1992a).

Another related approach is to scan an existing customer database for patterns that indicate specific concerns. When Toyota entered the Norwegian market, its executives found that customers were as much concerned with financing car purchases and improving repair as with reliability and performance. Using its large customer base, Toyota successfully bargained for competitive insurance

how to apply their proprietary technologies to products that better satisfy the customer than anything the manufacturer's design team could develop on its own.

⁵Selling by multidisciplinary teams raises difficult issues related to compensation. For example, corporations usually tie compensation to quarterly or annual performance reviews, even though it may take years to win a major account. Further, where the sales team is large, attributing sales results to any individual may be extremely difficult.

and financing and began to offer free diagnostic service. As a direct result, its sales in Norway rose by more than 30 percent, and its earnings rose correspondingly (Davidow and Uttal, 1989).

Using an existing customer database to learn more about the customer is also exemplified by United Services Automobile Association (USAA), which markets property and casualty insurance to military personnel (Teal, 1991). USAA succeeds because it concentrates on a niche that is large enough, affluent enough, and loyal enough to generate substantial profit. Rather than expanding its customer base, USAA has chosen to penetrate its special market: first, by expanding its coverage from active-duty and retired officers to separated officers, then to officers who left before the end of their tours, and finally to members' children and grandchildren. USAA's deep knowledge of its customers allows it to tailor products and services to their needs, and its investment in electronic imaging gives customers instant access to all their transactions.

These examples suggest that learning about one's customers is not a discrete practice, separate from all the others. Because the enterprise aims at satisfying its customers, all of its practices mirror that goal. As different as they are, these practices also provide information about the customer that can be transformed into newer and better products and services. The same information system that accepts electronic invoices provides information on what customers are buying. Similarly, co-locating design engineers in a customer's plant not only improves existing products but, more importantly, creates an environment in which producers can develop products that will actually be used.

New Product Introduction

Virtually none of these methods corresponds to traditional methods of test marketing. Firms no longer have the luxury of introducing products and waiting 12 to 18 months for results. This leisurely approach has many disadvantages, including that competitors can steal a march on the first company to test market the product. Moreover, the existence of systems that drastically compress the production cycle add to the pressure on firms to get information on what customers want. A firm that produces new car models in half its competitors' time not only gains an obvious competitive advantage, it is also better-positioned to shape the demand for its next models, even as its competitors strive to catch up with what it has just introduced. In effect, firms have to use other methods to anticipate what they cannot know in advance. They may pretest new products, by asking a few consumers to react to samples (Power, 1992). They may use computer models to project sales for products comparable to existing lines.

Finally, they may introduce a variety of products in several markets, commit to full-scale production of the potentially successful ones, and drop the rest (Power, 1992).

Approaches like these, which target consumers, are appropriate to products that improve incrementally on existing lines. But they are less adequate in two other areas: where the new product is genuinely new and not a marginal improvement and where the sponsor is a not-for-profit organization, which has no bottom line. In the former case, existing demand is not an adequate measure of need; in fact, the genuinely new product will itself create new demands that may lead to a stream of incremental improvements. The earliest personal computers were primitive devices that had no obvious or immediate market. But the promise of personal computing generated developments in microprocessors and software that led to distributed computing, desktop publishing, and the supersession of the mainframe as central processor and file server.

Firms develop revolutionary new products either by exploiting breakthroughs in technology that they themselves developed or building on technologies developed elsewhere. As discussed below, the Japanese have mastered the art of "tagging" promising technologies developed by others and building them into successful consumer products. This entails a high degree of competitive intelligence: the ability to track market leaders for technology susceptible to improvement (Kokubo, 1992). Competitive intelligence involves technical information gathering, but it is more than that. If the information collected is the right kind, someone in the organization must distribute it to those persons who can analyze its implications. Different companies may use the same technical information in quite different ways. For example, of two companies that manufacture plain paper copiers, one may examine the market leader's research capacity for toner development while the other focuses on man-machine interfaces (Kokubo, 1992).

In addition, firms can use nonmarket means, like standards development, to anticipate technologies that will satisfy customer demands. The past decade has seen a marked change in the activities of national and international voluntary standards organizations. Where formerly they drafted standards that reflected existing technology, they are increasingly developing those that *anticipate* emerging technologies. Nowhere is this more evident than in the movement to make computers and telecommunications "open"—that is, to make equipment interoperable, regardless of the manufacturer. This new approach is intended to provide end users, who demand interoperable equipment, with timely solutions in advance of new products. According to the Board on Telecommunications and Computer Applications of the National Research Council, such standards

"can provide the linkage between a market pull that demands new services and a technology push that provides new capabilities" (National Research Council, 1990).

In sum, for-profit firms have means at their disposal to determine what customers want that other organizations generally lack. The most successful manufacturers, retailers, and money managers do not separate scanning their markets from their other activities. The designer uses feedback from marketing and sales personnel to make products that customers find more "user-friendly" than existing product lines; the research laboratory is in constant touch with sales and engineering; and they all focus as much on what customers expect as on what they need (Davidow and Uttal, 1989).

Research and Development

One way that firms satisfy customer expectations is by developing a stream of new products built around their core competencies. Among firms that adopt the new paradigm, technology is never developed for its own sake but to strengthen this core of expertise. Where technology is inserted into operations, it adds value by improving the product, cutting lead times, or, in a service environment, making data available to operating and support personnel when they need it and in the format they want. Applied to product development, technology supplies new items more rapidly and at less cost than the competition. Applied to manufacturing, technology can eliminate rework, allow for product customization, and enable designers to make incremental improvements more often.

A New R&D Philosophy

More rapidly than most U. S. firms, Japanese producers have scrapped the old model of basic research leading to exploratory development and culminating in some end product. Major technological breakthroughs like the transistor signal new possibilities rather than their attainment (Rosenberg, 1982).⁶ It matters less where the breakthrough originated than how it was exploited subsequently. Compared to U. S. and European firms, the Japanese develop superior products in less time, often with technology that originated elsewhere (Stalk, 1988).

⁶The development of transistors exemplifies the disjunction between technologies and the products they make possible. When scientists at Bell Telephone Laboratories built the first transistors, they did not have specific applications in, say, aerospace or computers in mind. Rather, they suspected that solid-state circuitry could supersede vacuum tubes and that further research along these lines was warranted (Ceruzzi, 1989).

The Japanese approach to R&D is as radically different from the classical approach as it is in production, management, accounting, and marketing (Mowery and Rosenberg, 1989). In common with other divisions of the firm, Japanese R&D organizations rely heavily on the localized use of on-site information and on direct communication among relevant functional units without clear direction from a common supervisor. There is constant give-and-take between researchers and engineers. When a project begins at the corporate laboratory, engineers often transfer to work with the research team. Once researchers solve the basic problems, the engineering department of the manufacturing unit that commissioned the research continues the R&D.

This integration of R&D and business strategy is not, however, uniquely Japanese. The quality of R&D at many U.S. and European firms is at least equal to their Japanese competitors', but it often takes much longer to work its way into their product lines. These firms are now aligning R&D and business strategy because they must, given their substantial R&D investments, the risky nature of many R&D projects, and the need to meet shareholder expectations of constant growth.

For example, when Monsanto acquired pharmaceutical producer G. D. Searle & Co. in 1985, it realigned its R&D operations. Rather than allowing R&D to continue in isolation from marketing and production, Monsanto built a corporate technology strategy that integrated all of Searle's operations. First, business units negotiate agreements with R&D executives in those areas in which Searle should conduct research. Then senior R&D managers invite marketing participation in developing proposals for consideration by R&D units, including formal statements about the market potential for specific drugs. Before a decision to proceed is made, interdisciplinary teams drawn from manufacturing, quality, sourcing, and marketing help to develop strategies for marketing the product. Finally, when a go/no-go decision is made, it is the result of consensus from a committee of R&D and business representatives chaired by the chief executive officer (CEO) (Klimstra and Raphael, 1992).

Japanese and U.S. R&D Practices

Despite the move to integrating R&D with marketing and production, some notable differences between Japanese and U.S. firms remain. These have little to do with the resources applied to R&D *developed within the firm*. When Canon overtook Xerox in worldwide market share in copiers, its budget for reprographics R&D was a fraction of Xerox's (Prahalad and Hamel, 1990). The crucial difference is that Japanese firms are much more efficient in exploiting

technology developed externally; it takes them about 10 percent less time and more than 50 percent less money to commercialize a product based on external technology than it does in the United States (Mansfield, 1988).

But even the cost and time differences do not quite explain why firms like Sony, Hitachi, NEC, and Canon seem faster than many Western firms in bringing innovative products to market. Several complementary elements of Japanese R&D explain this superiority. The first is that Japanese firms intensively monitor developments outside their firms to introduce high-quality, lower-cost modifications to technologies developed elsewhere (Mowery and Rosenberg, 1989). An important function of the giant trading companies that are the core of each *keiretsu* (enterprise group) is to gather information that member firms can exploit. But large Japanese manufacturers have other sources of information beyond those supplied by the trading companies: R&D facilities located overseas, company-sponsored basic research at foreign universities, and sophisticated services for retrieving and translating foreign technical literature. Also, as Mowery and Rosenberg note, the combination of a knowledge base specific to the firm and the tendency of engineers to stay with the firm means that there is little "leakage" of knowledge to other Japanese or foreign competitors.

The second element in Japanese R&D is a philosophy of managed evolution. In Japan, innovative firms like Sony, Toshiba, and NEC progressed from borrowing and commercializing foreign technologies to operating at the technological frontiers (Mowery and Rosenberg, 1989). In the bearings industry, for example, Japanese firms first targeted the high-volume end of the business and quickly undercut Western competitors with their higher productivity and lower costs. At that point, they broadened their product lines, moving toward higher-margin products, even as their competitors dropped commodity items in a vain effort to control those segments with the greatest added value. In effect, Japanese bearings producers maintained their revenue base with low-margin items while developing higher-value, customized products (Stalk, 1988).

Third, Japanese firms apply R&D to the manufacturing process itself. According to one estimate, about 40 percent of R&D in Japan is devoted to manufacturing, compared to 10 percent in the United States. Many firms develop new manufacturing methods in their own engineering laboratories and implement them internally. In contrast, most U. S. companies tend to buy manufacturing systems from outside vendors. By treating automation systems as stand-alone devices, they lock themselves into solutions that may have been intended for other purposes, and they lack the experience that comes with developing solutions tailored to one's needs. They lose the link between product and

process design typical of many Japanese firms. They also face heavier startup costs and significant delays in adapting the technology to production (DoD Technology Assessment Team, 1988).

The Japanese firm is only the most extreme example of the worldwide drive to get products from the laboratory to the market as quickly as possible. What they have done can be, and is being, done elsewhere. Whatever their product line, firms that adopt lean production recognize that the only way to avoid having their products overtaken by obsolescence is to be the ones making them obsolete. Although Du Pont scientists invented nylon, they were also the first to invent synthetic fibers competitive with it (Drucker, 1992b). In this context, basic research and product development are complementary. Companies get feedback from customers and suppliers that suggest new possibilities, which then serve to organize the corporate research agenda. Basic research often serves to explain a process that engineers downstream do not understand, as when a semiconductor producer does fundamental research into the properties of matter as part of its design program (U.S. Congress, Office of Technology Assessment, 1989).

Multifunction Project Teams

In comparison to ongoing manufacturing, distribution, and business processes, the processes that design new products and facilities occur only infrequently. But the outcomes of these processes are vital to a firm's success, since they determine the products it offers and much of its fixed cost structure. The products developed must meet all relevant quality criteria, at a price customers are willing to pay, and reach market quickly, before customer preferences change or competitors introduce rival products. And the development process itself must be cost-efficient.

A development process that moves sequentially through a traditional departmental structure often fails to meet these requirements (Brown and Swoboda, 1992). As a product moves from marketing through engineering to manufacturing, its design can creep farther and farther away from that envisioned by its original planners. By the time a product design finally reaches manufacturing, it may be difficult to manufacture cost-effectively with minimal defects. Finally, such sequential design processes are notoriously slow and expensive.

Project teams are a better vehicle for development processes. They differ from the permanent teams that manage ongoing processes, being larger (up to several hundred) and existing only for the life of their project. Project teams are common

in many industries such as aerospace and construction, but the NMP firm project team differs from these traditional project teams in important ways.

Several principles guide the organization and management of an NMP project team (Womack, Jones, and Roos, 1990; Soderberg and O'Halloran, 1992; Wheelwright and Clark, 1992). A strong team leader receives clear goals and constraints from senior management but then is allowed to operate without meddling from the top. He assembles a team of experts from many functions—marketing, financial management, engineering specialties, manufacturing, purchasing, quality assurance, and whoever else may contribute to the design. The team is staffed early and collocated, and individuals stay with the team throughout its life;⁷ these steps help build cross-functional communication and prevent team members from bringing their departmental myopia to the project. Suppliers are selected early and brought on as full members of the team.

Concrete steps ensure that the final design remains faithful to customer desires. The team includes marketing people familiar with customer needs, and on highly engineered products (Main, 1992) even customer representatives can be included. Systems engineering and Quality Function Deployment (QFD) are employed to rigorously flow down specific customer requirements to all affected parts of the product (Hauser and Clausing, 1988). Affordable cost is seen as a firm customer requirement, and so target costing is used to ensure that the final product will be producible within market-defined price limits (Tanaka, 1989).

A deliberate effort is made to surface and resolve requirements and other interface issues as early as possible in the design process. In fact, the size of the team peaks during conceptual design when these issues are being sorted out (Womack, Jones, and Roos, 1990). Statistical Design of Experiments (DOE) or Taguchi methods are used to understand relationships between product and process design parameters and make optimal choices (Ealey, 1988). Early prototyping, sometimes on the actual production line, tests design integration while there is still time to make changes (Harmon, 1992).

An explicit goal of all team members is manufacturability at minimum cost but maximum speed and quality. The team uses existing components where possible (Ealey, 1988), minimizes parts counts, and works with production workers who will make components and assemble the product (Harmon, 1992). Value engineering is used aggressively to reduce component costs without sacrificing performance or quality (Dobler, Burt, and Lee, 1990).

⁷A firm may set up a matrix organization from which to staff project teams, but the matrix departments are not allowed to develop into suboptimizing functional domains (Womack et al., 1990).

Team activities are carried out in parallel where possible (Womack, Jones, and Roos, 1990; Wheelwright and Clark, 1992). Most importantly, tooling design and the manufacturing process start as early as possible and parallel product design. Bringing suppliers in to design subassemblies to specifications, instead of just components to customer-supplied drawings, also enhances parallelism.

In addition to creating better products, the development principles just described yield significant reductions in the cost and length of design efforts. For example, Chrysler's LH car team completed its task in only 40 months (1 year less than for previous models) and with nearly 50 percent fewer people than earlier design efforts (Kerwin and Treece, 1992b; White, Patterson, and Ingrassia, 1992).

5. Building and Moving Products

Supplier Selection and Management

The new business environment is serving to change the terms on which executives weigh make-or-buy decisions. Under the old management paradigm, purchasing decisions were driven by near-term considerations directly related to the annual, or even quarterly, bottom line—e.g., costs, corporate capabilities, the need to protect proprietary technology, production volumes, and supplier reliability (Scheuing, 1989; Dobler, Burt, and Lee, 1990).

But many companies are embracing radical change. New contracting instruments, incentives, and relationships are available, enabling secure suppliers to be developed for the long term. Vertically integrated manufacturers like USX (the successor to U.S. Steel) or IBM, as well as one-stop retailers, are at a real disadvantage compared to leaner, more focused firms. Some firms continue to use integration to ensure timely performance and access to relevant inputs (Camm, 1993). But other firms have concluded that the costs have come to outweigh the benefits. Organizations that persist in doing everything in-house are less able to avail themselves of specialized knowledge from outside the organization.

Purchaser-Vendor Relations

The new emphasis on lean production has two consequences for purchaser-vendor relations. First, the buying organization concentrates on those functions that confer a competitive advantage and looks to outside sources for everything else.¹ A core competence of lean production companies is that base of knowledge and skills that provides potential access to a wide variety of markets, makes significant contributions to customer satisfaction, and is difficult for competitors to imitate (Prahalad and Hamel, 1990).² Whether Honda's engines,

¹What a company does and what its executives think it does have not always coincided. For decades, AT&T executives believed that AT&T's business was to provide universal phone service. When they realized that their business was transmitting information—whether as voice, data, or video—they acquiesced in the largest corporate divestiture in history so that they could enter important nonregulated markets.

Similarly, senior Xerox executives now believe that their company will interact with the public through documents processed in a variety of ways, rather than through specific output devices. Remarks of Xerox Vice President Robert Spinrad at RAND seminar, December 3, 1992.

²One way of defining core competence is to identify those strategic subsystems that, because they are indispensable to the company's competitive position, should not be outsourced. Subsystems

Canon's imaging technology, AMP's electronic connectors, or 3M's expertise in coatings, each of these firms has know-how that adds value to many products.³

Outsourcing is the contracting out of technical or business functions that are integral to the enterprise (Oliver, 1993). Used with an awareness of its limitations, outsourcing allows the firm to do three things:

- gain additional flexibility by turning to alternate sources
- concentrate on those functions it does best
- exploit proprietary knowledge or economies of scale among suppliers.

A good example of gaining flexibility occurs in information management. Many companies, both large and small, are outsourcing the operation of data processing centers or performance of "back office" functions that require on-line transaction processing. Service bureaus like Electronic Data Systems, Computer Sciences Corporation, and Automatic Data Processing have vast experience in systems integration, data-center management, and software upgrades. In most cases, they provide their customers more options than an internal staff and at a fixed price. Because the contractor acts as its customer's smart buyer, it can subcontract from a variety of sources while reducing the fixed charges the customer would pay for maintaining the function internally. Outsourcing transaction processing frees the firm's internal staff to concentrate on longer-term functions, like strategic planning and the development of specialized applications programs. When General Dynamics, McDonnell Douglas, and Eastman Kodak contracted out their data management and Sun Microsystems outsourced its distribution center to Federal Express Business Logistics Systems, they signaled that they could, but need not, operate or produce everything themselves.⁴

may be strategic if they strongly influence what customers consider important product attributes, they require highly specialized skills or assets that few outside suppliers possess, or they involve rapidly changing technologies that offer the sponsoring firm an opportunity to take the lead (Venkatesan, 1992).

³Core competence and brand share are not the same. Although Canon's share of the laser printer business is insignificant, its desktop laser printer drivers are installed in more than 80 percent of such printers. Further, Canon's expertise extends to any product that uses imaging technology—fax machines, copiers, and semiconductor manufacturing equipment, as well as laser printers.

⁴Unless both parties understand the risks in outsourcing facilities management, the arrangement will not work. According to one industry expert, long-term contracts favor outsourcing, because it takes at least five years for vendors to break even on their investments. Even where this condition is satisfied, both sides must address a number of problems: exit criteria, sharing of productivity gains, and culture clashes brought about by the commingling of client and vendor personnel. In particular, the risks and rewards of outsourcing vary greatly, depending on whether the vendor manages "commodity" resources, like a mainframe facility, seasonal loads or peak volume service, or "core" business functions, for which few real data are available (Oliver, 1993).

Similar considerations apply in areas like transportation, warehousing, and aircraft maintenance. Larger carriers like Schneider National and Roadway Services, through its Roadway Logistics Systems subsidiary, have the technology and know-how to give their customers a range of options and, through systems that track in-transit items, the knowledge that orders are being filled on time and to specifications. In aircraft maintenance, full-service firms like Lockheed and AAR Corporation and specialists in engines and landing gear spare commercial airlines some of the heavy fixed costs of investing in automated diagnostic equipment, parts databases, and components.

Relations with Fewer, but Better, Suppliers

A second consequence of lean production is that large firms prefer long-term relationships with a small group of core suppliers. The new management thinking is that, so long as a company retains its core competence, it is better off working closely with a few suppliers than it is trying to control much larger shifting vendor coalitions.⁵ The buyer may designate one vendor, or at most two or three, for each product under contract. Lean companies have been known to buy virtually all their components from outside manufacturers, reserving to themselves the intellectual property that adds value to the final product.⁶ Some companies go further. To concentrate on product marketing, Visa and Mastercard often use archival American Express for transaction processing (Quinn, Doorley, and Paquette, 1990).

Rather than selecting suppliers on price alone, these lean production firms establish close, long-term relations with suppliers selected on the basis of quality, responsiveness, and the ability to improve.⁷ In many cases, they will work with single-source suppliers because

⁵This is the fundamental difference between Toyota and GM. GM has only begun to replace its traditional approach to vendor relations with Toyota's lean production approach—for example, by turning to PPG Industries to manage and operate the paint shops in its assembly plants. But where Toyota will select two suppliers for each part and allow them to compete vigorously with each other for a share of the work over a long period of time, GM has made it clear that no supplier relation is sacrosanct (Treece, 1992). Where Toyota limits suppliers per part to two, GM is tearing up existing contracts and seeking new bids. The risk to both GM and its suppliers is that, without explicit long-term commitments on GM's part, its suppliers cannot consider any investment whose cost cannot be recovered within the existing year's contract. On the other hand, by limiting sourcing for specified parts to two suppliers, Toyota may have created captive organizations that must depend on it for continuing support.

⁶The emphasis here is on intellectual *property*. So long as a firm controls the specialized knowledge it needs to capture and reproduce customer requirements, it is relatively less important to be able to design and manufacture subsystems in-house—provided capable suppliers exist (Venkatesan, 1992).

⁷Such a supplier may be either external to the organization or an in-house subsidiary. In neither case is the vendor guaranteed a long-term contract. Where in-house divisions, like GM's Delco

- using sole suppliers can lead to huge savings in transaction costs
- a supplier guaranteed a share of business is more motivated to work with its prime customer⁸
- suppliers are more willing to share sensitive financial and technical data
- they need suppliers to participate as equals in the design process.

Suppliers gain from these long-term contracts because

- such contracts insulate them to some extent from marketplace uncertainties⁹
- buyers provide technical assistance and even financing to improve their operations.¹⁰

Buying firms will expect much from their suppliers and give them much in return. For example, they may require first-tier suppliers to provide assemblies and subassemblies and buy components from the lower tiers. They will probably require their long-term suppliers to deliver fewer nonconforming parts, meet a just-in-time delivery schedule, participate in continuous improvement programs, reduce their product development cycles, and use standardized containers for shipped materials. In turn, the buyer can promise, though not absolutely guarantee, continuing business and provide the technical assistance the supplier needs to meet more demanding specifications. Thus Xerox wrote an activity-based costing program, put it on a personal computer, and gave it away to its suppliers. Similarly, Procter & Gamble purchases large quantities of raw materials, like plastics, and gives them to its suppliers to mold.

Most commercial organizations do *not* select contractors on price alone based on a fully detailed technical specification. The usual procedure is for the user to state the problem to the technical staff, which develops an acceptable technical solution and then negotiates with those few suppliers who (on the basis of experience) can do the job. In many cases, firms will place orders with suppliers before a contract has been signed or even in the absence of any formal binding

subsidiary, have traditionally supplied components to the assembly plants, they must now compete for some portion of the work against outside suppliers—and the outcome is not guaranteed.

⁸Some large firms limit suppliers to 30 to 40 percent of a particular product type such as an alternator or disk drive, both to prevent them from depending totally on a single customer and to benchmark their operations.

⁹We say “to some extent” because companies chosen as single-source suppliers are locked into design and product programs over which they have little control. They may have to make substantial up-front investments in plants or tooling, with no assurance that they will recoup their investments. Moreover, large manufacturers may insist on access to their suppliers’ operations but not the other way around (Burt, 1989).

¹⁰There seems to be a sequential, staggered relationship between supplier and customer, as they move from quality to on-time delivery to productivity improvement to flexibility (Mabert, 1992).

agreement. Where the product is a standardized item, firms may select the supplier before they draft final specifications (Kelman, 1990).

In sum, by working with a limited number of suppliers, large manufacturers (and retailers) acknowledge that they no longer monopolize all the know-how for building products as complex as automobiles, machine tools, or consumer electronics. To produce world-class products, they need suppliers to participate as equals in the design process—not on the eve of production when changes are difficult and expensive (Womack, Jones, and Roos, 1990). Under the new regime, large manufacturers look for certain things in their first-tier suppliers: a willingness to invest in new plant and equipment (preferably near the manufacturer) and the technical ability to review the design of a subassembly before committing to its manufacture. Companies like Ford Motor no longer provide detailed specifications to their suppliers, because they expect vendors to furnish the design ideas that flesh them out (Burt, 1989).¹¹

Quality Improvement

Improving Quality by Improving Processes

Ensuring conformance to specification, or preventing defects, is the initial focus of most quality programs. SPC is based on the principle that the source of defects is variation in processes; therefore, eliminating the root causes of variation is the best way to prevent defects (Gabor, 1991). Deming (1986) further distinguishes between *special* (one-time) causes of variation, such as incorrectly entered data or an overly worn tool, and *common* (regularly recurring) causes, such as ambiguous procedures or purchased components whose key dimensions vary slightly over time or across suppliers.

Eliminating special causes allows a process to operate consistently within well-defined control limits; it is then said to be under control. Periodic inspections verify that the process is operating within the control limits,¹² and a result indicating the process is outside these limits may result in its being shut down until the root cause of the excessive variation is pinpointed and corrected. Control limits can be set tighter than actual tolerances, so that corrective action is implemented before an unacceptable item can be produced (Feigenbaum, 1961).

¹¹Such relationships are for parts or products that the manufacturer or assembler no longer produces internally. For example, Ford produces only about 20 percent of its parts in-house. Manufacturers, however, still will not contract for certain things. Thus, Xerox continues to produce the lens and toner for its copiers, and Boeing is designing the wings, struts, and nacelles for its new 777 wide-bodied passenger jet.

¹²Control limits and continuous improvement are defined in the appendix.

In a manufacturing setting, SPC means that machine operators monitor and record key dimensions on parts as they are produced rather than having inspectors check batches of parts to see whether any are out of tolerance. Operators can then adjust machine settings as necessary to ensure that they always operate within limits where no defective parts are made. A business process example would be to have rigorous checks for data consistency at intermediate stages of compiling complex financial projections so as to prevent having to rework near-finished projections just before deadlines.

Once a process is in control, its performance can be improved by eliminating common causes of variation, tightening control limits, and then repeating this cycle continuously, moving to ever finer scales of measurement. Such improvements can be accomplished, for example, by clarifying procedures, strengthening preventive maintenance to ensure that machines operate consistently, or updating forms and software to minimize the chances of incorrect data entry. This continuous improvement cycle means that a process can move closer and closer to meeting its nominal performance standards.

Importance of Achieving Nominal Performance

Meeting nominal performance standards at each of several sequential subprocess can significantly improve overall process performance. For example, in a manufacturing process it prevents tolerance stackup,¹³ helping to improve important quality criteria like reliability and durability. Ford discovered this when it examined transmissions made to identical specifications by Ford and Mazda. The Ford-produced units required many more warranty repairs, because even though all parts were within specification, the deviations from nominal dimensions caused higher wear rates in use. By contrast, all components in the Mazda-produced transmissions were extremely close to nominal dimensions, and thus suffered much less damaging wear patterns (Ealey, 1988).

Genichi Taguchi, a Japanese quality engineer, proposed a method for evaluating the cost of deviations from nominal values (Ealey, 1988; Scherkenbach, 1988; Taguchi and Clausing, 1990). Its basic assumption is that *any* deviation from nominal performance causes a loss to society when the product is used. The Ford-produced transmissions just described produced such losses, as do any products or services that require customers to expend extra effort to cope with less-than-expected performance or to make a replacement purchase sooner than

¹³Tolerance stackup is a phenomenon in which each of several components is within tolerance but does not exactly meet nominal dimensions, causing the complete assembly to be out of tolerance or perhaps not even fit together at all.

they would if nominal performance and life targets were met. This attitude contrasts to traditional practice, which assumes that any performance within the specified acceptable band is equally valuable to customers.

The quality loss function (QLF) quantifies the loss caused by variation as a quadratic function of the deviation of any parameter or characteristic from its nominal value. For example, an electronic system component may have a nominal value and tolerance band for a key operating characteristic, such as its gain. The more that gain deviates from its nominal value, the greater the degradation in overall system performance. This degradation imposes some increasing cost to the system user, which reaches its maximum when the gain goes outside the tolerance band and the component must be repaired or replaced. The QLF (Figure 5.1) quantifies the user's loss caused by variation, allowing the manufacturer or repairer of the component to define the benefit of achieving nominal performance and thus decide how much additional effort to expend on doing so.

Although efforts to improve existing processes and products significantly impact customer satisfaction, the highest leverage time for quality improvement is during process and product design. At that stage, processes can be designed to minimize variation, for example, by specifying machinery and tooling capable of

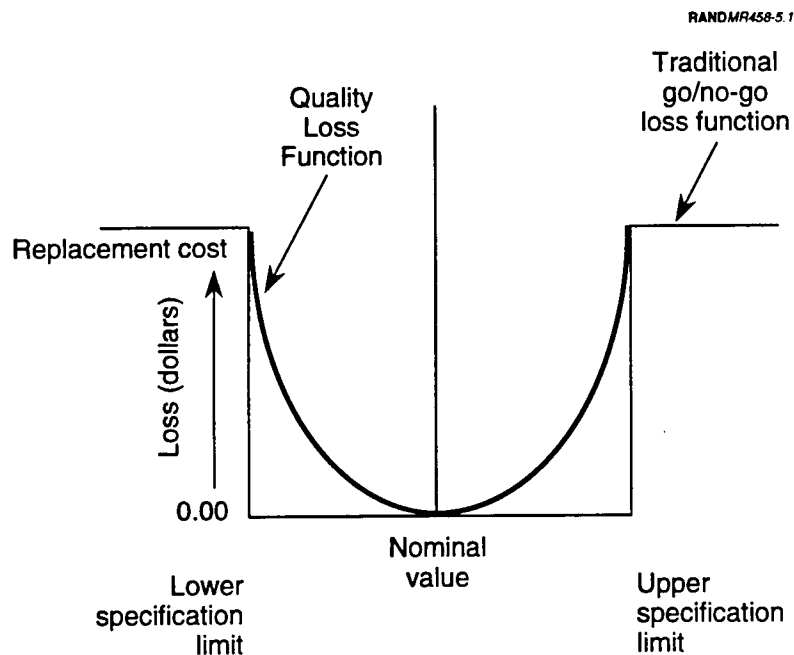


Figure 5.1—Quality Loss Function

very stable operation or designing component interfaces to minimize the chance of misassembly. Statistical techniques, such as Taguchi methods or DOE, can also be used to help make product designs as insensitive as possible to remaining process variations.

Process Improvement Techniques

The specific techniques (or tools) used for process improvement are powerful but surprisingly simple in concept, although their detailed application usually requires considerable time and effort by the process improvement team. The seven most commonly used tools¹⁴ are flowcharts, cause-and-effect diagrams, check sheets, histograms, scatter diagrams, Pareto charts, and control charts. These tools are simple enough to be used by all workers, given some training; for particularly complex problems, trained quality engineers assist in the use of more sophisticated statistical techniques (such as regression analysis).

All these tools are based on the assumption that most defects are the fault of the system, not the workers (Deming, 1986; Carr and Littman, 1990). Although they may need technical assistance from managers, engineers, or staff on some matters, only workers understand the details of the system well enough to surface all sources of improvement. Their active participation is thus necessary for quality improvement efforts to realize their full potential. A dramatic example occurred at Hewlett Packard, where engineers had devised modifications to a soldering process that cut defects in half. When worker suggestions were solicited, the resulting redesign of the process further reduced defects by a factor of one thousand, to two per million (Port, 1991).

Synchronized Small-Lot Manufacturing Process Flows

Manufacturing firms, especially in Japan, have been leaders in developing techniques to synchronize their processes and reduce lot sizes to reduce cost, pare inventories, enhance quality, and respond more quickly to customer orders. This section describes the general guidelines that firms follow in improving their manufacturing processes, methods to reduce the variability that can hamper process synchronization, production control systems, and the emerging emphasis on flexibility.¹⁵

¹⁴Described in the appendix.

¹⁵Except as noted in the citations, the material in this section was drawn from Glass & Schwartz (1988), Hall (1987), Reid (1990), Schonberger (1986, 1988), Sepehri (1986), Shingo (1986), and Suzuki (1987). A classic work on JIT manufacturing is Monden (1983).

General Guidelines

A handful of broad recommendations for improving manufacturing processes can be derived from the experience of NMP firms:

- Map processes to pinpoint activities and waiting time that can be eliminated
- Organize equipment around families of similar components, not functional departments
- Reduce batch sizes
- Reduce setup times.

Process Mapping. The first step in improving any manufacturing process is mapping it out, as is done for quality improvement purposes, but ensuring that cycle times are included for all subprocesses. The map is developed by a team of workers, engineers, and other support personnel who participate in the process. They use the as-is map to determine which activities (e.g., machining) add value to the items being manufactured, which NVA ones (e.g., final inspection and rework) can be eliminated, and where reducible waiting time (e.g., during long setup times) occurs. Recalling the 95/5 rule, it is not unlikely that teams find 95 percent or more of the overall process cycle time absorbed by NVA activities or waiting time. The team can then apply some of the same tools used for quality improvement, such as Pareto charts and cause-and-effect diagrams, to find the sources of NVA work and set priorities for changes to the process. A goal of reducing manufacturing process cycle times by 90 percent is not unrealistic.

One common source of NVA activity is functional department layouts in factories. At each handoff from departments, a batch of components must be transported to the next department, be scheduled into that department's flow, wait for its turn to be worked on, and then start the cycle again as it moves to the next department. Since this sequence of events is time-consuming, large WIP inventories result. The considerable effort involved in moving batches between departments and scheduling them in each department clearly adds no value to the items. If inspection is carried out only at the end of a long multidepartment sequence of operations, determining causation of defects may be effectively impossible.

Manufacturing Cells. One solution to the problems arising from a functional layout is a manufacturing cell (Figure 5.2). Instead of having parts move back and forth in batches from, say, the grinding to the turning to the drilling department, a cellular layout would have grinders, lathes, and drill presses grouped close together into a cell, with machines in a sequence that matched the

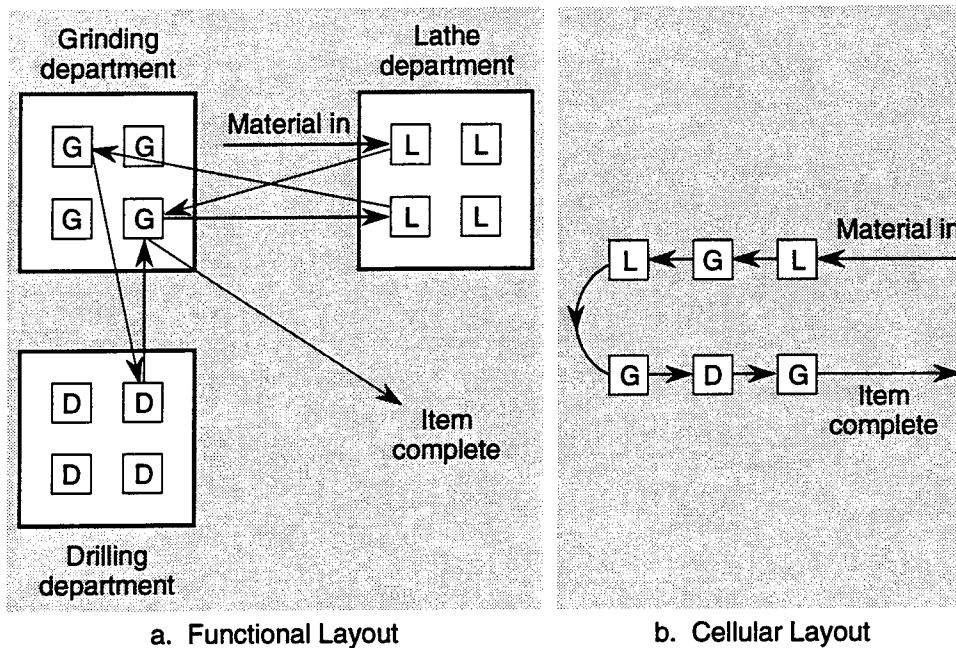


Figure 5.2—Functional vs. Cellular Layouts

shortest possible arrangement of machining steps. Once the machines in the cell are set up for a batch of a given item, parts can be moved individually from one machine to the next by operators or simple conveyors.¹⁶ This method eliminates waiting and transportation time between departments, and thus WIP inventory as well; the scheduling task is also greatly simplified. Quality improves, because if a defect is detected, its cause can be traced back immediately through the cell.

Using group technology (GT) principles, machines that make up an individual cell are chosen and arranged to produce a family of parts with similar processing characteristics, for example, crankshafts for several different engines (Hyer and Wemmerlov, 1984). This also helps reduce setup times, since machine changovers are less extensive across parts within a family than across dissimilar ones. Thus, on short notice, a cell can produce different items in its parts family in any sequence desired. This increases the process's responsiveness to variations in demand and reduces the need for inventory in downstream processes.

In most shops, some parts do not fit neatly into the parts families assigned to cells. Therefore, a fraction of the shop's machines are usually maintained in a

¹⁶A cellular layout implies that operators be crosstrained to operate all machines in a cell and perform the necessary in-process quality checks.

functional (job shop) layout to accommodate these parts (Hyer and Wemmerlov, 1984).

The dedication of machines to cells usually results in lower average machine utilization rates than for a process layout (Morris and Tersine, 1989). However, the associated reductions in WIP inventory and improvements in quality and throughput time offset this drawback.

Small Batch Sizes. Reducing batch sizes is a natural adjunct of moving to a cellular layout.¹⁷ Smaller batch sizes mean shorter average waiting times for each piece in a given batch, as well as for subsequent batches awaiting their turn to be worked on. This reduces cycle times and, therefore, WIP inventory. Small batch sizes also help improve quality, because if a defect is discovered, the number of bad items produced is limited to the batch size, and the cause of the defect can be found in the machine setup or other conditions unique to that batch.

The assembly line analog to small batch sizes is mixed model production, where individual units of different models of a product can be produced in any order. For example, while most U.S. auto plants assemble only one model, Japanese plants routinely produce several models each, and Mazda's newest assembly line can make 12 different models (Miller, 1992). Such plants can make exactly the mix of models demanded by customers in a given time period, which reduces the level of FG inventory the firm must hold. By devoting more line slots to popular models and fewer slots to slow-selling ones, the firm can simultaneously keep utilization high and avoid lost sales due to capacity constraints.

Short Setup Times. Making small batch sizes economical requires drastically reduced setup times, and the literature is filled with stories of setup times reduced from hours to minutes.¹⁸ Machine setup is a subprocess susceptible to analysis and improvement using general techniques like process mapping. The specific techniques of quick setup are relatively simple and where machines and tooling are large or complex can be applied incrementally in a continuous improvement framework. The eventual goal of such setup time reduction efforts is an economic lot size of one unit, which minimizes WIP and FG inventories and maximizes responsiveness to special orders.

¹⁷However, batch size reduction can also be pursued profitably in a facility with a functional layout or if some manufacturing steps, such as metal plating, cannot be located at each cell that calls for them.

¹⁸Suzaki (1987) contains a concise chapter on the techniques of setup time reduction, but a more comprehensive source is Shingo (1985).

Tasks *external* to the machine being set up can be accelerated, for example, by locating dies and tooling close to machines or performing preliminary adjustments before tooling is inserted into the machine while the previous batch is being run. Second, *internal* setup tasks can be accelerated by, for example, using rollers to insert large dies or tools, simplifying fasteners and attachment mechanisms, and using customized gauges instead of general-purpose measuring instruments for adjustment. In the long run, tools and dies can be designed to have simplified adjustments and standardized interfaces with machines, and the items being produced can even be redesigned to facilitate faster setup.

Benefits and Implementation. In addition to the direct benefits of reduced WIP and FG inventory, improved quality, lower direct cost, and shorter cycle times, application of the guidelines just enumerated significantly reduces indirect costs as well. First, cellular layouts and inventory reduction decrease the floor space needed for manufacturing and inventory storage. Stories of Just-in-Time (JIT) implementation often point to reduced space requirements, and the IMVP study of auto assembly plants found that Japanese plants use 27 percent less floor space per automobile than their U.S. or European counterparts (Womack, Jones, and Roos, 1990). Second, shortening cycle times, reducing inventories, eliminating defects, and simplifying manufacturing flows greatly reduce the indirect staff needed for activities like inventory management, expediting, and scheduling (Tatikonda and Tatikonda, 1991). A survey of more than 100 manufacturing plants by the Boston Consulting Group found that those with *robust* (synchronized) processes had overhead costs dramatically (often 50 percent or more) lower than their traditional organized competitors (Blaxill and Hout, 1991).

The experience of firms that have successfully synchronized their manufacturing processes indicates that implementation of changes should be gradual. For example, one segment of a factory's production can be selected for the pilot manufacturing cell, maintaining production as usual in the rest of the plant. The pilot cell will both surface implementation problems and provide an example of the benefits of synchronized process flows. Addressing the problems inherent in the original processes (by, for example, cutting setup times, cross-training workers to operate all the machines in a cell, or redesigning products for enhanced manufacturability) takes time. Incremental batch size reduction thus allows processes to adjust to the problems uncovered by each reduction. The analogy of a river filled with rocks is often used—each time the water level in the river (batch size) is lowered, new rocks (problems) are uncovered and must be removed.

Another cautionary note is that none of the process changes just described requires a high level of automation. For example, manufacturing cells can provide virtually the same benefits as flexible machining systems (FMS) at much lower cost. Moreover, many firms have learned the expensive lesson that simply automating inefficient processes does not necessarily improve productivity. Perhaps the most dramatic example of this is General Motors, which invested tens of billions of dollars in automation during the 1980s but remains the country's least productive automaker (Schonberger, 1990; Kerwin and Treece, 1992a).

Variability Reduction

Two themes run through these guidelines for manufacturing process improvement—simplification and the elimination of waste. Simplification is exemplified by the replacement of complex multidepartment process flows with manufacturing cells. Waste as used here means any use of time, material, effort, inventory, or other resources that can be eliminated without impacting the quality of the items being manufactured. Both simplification and waste elimination are goals that can be approached incrementally in a continuous improvement framework.

Another essential goal is reducing process variability. A synchronized process, with its tightly sequenced subprocesses, is disrupted by any variation in subprocess cycle times and operates most efficiently when demand variability is minimized (Huang, Rees, and Taylor, 1983; Schonberger, 1986; Grauf, 1990; Crawford and Cox, 1991). Traditionally organized processes cope with such variability by having large batch sizes and placing buffer stocks between subprocesses, but these measures vitiate the very benefits that process synchronization aims for. Eliminating the sources of process variability is a more effective solution;¹⁹ several techniques for doing so are detailed below.

- *The quality improvement techniques discussed earlier in this section (such as SPC and poka-yoke²⁰ systems) that prevent defects and ensure that all components meet nominal requirements. Defective components give rise to variability in cycle time by requiring time for rework or fabricating replacements; buffer stocks or extra units in each batch are traditional, but wasteful, solutions. Quality improvement techniques can eliminate the waste of sorting within specification components to prevent excessive*

¹⁹The logic is exactly analogous to preventing defects by eliminating sources of variability.

²⁰Defined in the appendix.

tolerance stackup or meet close-tolerance fit requirements, such as between pistons and cylinders.

- ***Maintain orderly and clean working areas.*** Removing all unnecessary equipment from work areas and assigning a unique place to every tool, transport cart, gauge, or other remaining piece of equipment minimizes the time workers expend searching for what they need for their next task. That search time is the same every time a piece of equipment is used and for all workers who may use it. Keeping work areas clean prevents dirt or other contaminants from degrading equipment performance. Gauges and other tools remain well calibrated longer when they are carefully cleaned and stored.
- ***Making work processes highly visible*** reduces variation as a result of information availability. For example, schedules, procedures, and drawings can be posted at each workstation, and examples of good and bad products can be displayed nearby. Relationships between subprocesses can be displayed by simple means such as lines on the floor or assigned places for batches of components being worked on. Colored lights can be used to indicate a machine problem that requires immediate assistance or the overall status of an automated subprocess.
- ***Ensuring the accuracy of all information used by workers and schedulers*** (e.g., bills of materials (BOMs), drawings, specifications, customer orders, inventory counts, etc.). Any mistake takes time to rectify, and a tightly synchronized flow has no slack for components made at the wrong time or to the wrong specifications.
- ***Developing standardized work procedures and having all workers use them.*** At firms like Toyota, factory tasks are planned down to the second. But a key difference between the NMP firm and traditional ones is that workers themselves, not just industrial engineers, develop work standards (Adler, 1993). This brings to bear the workers' own experience and innovations, and increases the chances that they will follow procedures rigorously.²¹
- ***Preventive maintenance programs*** can dramatically reduce unexpected machine breakdowns, in return for some planned maintenance downtime (Nakajima, 1984). Workers can be trained to perform basic maintenance tasks (e.g., lubrication, tightening bolts, making adjustments) on the machines they operate. The maintenance staff then concentrates on

²¹In contrast, traditional top-down imposition of work standards can alienate workers and even lead to their deliberately not following those standards (Hackman and Oldham, 1980; Fucini and Fucini, 1990).

developing maintenance programs, troubleshooting complex problems, and doing major overhauls and modifications.

- ***Balance capacity across subprocesses***, i.e., eliminate bottlenecks. In terms of their effect on synchronized process flows, bottlenecks can be seen as variability in throughput capacity across subprocesses. They can be relieved by measures like adding some flexible machines to meet peak demand or reallocating tasks across subprocesses.
- ***Standardize components and assembly sequences across models*** where possible,²² varying only those components necessary to customize a product for a particular order. This facilitates mixed model assembly and allows custom orders to be inserted into the order stream as late as possible.
- ***Reduce delivery time variability*** both for deliveries within the plant and from suppliers. Cellular layouts and small batch sizes enable batches of parts to be transported simply and reliably, using carts or simple conveyors. Ensuring deliveries from suppliers requires working with them to synchronize their own processes and coordinating their production control system with that of the customer's plant.²³
- ***Work with customers to reduce demand variability*** by obtaining schedule information from them and by making smaller but more frequent deliveries to them, according to the rate at which they use the purchased product. In addition, sales efforts may be increased during periods of slack demand.

Note that techniques such as standardized work and making information quickly available not only minimize cycle time variability but also cycle time itself. Essentially, they are means to rigorously define the best practice for each task and to ensure that everyone who performs that task follows the best practice. These techniques can thus be seen as a way to codify and diffuse the learning of individuals and teams. Of course, any procedure should be subject to continuous updating as new ideas are developed by participants in the process.

Production Control

All the preceding recommendations can be employed in conjunction with either "push" or "pull" production control systems (Krajewski et al., 1987). In either

²²Even within a given final product, components can be standardized by, for example, using the same fastener in many different locations.

²³Until this integration is achieved, buffer stocks may be necessary to insulate the plant from disruptions caused by late supplier deliveries or purchased items that fail incoming inspection.

case, reducing cycle times and their variability supports process synchronization and reduces scheduling horizons and order response times.

In a push system, production starts when raw materials or purchased components are released to the plant's farthest upstream subprocesses, and batches then cascade from one subprocess to the next. Release dates are based on estimated lead times and need dates for the completed product. Manufacturing Resource Planning (MRP II) synchronizes subprocesses by scheduling releases to each subprocess so that components will be completed exactly when needed by the next subprocess downstream.

Kanban is the pull system used in JIT, where an upstream subprocess (e.g., subassembly fabrication) does not begin production of a given batch of its output until it receives a signal to do so from the downstream subprocess (e.g., final assembly). Supporting kanban is the fact that in a full-up JIT factory, all subprocesses throughout the plant are carefully balanced and synchronized to a common cycle time. Kanban fine tunes the inventory levels between subprocesses, but controlling overall factory scheduling is a master production schedule (MPS) that defines the mix of models to be produced and is frozen for some period into the future, often a month. This frozen MPS minimizes the impact of demand variability on the factory's processes but still allows special orders for options, like paint color on autos, on short notice.

Each system has pros and cons, and neither has been shown to be superior in all manufacturing environments. MRP II helps schedule complex manufacturing flows with long lead times for components. JIT is most effective in high-volume, repetitive manufacturing; since it operates on a frozen MPS, however, it is not very flexible in the face of highly variable demand (especially if component lead times are long).²⁴ MRP II requires a dedicated computer program and a staff to operate it, and the program is often too complex to be run every day. JIT, however, does not require a sophisticated computer system and is updated in real time by kanban. MRP II's sensitivity to lead time variability is often underemphasized, and its methods for dealing with bottlenecks are cumbersome. JIT, on the other hand, forces firms to greatly reduce variability and balance capacity across subprocesses to mitigate bottlenecks. Hybrid systems are possible, for example, using MRP II for long-lead or customized components and JIT for more repetitive subprocesses (Karmarkar, 1989).

²⁴This limitation can be mitigated if the overall manufacturing cycle time is reduced to less than the order response time expected by customers.

Theory of Constraints/Optimized Production Technology. The Theory of Constraints (TOC) is a manufacturing control philosophy developed by Eliyahu M. Goldratt (Goldratt and Cox, 1986; Goldratt, 1990; Fawcett and Pearson, 1991). TOC focuses first on finding the relatively few bottleneck (constraint) subprocesses that limit the throughput capacity of an entire shop. (Redesign of cost accounting systems is important in pinpointing constraints.) Then production is scheduled to maximize the utilization of the identified constraints, and capacity is added to relieve them. TOC principles can be implemented by purchasing the proprietary Optimized Production Technology (OPT) production control software; some firms claim significant benefits from using OPT (Aggarwal, 1985; Glass and Schwartz, 1988; Goldratt, 1988; Schonberger and Knod, 1988).

TOC's strong points are its emphases on identifying and relieving bottlenecks and on reforming cost accounting systems to make them more relevant for production management. It can be implemented without making major investments in changing shop layouts, modifying organizational structures, or retraining shop-floor workers. On the other hand, TOC does not emphasize the benefits to be gained from waste elimination and variability reduction at nonbottleneck subprocesses or from training and empowering workers. Overall, the benefits of TOC/OPT should be achievable by applying the process synchronization recommendations discussed above, in either a JIT or MRP II environment.

Flexibility

The dramatic reduction in setup times and overall manufacturing cycle times achieved by some firms has allowed them to make great advances in flexibility—not just making products to order, but customizing those products to a degree never before feasible. Japanese firms are, unsurprisingly, the pioneers in this area (Association for Manufacturing Excellence, 1991; Iacocca Institute, 1991). For example, Fuji Electric now offers three times more varieties of magnetic contactors (used in machine tool control motors) than in 1988 and fills orders three times faster—in only 24 hours (Stewart, 1992a).

In many cases, such as at Fuji, investments in enhanced flexibility are very costly and are based on years of experience in synchronizing processes. Fortunately, however, the guidelines outlined in this section—by cutting cycle times and batch sizes and minimizing variability *internal* to processes—can achieve quantum increases in a firm's ability to respond to variable demand. These measures carry relatively modest costs and set the stage for more sophisticated

future investments in flexibility. Firms can also make focused investments in flexibility by setting up dedicated manufacturing cells for the (low-demand-variability) products that make up the bulk of sales and maintaining some flexible, fast-response job shop capacity to meet demand for items with lower but more variable demand (Schonberger, 1990; Carr et al., 1993).

Firms should ensure that they devote their customization efforts to product features that matter to customers (Child et al., 1991). Many Japanese firms are reducing variety on some product features, after falling into a pattern of proliferating technical options that added significant manufacturing complexity and cost, but little value in the eyes of customers (Pine et al., 1993; Stalk and Webber, 1993). Customers can even become confused by having too many choices on minor product features, such as the 87 varieties of steering wheels offered by Nissan (Pine, Victor, and Boynton, 1993).

Shipping and Distribution

The producer's transformation is scarcely completed once it masters the processes of producing quality items at lowest cost in minimal time. In some ways, the hardest part remains: to ensure that the product reaches the assembler, retailer, or end user in the shortest time at the least cost. If a company does not ship on time, it may lose the order. Increasingly, these groups are pressing their suppliers (who may be each other) to substitute integrated distribution systems for the "stovepiping" of functions that has been as much of a problem in distribution as in product design and manufacture.

Streamlining Distribution

Such systems may extend from locating suppliers close to their customers and making deliveries close to where they are needed in the plant, to formal logistics alliances among retailers, manufacturers, and carriers linked by information technology, to the creation of spare parts systems that can fill more than 99 percent of orders within 24 hours. Manufacturers are working more closely with their primary carriers, because distribution enables the former to fill orders reliably and to assure that orders arrive on schedule. Both civilian and defense agencies are studying newer concepts of inventory and transportation management in an effort to reduce response time and costs, correct demand predictions quickly, and place the user in control of supply operations.

Producers and their vendors are streamlining distribution, including warehousing, because it is one of the few remaining areas where major cost

reductions are possible. Improvements in production tend to magnify distribution as an element in fixed costs, accounting for between 30 and 40 percent of a product's cost (Koselka, 1992). Distribution itself has subordinate costs, such as the costs of operating warehouses, administration, and, in particular, carrying inventory.²⁵ In contrast to classical production models, in which inventory meets variations in product demand and allows flexibility in production scheduling, the JIT model considers inventory a heavy fixed cost. Less inventory results in lower storage and other carrying costs, such as shop-floor material handling (Chase and Aquilano, 1985). Reliable, high-quality products do not require large stocks, because reliable suppliers can deliver spare parts on a few hours' notice.²⁶

As more manufacturers adopt JIT systems, the availability of reliable carriers and components suppliers becomes critical to the success of the enterprise. JIT requires suppliers and their carriers to commit to shipping payloads that are large enough to be economical, yet small enough to keep inventory minimal (Jackson, 1983). Only advanced automated communications between a small number of carriers and their customers can make JIT work in either its pure or modified versions. Thus JIT, the desire of large retailers to reduce inventories, the rise of a small number of full-service national carriers, and the deregulation of transportation since the early 1980s have led to integrated distribution networks that link suppliers, large manufacturers, and retailers.

Integrated and Automated Distribution

The move toward integrated shipping and distribution has two principal features (Interagency Transportation Task Force, 1988):

- establishing a unified distribution network in which different divisions share storage facilities²⁷

²⁵According to one estimate, average overall distribution costs are approximately 39 percent for transportation, 12 percent for administration, 24 percent for warehousing, and 25 percent for inventory carrying (Culbertson, 1992).

²⁶Commercial airlines often find it cheaper to use whole engines for spare parts than to accumulate inventories of spares. They can keep inventories low because General Electric (GE) and Pratt & Whitney have large distribution centers. GE customers can buy parts through company catalogs, confident that they will be shipped as few as four hours from receipt of the order (United States General Accounting Office, 1991a).

Caterpillar Tractor's parts service and support is another example of responsive distribution. With some 470,000 discrete items in the system, Caterpillar commits to delivering any "current part" to customers within 48 hours, either directly or through dealers. The system, which can handle up to 50,000 daily orders, is a major profit center for Caterpillar. (Information provided by Nancy Moore, RAND.)

²⁷Storage or warehousing operations include receiving (logging incoming shipments), putaway (placement of pallets on shelves), picking, packaging, shipping, and inventory status tracking.

- establishing communications among order processing, manufacturing, and distribution.

These features reinforce each other. Creating an integrated network combining procurement, production, and distribution demands automation. Using electronic data interchange (EDI), commercial firms employ information technology to automate management reporting and rate-and-routing information, accept invoices from suppliers in standard formats and pay them electronically, and track shipment status and location (Payne and Anderson, 1991). A system like COSMOS IIB developed by Federal Express uses hand-held computers to track in-transit items. The computers scan and record air bill numbers, the package carrier, the recipient, and status at the point of pickup. This information is then radioed to the central COSMOS system in advance of dropoff at the next stage of processing and enables the company to track packages as they move from point to point (American Management Systems, 1991).

But EDI can do much more. EDI can be, and is, employed to transmit purchase orders and invoices between vendors and their customers. Automated systems can also generate a variety of standardized and customized reports that allow shippers to generate optimization models for locating warehouses, route planning, and comparing rates offered by different carriers.²⁸

EDI is not just a cheaper alternative. Its real advantage is that it gives users greater control over costs, because traffic managers can compare rates rapidly and negotiate lower rates. Further, several large companies use it to monitor carrier performance, minimize payment of overcharges, and reduce errors on shipping bills. With EDI, there are fewer errors than with manual systems, because data need be entered only once and automated systems periodically check shipping documents for errors.²⁹

The uses and benefits of automation do not end with goods in transit. Automation sharply cuts shippers' transportation costs without significantly reducing the time goods spend in transit (Koselka, 1992). But the same reasons that led shippers and retailers to reduce their stocks demanded that they reduce the time goods spent in warehouses and transshipment points. Shippers and

²⁸EDI can also be used to divert in-transit packages to other transportation channels. Automatic diversion of supplies could be a critical wartime asset: if there were sudden changes in the location of a recipient unit, if transportation channels became congested or damaged, if a unit's size or mission changed, or if shipment priorities changed (Payne and Anderson, 1991).

²⁹The same manufacturers and retailers can use EDI to eliminate the manual auditing of freight bills.

their carriers have adopted several complementary approaches to cut in-transit times: shipping directly to customers,³⁰ automating shipment-related paperwork,³¹ and using intermodal freight transportation—the carriage of containers by railcars, with pickup and delivery at each end by trucks.³²

With technologies like EDI available, warehousing is decreasing. Even where goods go through an intermediate warehouse, the time actually spent there has dropped sharply, as the warehouse goes from a *holding yard* to a *switching yard* (Drucker, 1992a). This change has profoundly affected retailers in two ways. First, retailers like Wal-Mart and K-Mart use their electronic scanners to tell their suppliers what to produce, in what quantities, and when to ship to their stores. It is not unusual for large retailers to ask them to ship goods tagged and hung directly to the selling floor. Only 10 percent of Wal-Mart's square footage goes for inventory, compared to an industry average of 25 percent (Koselka, 1992).

Second, where goods are stored in warehouses awaiting an order, there is the same effort to squeeze out non-value-added activity that we noted in production. Some wholesalers and shippers are moving toward *real-time warehousing*, highly-automated facilities intended to make all items visible and accessible.³³ By means of specialized applications software, warehouse managers can track all materials-handling equipment, like forklifts, and thereby minimize the number of times an operator returns to home base with an empty forklift. These programs also drive hand-held computers that track every item in a warehouse and provide real-time updates on items entering the warehouse. An operator can scan low-density barcodes from 30 feet away, update information, and enable a facility to deal with backorders immediately, as they arrive. This procedure avoids three time-consuming steps—logging, putaway, and picking—

³⁰Besides reducing overhandling and damage to goods, direct delivery may reduce shipping costs if low-value, small-quantity orders that met direct-delivery criteria were consolidated.

When Operation Desert Shield (ODS) began, the General Services Administration worked with vendors to shorten delivery times by accelerating direct deliveries. Ultimately, some 50 percent of orders to support ODS were filled directly from vendors to customers (United States General Accounting Office, 1992).

³¹In so doing, the manufacturer gives its carrier unprecedented flexibility to depart at off-peak traffic periods (Bowersox, Daugherty, and Droge, 1989).

³²Although intermodal transportation is not fully established, especially east of the Mississippi, it could shorten transit times by reducing the time cargo sits in warehouses waiting for pickup (DeBoer, 1989).

³³Particularly for firms that adopt JIT, the layout of warehouses and receiving areas also changes. Since their subsystem suppliers are fully qualified, there is no need for separate facilities or receiving areas where components are inspected before being stored. Compared to conventional facilities, Japanese JIT plants have more doors and fewer docks. Some plants allow drivers to deliver cargo directly to work areas (Jackson, 1983).

and enables managers to take inventory snapshots in real time, without having to close the warehouse for periodic physical inventory checks (Chernofsky, 1992).³⁴

New Carrier Relationships

As they move toward integrated, highly automated distribution systems, many large shippers also reduce the number of carriers with whom they deal, both to simplify communications channels and to exploit the technologies and services some carriers offer. Up to the mid-1980s, large nationwide shippers dealt with upward of 2,000 carriers, greatly adding to the complexity of their operations (Interagency Transportation Task Force, 1988). These shippers have realized major savings by cutting the number of carriers to 1,000 or fewer. There are obvious savings in administrative expenses: When Du Pont reduced the number of carriers with which it did business from 4,000 to 1,000, it cut the number of people buying transportation services from 18 to 4 (Interagency Transportation Task Force, 1988).

There are more far-reaching advantages to stronger carrier relationships than reducing administrative costs. With the deregulation of transportation, large customers have the flexibility to work with a variety of carriers, because they are no longer locked into noncompetitive rate structures. These customers increasingly work with full-service national carriers like Roadway Services, a holding company for several transportation-oriented businesses. Roadway gives them the software to access shipment information on-line and to communicate electronically with any Roadway Express trucking facility.³⁵ Roadway Express tracks shipments in its system to identify those that will arrive at the destination terminal the next day, allowing customers to plan delivery routes up to one day in advance. Another subsidiary, Roadway Logistics Systems, provides customized logistics services involving Roadway and other transportation companies (Roadway, 1992).³⁶

Such long-term relationships are evolving into alliances involving manufacturers, carriers, and retailers. They are relationships rather than a series of transactions, and they entail a high level of performance, to the point where suppliers will buy critical out-of-stock parts from competitors rather than miss filling a customer's order. Compared to the internal vertical integration once characteristic of U.S.

³⁴The error rate with barcoding is 1 in 2.5 million, compared to a 1 in 300 rate with manual operations (Scaringe, 1992).

³⁵Roadway's provision of free software to its largest shippers is a shrewd marketing strategy, since it locks them into Roadway.

³⁶See footnote 4 of this section for another example of customized logistics services. Caterpillar has used its success in managing its own parts operations to sell its services to other large companies.

auto producers, loosely coupled vertical and horizontal alignments have arisen across the production-distribution spectrum. Examples of the former include the distribution link between Procter & Gamble and Wal-Mart, where traditional wholesalers and purchasing agents have been eliminated, or the more complex arrangement in the women's ready-to-wear apparel industry involving a fiber manufacturer (Du Pont), a fabric producer (Milliken), a garment producer (Leslie Fay), and a department store chain (Dillard's). Here, the companies function like units within a kind of *virtual organization*. An example of the latter is the use of EDI to facilitate the joint delivery of *different* products to a single customer (Bowersox, 1990).

6. Supporting Business Processes

Introduction

The "core" business practices described in the preceding sections cannot stand alone. No amount of exhortation to integrate, no collocation of team members, no preaching about the customer's primacy will help managers assure that business processes are tightly integrated or that the customer really does affect the firm's behavior. All the old animosities and internecine battles will remain, so long as changes are not made in the ability of the various intrafirm constituencies to understand their own functions and how they affect the customer. Nor will the battles diminish until the incentive structure changes so that department and team members recognize that they will either hang together or hang separately.

Firms need systems to support the business processes described earlier, whether these include production, accounting, or human resources. Production support systems are needed to assure more integrated information flows in the firm's internal operations and may include a variety of "production-dependent" technologies. The management systems are important because of the need to maintain high levels of efficiency—ensuring that available resources are used most productively. Recent innovations in accounting theory and practice appear to identify the real costs of designing, manufacturing, and delivering products to consumers.

Finally, new human resource policies accentuate the interdependence and control of the individual workers whose contributions determine the firm's (or a product line's) success or failure in the long term. In addition, they also seek to intensify the interdependence of the traditional functional departments.

Information Management

Shipping and distribution aptly illustrate how heavily business and production processes depend on information systems. Though exceptional, they are not unique. Any commercial enterprise larger than a single office needs information technology to knit its various functions together, whether field offices sending current financial data to divisional offices and headquarters or laboratories exchanging technical data with product development centers and the factory floor. But geographical dispersion, which makes some kind of automated

communications backbone necessary, is relative. Communications can link sites halfway around the world or as near as the next room. In either case, automated systems can increase processing speeds and collapse the time between an event and its consequences (Rockart and Short, 1991).

Problems in Assimilating Information Technology

Despite its benefits, information technology (IT) cannot be superimposed on organizations unprepared to exploit it. Organizations move through three stages in using IT. They can automate existing organizations to wring paper out of the system and reduce the number of workers needed. Most firms are still at this stage. Their approach merely reinforces an old view of technology adoption whose aim was to build a machine that would remove the human from some process or simply accelerate some existing manufacturing operation. Some organizations have attained the second stage. They have "informed" their operations: Recognizing that some benefits of IT are unknown or unpredictable until a system is in place, they often acquire new information as a by-product of their activities and use it to generate leads for new products and services (Morton, 1991).¹ Finally, executives at some companies realize that using IT effectively requires that it be applied to all business processes because all units need to share information. According to this view, which runs through our report, marketing is not something absolutely distinct from R&D, R&D from manufacturing, or manufacturing from shipping, distribution, and parts resupply. All these processes draw from the same information sources, and workers in any one area need to be able to communicate with the others.

Means for enabling firms to share information among all their units have existed since the mid-1980s, when the nature of the technology fundamentally changed. The key problem in information is no longer one of allocating a scarce resource, as it is one of digesting the enormous amount of potentially relevant data and turning it into useful information for practical action. Processing and communications power that was available only through central mainframes has migrated to desktop and laptop computers that link up to other computers through local area networks, modems, fax boards, and soon wireless receivers operating on radio frequencies.

IT as much as anything can enable firms to make those simultaneous improvements in quality, price, and speed discussed in earlier sections. It is not

¹For instance, when a cashier electronically scans an item at a Wal-Mart or K-Mart line, the encoded information will speed the transaction, give the company information on which products are moving and in what quantities, and at a certain point automatically trigger a reorder to the supplier.

that computers, switching systems, satellites, and high-speed laser printers perform functions different in kind from older technologies, like the telegraph, the punched-card sorter, and the telephone, which also collapsed distances and shrank times. Any information technology must be able to convert information from one form to another, store it, manipulate it in some fashion, and transmit it from one place to another (Yates and Benjamin, 1991). The changes are in the speed and the number of transactions that occur.² High-bandwidth optical fiber communications can now carry thousands of voice, data, and video messages simultaneously. Very large databases for parts ordering, airline reservations, shipping rate negotiations, and credit card transactions can store information on vast numbers of items: information that can be updated in real time, transmitted to dozen of sites instantaneously, and used to track hundreds of thousands of transactions hourly.³ In the area of product design, a relatively inexpensive workstation can use computer-aided design (CAD) software to construct three-dimensional models of machine tools, automobiles, and aircraft that can be analyzed, redesigned, and rotated on the screen (Milgrom and John, 1990).

The very abundance of cheap, powerful technology poses many problems, even for enterprises whose executives think they know how to employ it. The devolution of the old central processing systems to isolated or networked users implies substantial improvements in the integration of information with most firms' core production processes. But for most firms, the promise of technology has been somewhat greater than the performance (Attewell, 1992). Put another way, there may be no correlation between a company's IT investments and its financial performance (Strassmann, 1990).⁴ Faced with the choice of doing nothing or somehow lagging their competitors, corporate executives may invest on faith, hoping that the investment will lead to greater productivity over time.⁵

But the lack of fit between IT investments and results is not just a matter of using the wrong effectiveness measures. It also reflects a real problem. For every Wal-Mart, Hewlett-Packard, Caterpillar, and Federal Express that knows how to use

²The time for transmitting a page of text from New York to Chicago fell from 252 hours in the prerailroad 1840s to 48 hours in the 1850s (railroad), to 0.083 hour (telegraph), also in the 1850s, to 0.0019 hour in 1988 (Yates and Benjamin, 1991).

³During peak periods, a computerized reservation system like American Airlines' SABRE handles nearly 2000 messages per second and creates more than than 500,000 passenger name records every day. The database contains 45 million fares with up to 40 million changes entered each month (Hopper, 1990).

⁴Among these measures are information technology expense-to-revenue, revenue-per-employee, computer personnel-to-total employment, and profit-per-employee.

⁵One could also argue that the problem is not so much a lack of correlation as the inadequacy of current effectiveness measures in reflecting a company's operations. A recent survey of service companies' use of technology ranked Wal-Mart at the bottom, because those who devised the effectiveness formula did not realize that a successful retailer incurs only a small amount of value added for each dollar of revenue (Strassmann, 1990).

IT to support and strengthen all its operations, many more use technology only to "pave the cow paths" (Hammer, 1990). Where firms use automation as an alternative to restructuring, they succeed only in superimposing another layer on existing bureaucracies, which can usually find ways to defuse or neutralize the threat to things as they are. In addition, implementing IT can create chaos while people and processes adjust, thus yielding **lower** productivity in the short term (Attewell, 1992). In these cases, automating the existing organization may make it more, not less, difficult for those inside to understand what they do. Perhaps more important, it may make it less able to change.⁶

Systems Development Approaches

Even where firms wish to go beyond automating things as they are, they often fail for lack of a clear vision of how the technology would enable the firm to perform its mission better (Levine, 1990). Again and again, the trade press reports horror stories about organizations betting the store on a major systems development. Systems developments may fail because the sponsor made too abrupt a transition from paper-based to highly automated systems. Or a corporate division's development plan may fail because no common theme runs through all the parts. Or a proposed development may prescribe technology more advanced than users need. In each case, corporate executives lack a clear vision of how the technology would enable their firms to perform their missions better (Levine, 1990).

When systems developments succeed, they do so *because they support functions across the organization*. Otis Elevator's OTISLINE system is an excellent example of how a new or reconfigured system can integrate many functions across all divisions.⁷ Otis sponsored the new system once executives realized that, as new commercial and residential construction shrank, capturing a larger portion of the service business was essential. To this end, the company designed OTISLINE as a centralized 24-hour automated service that replaced over 350 independent answering services in North America with one system that could dispatch a service person to the scene in 30 to 60 minutes. Once the company decided on a replacement, it centralized the first phase of implementation to assure that all

⁶But even where a company uses IT to innovate, it may leave things more or less unchanged. A company may gain a temporary advantage with a new product, but it will soon be matched by competitors. In that case, the innovations will not necessarily expand the market, even if each company was right to innovate (Weber, 1992b).

⁷The document from which we draw OTISLINE case material notes that OTISLINE exemplifies a *bounded grand design* strategy—a comprehensive strategy for systems modernization but one that *bounds* the effort based on schedule and budget targets and organization-related specifics (American Management Systems, 1991).

company technology activities were integrated. As maintenance and service data on each elevator or escalator were entered, they could be used, not only for field maintenance, but to improve product research, sales, and manufacturing (American Management Systems, 1991).

OTISLINE succeeded because, from the outset, its sponsors had a very clear idea of what information systems could do to make the firm more productive (American Management Systems, 1991). They had a well-defined objective—capturing a larger share of the service market—and a specific plan for attaining it. They also knew that, while their clients were geographically dispersed, they had roughly similar requirements. Thus, a single platform that could evolve seemed the appropriate way to improve service that responded to elevator and escalator mechanical problems. Additionally, while OTISLINE technological solutions were aggressive, they were well within proven technology. OTISLINE is a sophisticated system that uses computer-aided voice communications, integrated voice and data communications, and a variety of mainframes and personal computers. Otis successfully tested each element of the new system before adopting it. Once OTISLINE was deployed in phases, the company could enhance it, for example, by adding a PC-based remote elevator monitoring system. A final important feature in developing OTISLINE was that the system was data driven. That is, the company used the data entered once, when service calls were made, and then relied on it both for field maintenance and product improvement.

The Federal Express COSMOS IIB Tracker System mentioned in the preceding section represents a more incremental approach to systems development (American Management Systems, 1991). Given the highly competitive nature of overnight package delivery, Federal Express must maintain complete control over every package shipped. The company turned to automation to improve client service and to gain greater control over the movement of packages, or rather, by answering package location queries and improving on-time delivery, COSMOS IIB was precisely the way to improve customer service.

COSMOS consists of a hand-held computer that scans and records the air bill number, the carrier, the recipient, and status at point of pickup, and radios the information to the central COSMOS system before the package reaches the next drop-off point. Federal Express can use this radioed information to track packages as they move from point to point and use up-to-the-minute data to schedule deliveries.

Compared to OTISLINE, Federal Express developed and deployed COSMOS IIB incrementally. To a greater extent than OTISLINE, developing COSMOS was

risky. It required the company to approve a major investment in more than 40,000 hand-held computers that used technology much more advanced than the existing system. To minimize the risks, Federal Express chose a phased approach. Its Information Services Division first monitored the advance of hand-held computers before determining that the technology was mature enough to meet the company's needs. After prototyping specially modified hand-held units, the company then drafted a systems architecture that specified how a tracker system would be developed and operated and how it would connect to related systems. The actual development required Federal Express to update its own information systems, even as the vendor developed the hand-held computers, and to train its couriers, managers, and systems personnel in using the new system. When COSMOS IIB was deployed, it was completely integrated with existing systems and software.

This account at least suggests why COSMOS IIB met its goals. First, system planning and business planning were integrated. COSMOS IIB was only one of many projects competing for corporate investment. To justify proceeding, those who championed the project worked with couriers and managers, as well as systems analysts, to develop the specifications. Thus they gained and kept the support of top executives from the prototype stage on. Second, the project proceeded in stages in such a way that each phase built on the preceding phase of development. Third, as with OTISLINE, developing COSMOS IIB offered significant benefits that justified a substantial investment (American Management Systems, 1991). Once deployed, the new system reduced operating costs, improved package deliveries by scheduling them more accurately, and thereby improved customer service.

OTISLINE, COSMOS IIB, and comparable system developments illustrate how newer systems differ from more traditional ones.⁸ Generally, the state of technology is *not* the principal constraint in developing solutions to problems. Sophisticated technology is usually available to meet requirements if they are defined narrowly enough. Unfortunately, the complex situations most organizations face today do not usually lend themselves to straightforward, off-the-shelf solutions. Commercial enterprises are seeking to integrate their internal *and* external operations. Systems must be able to accept data from a range of sources and process them for a changing range of users. Moreover, as users learn about IT tools, they demand a variety of sophisticated applications that can work

⁸Other examples of successful design would include the integration by the Travelers Companies of claims processing, end-user computing and financial modeling, Frito-Lay's use of IT to improve sales and distribution, McKesson's Economist System cited immediately below, and the Communications Network for Electronic Reinsurance (CONFER) developed by General Re, the largest U. S. commercial reinsurer (American Management Systems, 1991).

together. Linear programming, databases, text processing, and spreadsheet design and use are typically "requirements" for most business undergraduates today.

Newer information systems differ from their predecessors because they are integral to corporate business strategies. While American Airlines' SABRE reservation system, McKesson's Order-Entry System, and Merrill Lynch's Cash Management System were initially designed to overcome operational bottlenecks, they now serve both to support and to reshape the sponsoring organization (Venkatraman, 1991). They are also major profit centers in their own right. A system that does only one thing, no matter how well, is less useful to such an organization than one that combines several functions, because the latter is better placed to help the organization develop new products and services.⁹

Information Technology in the New Business Environment

Organizations that adopt the new management paradigm make very specific demands of information technology.¹⁰ As they evolve, they look for interoperable, vendor-independent systems that can accept and transmit data from a variety of users.¹¹ They, or rather the managers that employ them, have moved beyond simple transaction processing. In this environment, organizations integrate all their business processes seamlessly.¹² Business networks specific to the organization share information and expertise. Thus, production engineers receive design data from product development offices,

⁹A good example of IT deployment is McKesson's Economist System, which has created new management reports as a by-product of its order entry system, third-party claims processing as something incidental to the same dataset, and drugstore credit card systems (Venkatraman, 1991).

¹⁰Some readers may wonder whether our emphasis on system development may not slight system operations. In practice, the two are hard to distinguish. Whether proprietary or supplied by vendors, information systems must be maintained, modified, or redesigned to accommodate new business conditions. All systems deteriorate because none is fully optimized. Without organizational commitment, systems will atrophy, either because the system no longer meets the needs of the organization or because existing systems cannot accommodate newer technology (Wilmeth, 1990).

¹¹This observations seems to contradict what was said above about the power of proprietary systems like SABRE. But even SABRE and other centralized systems are becoming too big and expensive for any single company to develop on its own. American Airlines, according to the executive who once directed SABRE, will share the system with those who want access to it. He adds that "for companies to remain low-cost providers of information, they must tap the enormous capacities of their systems. Tapping that capacity requires opening the system to as many information suppliers as possible and offering it to as many information consumers as possible" (Hopper, 1990).

¹²A short list of application tools that could be incorporated in corporate systems would include scanners, faxes, CAD/CAM software and workstations, video conferencing, audio conferencing, electronic bulletin boards, value-added networks, wide area networks, computer-aided software engineering (CASE), compact-disk storage media, and expert systems for design, diagnosis, and problem solving.

interpret, modify, and reconstitute the data and ultimately send them to the shop floor to be embodied in specific products.

Under such conditions, organizations are shifting their attention from systems to information and from technology to the uses to which the technology can be put (Hopper, 1990).¹³ As technology becomes even more powerful, it actually becomes easier to use. With programs that allow users to move easily between word processing, spreadsheets, and CAD/CAM (computer-aided design/computer-aided manufacturing), the technology is becoming more transparent to users. But ease of use does not necessarily translate into ease of application. Even those organizations that do understand how to use information are still absorbing the lessons learned from rethinking the meaning of "information management."

Automating corporate operations gives rise to two paradoxes. The first is that the more powerful the technology, the more harm it does when isolated or encapsulated within the organization. Isolating automation to one function or one part of an organization will not work, at least in the long term, because it simply creates bottlenecks and discontinuities. For example, a product development unit working with CAD/CAM software may not be able to send design data to the shop floor if the plant's communications hardware cannot handle data-intensive applications.¹⁴ Precisely because such units are "islands of automation," firms cannot fully realize their investments.¹⁵ The firms that this report considers have automated successfully because they realized that automation had to go beyond marginal adjustments. It required substantial, closely coordinated changes across all operations (Milgrom and John, 1990).

The second paradox is that training becomes more necessary as technology becomes easier to use. Access to any technology is no guarantee that it will be wisely used.¹⁶ In particular, users can no longer think of their hardware and

¹³Using information and manipulating it are not necessarily identical. A firm may outsource its data processing operations to free its internal staff to do high-level programming and strategic planning, to exploit a vendor's superior technical competence, or to reduce costs. But the information generated by outsourcing is as fully available to the organization as if it had been generated internally. See outsourcing discussion in preceding section.

¹⁴A similar situation occurred during Operation Desert Storm, where the lack of up-to-date distributed communications for processing huge volumes of data hindered the dissemination of imagery to tactical forces (Macedonia, 1992).

¹⁵The problem transcends lack of capacity. Milgrom and John (1990) have shown that certain practices or groups of activities are complementary, in that increased marginal returns for any subset generate increases in the remaining activities. To institute one practice without introducing complementary practices may be unprofitable, a point to which we return in the final section of this report.

¹⁶Operating in traditional fashion, a General Motors plant took 34 hours to produce a car with an average of 1.16 defects. After GM invested \$650 million to automate the plant, it still took almost

software as stand-alone devices. The new business environment has spawned a variety of task-oriented teams that can use IT to exchange ideas, work on problems, and collaborate on designs. None of this is inevitable. Training is needed to make IT effective—to enable users to understand the organization's information architecture, to adapt to upgrades of current systems, and to prepare users who did not include system operation or application development (Stasz et al., 1990). Compared with those in traditional organizations, workers in firms that adopt the new paradigm do not merely perform discrete tasks. To work effectively, they must have a better understanding of their place in the organization than traditional firms would have considered necessary or desirable. The concurrent introduction of advanced information systems only makes the need for such training imperative.

Management Accounting

Current accounting systems provide misleading information about internal costs within the firm, because the traditional allocation of indirect costs to direct product costs can lead to flatly wrong assessments of true marginal costs. In turn, this leads to nonproductive management decisions. The new approach to management accounting clarifies true marginal costs and improves managers' ability to identify problems and make realistic choices (Cooper and Kaplan, 1988; Hiromoto, 1988; Blaxill and Hout, 1991).

The new cost accounting philosophy rejects the prevailing approach that allocates most overhead costs to direct labor. With direct labor a shrinking proportion of total costs, accounting systems must reflect the actual costs of production. Adding materials costs and machine hours makes things easier but not necessarily more accurate. By allocating costs by direct labor, materials, and machine hours, conventional accounting overstates profits on specialty products and understates them on high-volume commodity items (Cooper and Kaplan, 1988). At a certain point, it would be cheaper to exit the market than to continue selling some "profitable" items.

The new accounting approach is *activity-based*. Virtually all costs can be broken down and then traced to individual products and support activities (Cooper and Kaplan, 1988). Activity-based costing (ABC) makes it easier to identify expensive resources, those whose consumption varies by product type, and those for which demand patterns do not correspond to traditional allocation measures like direct

34 hours to manufacture a car. The principal change was that the cars now had an average of 1.37 defects (Osterman, 1991).

labor, processing times, and materials. Companies that adopt this approach will often begin by collecting data on direct labor and materials costs. They will then examine the impact of specific products on indirect resources, first, by looking at expensive resources, second, by focusing on resources whose consumption varies by product type, and third, by identifying resources for which demand patterns do not correlate well with direct labor or processing times (Cooper and Kaplan, 1988).

The first step really emphasizes that different products must be treated differently. Consumer goods, high-technology products, and certain capital goods have different cost structures that a firm's cost systems should reflect. A consumer goods company needs information on its marketing and distribution as well as manufacturing costs, only some of which differ by product line. By contrast, a capital goods manufacturer might be more concerned with the relation of manufacturing overhead, like depreciation, to specific products. In another category, research and development, it would be essential to distinguish between R&D that modifies existing products and R&D that explores entirely new ones. The first kind of R&D can be charged back to existing products. The second is an investment in the future—not a cost of the period during which it occurs (Cooper and Kaplan, 1988).

ABC not only traces existing costs more accurately than conventional systems but also points to opportunities for increasing profits. It does so in two ways. First, ABC can justify new production systems by explaining how and why they are profitable and by quantifying the benefits. Second, by unraveling the costs of producing an item, executives can decide where to focus their investments. Based on an ABC analysis, a manufacturer may prefer to produce high- and low-volume products in separate facilities instead of under one roof (Cooper and Kaplan, 1991).

ABC enables managers to pinpoint and evaluate areas for improvement by allocating costs to products and thereby make more appropriate pricing decisions. These systems do not provide traditional accounting information as much as they provide management information. An ABC system reveals the hidden costs of producing certain products, identifies opportunities to reduce resource consumption and redeploy those resources, and suggests ways for repricing products to better reflect their true costs. By pinpointing exactly where managers can get the greatest return on investment, an ABC system also justifies changes in production systems that make those returns possible.

Organizational Design, Human Resources, and Management

This section describes several important changes in organizational design, human resource policies, and management style and tasks that support process redesign and enhance the efficiency of the redesigned processes:

- self-managed teams
- changes in human resource policies and management style
- organizations focused on products and processes.

Self-Managed Teams

In addition to participating in process improvement and redesign efforts, teams of properly trained workers can, in fact, manage the processes they operate.¹⁷ This becomes possible for two reasons. First, process improvements are specifically aimed at preventing the crises that managers in traditional organizations spend much of their time resolving. Second, recognizing the repetitive patterns in processes and setting up standard procedures to deal with the most common range of situations obviate the need for managers to make task management decisions whenever situations change slightly.

In an improved process in which crises are rare and most tasks proceduralized, worker teams can also take over many tasks formerly performed by indirect departments. Members of these teams can perform their own in-process inspections, schedule jobs through their processes, order materials, and train new team members. Manufacturing workers can do routine equipment maintenance and control the small remaining WIP inventory rather than call in specialists and then wait until they show up.

In some cases, teams can take on work that was done by professional indirect staff, such as interviewing job candidates and making hiring decisions. At NUMMI, a Toyota-GM joint-venture automobile factory in Fremont, California, teams design their own jobs, a task that formerly required a staff of 80 industrial engineers (Adler, 1993).

Teams also accomplish some things that a traditional hierarchical structure cannot. For example, they can apply pressure for attendance and work discipline

¹⁷See, for example, Adler (1993), Katzenbach and Smith (1993), Case (1993b), Magnet (1992a), Ostroff and Smith (1992), Stalk and Hout (1990), Stayer (1990), and Stewart (1992b).

through peer pressure (Barker, 1993). Crosstrained team members can rotate jobs to relieve boredom and physical stress or fill in for colleagues when absences occur. Workers who have developed their own work procedures and problems solutions need not be coerced by supervisors into applying them diligently, which is especially important given the absence of slack in synchronized processes.¹⁸

What roles do the remaining managers and indirect staff play? Managers can provide leadership and expertise in training, process improvement efforts, problem solving, or dealing with complex, unique occurrences. Perceptive managers can also rise above the details of a particular process, seeing where the system can benefit more from reengineering a whole group of processes than from fine-tuning one or more existing processes (Senge, 1990; Senge and Sterman, 1992).

Indirect departments help establish programs and guidelines for teams or perform tasks requiring specialized skills. For example, quality assurance can provide training, methodologies, audits, and help with complex problem analyses (Juran, 1962). Personnel can set interviewing and hiring guidelines for teams and help if a problem worker must be terminated.

Changes in Human Resource Policies and Management Style

Self-managed teams, innovative human resource policies, and changes in management style appear to be mutually reinforcing. One indication is that while some firms have experienced significant productivity gains from thoroughgoing team implementations (Stewart, 1992b; Case, 1993a), other U.S. firms that have implemented programs like quality of work life (QWL), employee involvement (EI), and quality circles (QCs) within traditional organizational contexts have seen ambiguous effects on firm performance (Levitan and Werneke, 1984; Bailey, 1992; Kochan and McKersie, 1992). This result may be caused by the difficulty in measuring variables and relating them through testable models (Porras and Silvers, 1991; Bailey, 1992). But others blame implementation that was not thorough enough, for example: merely cosmetic enrichment of unpleasant jobs (Herzberg, 1987), teams that exist on paper but not in fact (Womack, Jones, and Roos, 1990), or quality circles

¹⁸Although self-managed teams provide workers a much greater degree of control than traditional organizations, they can also create new kinds of stress for members. The relentless work pace of JIT processes, group-imposed work norms, and mutual accountability for results are pressures not found in traditional organizations (Klein, 1989; Inman and Brandon, 1992; Barker, 1993).

established without real purpose or authority (Lawler and Mohrman, 1985; Shea, 1986).

In addition, those who write about TQM, JIT, and other new management philosophies insist that human resources policies and management style should support worker/management cooperation and worker input into process improvements; this view is implicit in discussions of self-managed teams.¹⁹ Young (1992) summarizes much of this information succinctly and proposes a research framework but does not yet report data. Nevertheless, several themes recur in discussions of human resource policy and management style changes that enhance the performance of redesigned processes.

The first is that workers must be more broadly and systematically trained than is currently the case in most organizations (e.g., Deming, 1986; Reid, 1990; Suzuki, 1987; Woutat, 1991). First, they need structured training in all the tasks their team performs and that they may be expected to rotate through. Second, they need training in statistics, process improvement techniques, group skills, and communications. They also need to learn the basics of the indirect tasks once done by others, such as scheduling, job analysis and design, and maintenance. Finally, some firms train all employees in understanding the basic products, organization, philosophy, mission, and values of the firm.

Second, traditional evaluation and incentive programs that evaluate only individual performance usually are modified in a team environment (Kanter, 1987; Schonberger, 1990; Dumaine, 1992; Stewart, 1992b).²⁰ Firms may use a mix of evaluation and incentive criteria to prevent individuals (or teams) from concentrating on one aspect of their performance to the detriment of the team or the firm as a whole. Potential criteria include aspects of team performance, overall firm performance, and individual employee skill development. The ability to lead groups in solving problems and improving processes can become an important promotion criterion (Davenport and Short, 1990; O'Boyle, 1992).

Third, job security provisions, such as pledges not to lay off workers because of worker-generated process improvements, are an especially important

¹⁹In extreme cases, implementation of JIT without sincere attention for workers' concerns can lead to alienation as great as that in traditional factories. Profound worker dissatisfaction developed at Mazda's Flat Rock, Michigan, factory as a result of intense pressure to increase production rates, heavy-handed top-down imposition of work standards and *kaizen*, insufficient responses to health and safety issues, management's unwillingness to pay for necessary tools or rudimentary worker comfort items, lack of crosstraining and job rotation, and other problems (Fucini and Fucini, 1990). A similarly oppressive environment is reported to have developed at the Subaru-Isuzu automotive plant in Indiana (Graham, 1993).

²⁰A recent *Harvard Business Review* article (Kohn, 1993) contains a spirited critique of incentive plans (with an extensive reference list); the November-December 1993 issue of the *Harvard Business Review* has responses from several compensation experts.

underpinning for virtually all the new management principles discussed so far (Woodruff et al., 1992; Young, 1992; Adler, 1993). From the perspective of management, knowing a worker will be a long-term employee is an incentive to invest in developing that employee's skills. On the worker's side, a commitment from the firm can elicit the constant innovation required for continuous improvement and the steady work pace dictated by a tightly synchronized process.

Finally, managers and indirect staff in a team-based organization see their role as assisting workers in doing their jobs, not controlling activities in detail or performing tasks that can be delegated to workers (Greenleaf, 1977; Senge, 1990; Kiechel, 1992). Leadership and motivation skills are important to managers in this environment (Harris and Drucker, 1993; Webber, 1993). An analogy is often made to athletic team coaches, who set policies and procedures and conduct training but in the end must stand on the sidelines as the athletes play the game. Bringing about this attitude change is often a difficult implementation problem when moving to a self-managed team organization. Training programs can be set up to help managers understand and perform in their new role, but supervisors who continue to resist the changes may need to be replaced (Klein, 1984; Krantz, 1989; Stern, 1993).

Organizations Focused on Products and Processes

Hierarchical decisionmaking and coordination can degrade the performance of synchronized processes by imposing a delay for communication upward, evaluation by the decisionmaker, and communication back down (Suzaki, 1987).²¹ The difficulty may be compounded if information is distorted in the up and down communication. Some alternative approaches are standardizing procedures, empowering teams to make local decisions about their processes, and using horizontal communication mechanisms between teams, such as the *kanban* inventory control system used in JIT factories.

In addition to giving greater emphasis to horizontal coordination mechanisms, firms can reap further benefits by structuring their organizations around processes and products, minimizing the use of traditional departments (Schonberger, 1990; Byrne, 1993). Firms with multiple product lines can set up self-contained units, each containing the synchronized critical path processes necessary for a given product line, associated business processes, and perhaps

²¹Aoki (1990) proposes that a horizontal mode of coordination, instead of a traditional hierarchical mode, is one of the most important factors in the success of Japanese firms. Ostroff and Smith (1992) also advocate moving from vertical to horizontal organizational structures.

some functional specialists. Each unit's leader has great operating autonomy but is also held accountable for the unit's performance. Within the unit, self-contained subprocesses (run by self-managed teams) are set up at as low a level as possible. Functional departments and production processes are shared only when they clearly have scale economies that outweigh the advantages of being split off into the product units. At Kodak, for example, six product "flows" have been organized. Black and white film, one such flow, forms the basis for the "Zebra Team" unit. It has several self-contained manufacturing "streams" and all necessary support functions except human resources and accounting (Ostroff and Smith, 1992; Stewart, 1992b).

A multifunction product-focused unit can be both more responsive to customer needs and more efficient than a traditional organization. Its small size, strong leadership, and clear focus on certain products help prevent suboptimizing along departmental lines, since people in each process can clearly see how their actions affect the performance of the entire system. Because the chain of internal customers leading to the final customer is short, performance measures for each process can be clearly tied to customer satisfaction (Ostroff and Smith, 1992). Horizontal communication is enhanced, and conditions are ideal for synchronizing flows in manufacturing, distribution, and business processes.

The organizational structure of such a focused, self-contained unit can be quickly changed in response to changes in technology or customer needs. A *pull* mentality drives such an organization—customer needs determine both its design and its day-to-day activities. By contrast, the difficulty of *pushing* products, information, and new designs—let alone structural changes—through a traditional departmental organization leads to both inefficiency and rigidity.

Multifunction, product-focused organizations generate economies of coordination that may exceed the economies of scale derived from compartmentalizing skills in functional departments. The efficiencies deriving from synchronized process flows or from product designs optimized for manufacturability are examples of economies of coordination. Nevertheless, economies of coordination are consistent with the economic principle that efficiencies derive from the division of labor—the division is by process and not by functional skill. A group dedicated to a given process can bring to bear many concrete techniques to maximize its efficiency in a way that a traditional functional structure cannot.

The traumatic transitions being experienced by General Motors and IBM (Kirkpatrick, 1993) demonstrate that there is no clear model to guide the transition of large, diversified firms to independent product-focused

organizations.²² On the other hand, firms like Johnson & Johnson (Weber, 1992a) and Hitachi (Gross, 1992) have prospered for years with 100 or more independent units. General Electric (Tichy and Charan, 1989; *Economist*, 1991) and Asea Brown Boveri (Rapoport, 1992) have in recent years aggressively trimmed headquarters staffs and given more independence to operating units. Prahalad and Hamel (1990) suggest that the key to the success of diversified firms is how well they develop and employ their core competencies, such as fundamental technologies applicable to a broad range of products.

²²Creating such independent units is not the same as the unrelated diversification many traditional firms engage in (Porter, 1987).

7. Implementation Issues

Introduction

Although this report relates many stories of performance improvements in firms that adopt the new management paradigm, our account leaves some important questions unaddressed. First, what fraction of firms have adopted the new paradigm? Second, what bottom-line performance benefits are to be expected from adopting it? And third, what lessons can be gathered from the experience of firms that have either successfully adopted the new paradigm or tried to do so and failed? These three questions are the subject of this concluding section.

How Extensive Is Adoption of the New Management Paradigm?

There are no rigorous, objective evaluations of the prevalence of that complex of business practices we call the new paradigm across the full range of firms and industries. Although surveys of the adoption of innovative management practices and organization structures provide some data, the survey method has several drawbacks in assessing the prevalence of a new paradigm. Because intensive multifirm case studies remedy some of these deficiencies, we discuss the relatively few that have been described in the literature. But even these studies cannot evaluate the observed differences in adoption rates across industries.

Surveys

Surveys of firms are popular tools for many purposes, but they fall short of gauging the extent of implementation of a complex set of interrelated business practices. A survey may be sent to a biased sample of firms, for example, based on membership in an industry or association whose members are either more or less likely to adopt the new paradigm than firms in a representative sample would. Some reports and articles fail even to discuss sampling design, so that readers are unable to understand and critique it. Very low response rates (e.g., 25 percent or less for many surveys reported in *Production and Inventory Management Journal*) often render the significance of results questionable. For

example, firms that have adopted the new paradigm may be more likely¹ to respond than firms that have not. Some reports do not even publish response rates, only the total number of responses received.

Even for responses that are received, methodological concerns remain. It is difficult to assess from published reports the degree of possible ambiguity or bias in the wording of questions or analysis of data. This is of particular concern for the large number of surveys conducted by consulting firms, who have marketing motives in conducting the research and presenting the results. Respondents may incorrectly say their firms are following certain practices, either because they misunderstood the terminology used in the questions or because they want to give socially desirable responses. Similarly, firms may respond affirmatively even if certain practices are being applied only superficially or in a small portion of their operations. But perhaps most troubling for the questions raised by this section, even a firm that has implemented a subset of the interrelated practices discussed in this report may not really have adopted a new paradigm.

For what they are worth, some of the better-quality surveys indicate that many firms say they are implementing at least some of the practices discussed in this report. Hiam (1993) analyzed six surveys of the rate of TQM implementation. Despite the methodological deficiencies of individual surveys, all report TQM implementation rates among responding large firms between 75 and 85 percent. Eighty-five percent of respondents to a survey of members of The Business Roundtable (an association of large corporations) indicated they had adopted TQM (Quality Progress, 1993). In a survey of members of the Association of Manufacturing Excellence, 89 percent of respondents indicated they had applied at least one of ten JIT practices,² while 85 percent had applied three or more, and 18 percent all ten (White, 1993). A survey of members of the American Electronics Association showed 72 percent of respondents had implemented TQM, 57 percent JIT manufacturing, and 53 percent Design for Manufacturability (Pittiglio Rabin Todd & McGrath, 1993a). But only 35 percent of respondents to a similar study of software firms had implemented TQM (Pittiglio Rabin Todd & McGrath, 1993b). The International Quality Study, which surveyed automotive, banking, computer, and health care firms in the United States, Canada, Germany, and Japan, found considerable variation across countries in implementation rates for individual management practices (American Quality Foundation, 1991).

¹Or may not be—one simply cannot be sure.

²Quality circles, total quality control, focused factory, total productive maintenance, reduced setup times, group technology, uniform workload, multifunction employees, kanban, and JIT purchasing.

Case Studies

Detailed case studies are more effective than surveys for determining the depth and breadth of implementation of new practices by individual firms. However, the subjects of case studies are usually not chosen representatively, and implementation successes are probably reported more often than those of failures. Therefore, case studies cannot describe the extent of implementation of a set of new practices, unless the cases are chosen as part of a representative sample of firms within or across industries. A comprehensive case study of all firms in an industry would give the most detailed data about implementation in that industry.

Some carefully constructed studies of this type reveal a less favorable picture of the implementation of new business practices than the surveys just cited. The MIT Commission on Industrial Productivity studied eight manufacturing industries,³ comparing U.S. firms to their competitors in Japan and Europe. They found that most U.S. firms in these industries lagged their leading foreign competitors in the implementation of new business practices (Dertouzos et al., 1989). A related study by the International Motor Vehicle Project (IMVP) examined all auto assembly plants in the United States, Japan, and Europe, and found much more extensive implementation of new business practices in Japan than in the United States or Europe. IMVP studies of design teams showed similar patterns (Womack, Jones, and Roos, 1990). A study of 550 firms by the National Center on Education and the Economy's Commission on the Skills of the American Workforce (1990) estimated that 95 percent of U.S. firms still have predominantly traditional, rather than new paradigm, organizations and practices. Citing research by the Work in America Institute, its president estimated that as few as 2 percent of U.S. workers are employed in truly participative organizations, although that percentage is growing (Quality Progress, 1993).

Adoption Patterns in Different Sectors

Our reading of the management literature indicates that rates of adoption of the new paradigm differ significantly across sectors of the economy—intensive in some industries, diffuse in many others, and scarcely under way in a few. Implementation of new paradigm practices appears highest in manufacturing, the sector where U.S. firms were affected earliest and most strongly by the

³Semiconductors, computers, and copiers; commercial aircraft; consumer electronics; steel; chemicals; textiles; automobiles; and machine tools.

intensified global competition of the last two decades. U.S. manufacturing firms were also able to imitate practices that had been highly refined by Japanese competitors. Logistics firms appear to be implementing new paradigm practices at a rapid pace, though. For example, Quick Response programs in the retail industry tightly integrate retailers, distributors, and manufacturers all along the supply chain to reduce pipeline inventories and fill orders faster. Firms that provide their clients third-party logistics services (complete processes including transportation, warehousing, and even order fulfillment) are growing very rapidly (Muller, 1992). Service industries appear to be adopting new business practices, especially for the transaction-intensive operations typical of banking and insurance.

The extent to which other service industries adopt new business practices is more difficult to project, either because their complex outputs are less easily defined or because they have large numbers of relatively independent workers interacting individually with clients. Adoption of the new paradigm in public-sector organizations faces a range of additional challenges, including the absence of competitors for many government services, the fact that recipients of services usually do not pay for them directly (or at all, in many cases), and intrusive oversight by political authorities.

What Are the Performance Benefits of Adopting the New Paradigm?

Successes and Failures

The business literature links many firms' success in their markets directly to the extent of their adoption of the new paradigm. Japanese manufacturing firms are the best known examples. Their competitive achievements are attributed to their mastery of techniques like TQM, JIT, and continuous improvement (Dertouzos et al., 1989; Womack, Jones, and Roos, 1990). But many large U.S. firms are also increasing their market share and raising profits by implementing the same practices that their Japanese competitors developed earlier. Chrysler's recent successes have been credited largely to innovative team-designed vehicles and efficient lean manufacturing. General Electric has revitalized its product lines by implementing many new practices—including product design teams and lean production and distribution—and adding its own refinements (Stewart, 1991). Low prices made possible by its efficient distribution processes underlie Wal-

Mart's dramatic growth.⁴ United Services Automobile Association (USAA) has prospered by applying information technology and empowering employees to provide high levels of service to its insurance customers.

Our reading of the literature yielded hundreds of similar success stories at small firms or in particular shops, offices, or product lines of larger ones.⁵ A casual reader might not discern the pattern in stories that are often found in brief articles or buried in longer ones. And evaluating the bottom-line impact of successes in small units of large firms is difficult, since results are usually described in terms of process performance measures, not profit or market share impacts.

Nevertheless, the question remains, What proportion of attempts to implement new paradigm practices fail to produce performance benefits? The large number of success stories cannot address this question, since failures are almost certainly less likely to be reported than successes. Even though anecdotal evidence suggests that failure rates are significant,⁶ we found no convincing, objective research that estimates them. And failure rates alone do not explain whether the failures were caused by new practices not having the potential ascribed to them or by other factors external and internal to the firm.⁷

Disillusionment with TQM?

Since TQM is the most widely implemented group of new paradigm practices, assessing its effectiveness should provide some basis for evaluating the efficacy of the new paradigm. Unfortunately, the available data conflict and do not offer a clear answer to the effectiveness question. Even though most large U.S. firms have TQM programs, recent articles describe some managers' disappointment with their performance effects (*Economist*, 1992; Mathews and Katel, 1992; Jacob, 1993). On the other hand, most studies of TQM report that implementing firms are satisfied with results (Hiam, 1993).

The varying definitions of success and failure used in different articles and studies help explain the confusion surrounding this question. Complaints about TQM can be seen as essentially *subjective*, i.e., that TQM did not achieve the

⁴Unfortunately, Wal-Mart is accused of treating its employees much less well than it does its customers (Grant, 1992).

⁵Suzaki (1987) and Sepehri (1986) provide detailed tables of several such examples of JIT manufacturing.

⁶For example, reengineering consultants estimate that between only one-third and two-thirds of reengineering efforts succeed.

⁷Some of these factors are discussed later in this section.

results anticipated for it, or *objective*, i.e., that TQM did not lead directly to improvements in bottom-line performance. Unfortunately, most studies concentrate on subjective measures, such as self-reports of whether implementing organizations expect benefits from TQM or are satisfied with results. Of the 20 TQM studies reviewed by Hiam (1993), five report no performance measures, and ten report subjective measures. Most firms in these studies profess themselves very or somewhat satisfied with the results of TQM, as do 70 percent of respondents to a recent survey by Price Waterhouse (1993). However, a survey by Rath & Strong (1991) takes a more negative tone, reporting that half of respondents achieved either none or less than half of their TQM objectives.

Only a small number of studies have attempted to evaluate TQM effectiveness objectively. The General Accounting Office studied 20 firms that scored high on the Malcolm Baldrige National Quality Award criteria (United States General Accounting Office, 1991b).⁸ Most respondents in this small sample reported that TQM had favorable impacts on productivity, market share, and profits. Hiam (1993) briefly reports a "strong" correlation between product or service quality levels and profits for firms in the Profit Impact of Market Strategy (PIMS) database.⁹

What is clear is that the strong emotions of both TQM proponents and skeptics may color their analyses. TQM adherents often take an almost religious tone in their writings and have probably oversold TQM as a panacea for all U.S. corporations' ills. But sceptics sometimes pounce on any bad news as an excuse to denigrate TQM without working to understand its underlying logic.

The Impact of Other Factors

Our review of the literature suggests that there is a compelling link between adopting the new management paradigm and improved market and financial performance. But as the debate over TQM's effectiveness demonstrates, the complexity of business organizations and their relationships with their environments means that the impact of any new set of practices on overall performance is influenced by many factors external and internal to particular firms (Garvin, 1991).

External Factors. Many accounts of the success of new management practices in particular firms fail to emphasize the contribution of favorable environmental

⁸The GAO study is one of the five studies in Hiam (1993) that used objective measures.

⁹This analysis is not one of the 20 TQM studies he reviewed.

factors. For example, Harley-Davidson's dramatic 1980s turnaround was based on increased quality, productivity, and attention to dealers and customers (Reid, 1990). But even blessed with a strong brand name and a fanatically loyal core group of "biker" customers, Harley was saved by the government's granting it timely protection from Japanese competitors' imports. Motorola is a model of TQM, but it is fortunate that much of its business is in wireless communications, where rapid technological improvement is possible and demand is growing dramatically.

On the other hand, external factors may overwhelm the real performance benefits derived from implementing new paradigm practices. For example, a firm might make significant, cumulative improvements to a particular product (e.g., mainframe computers), only to see a competing product based on fundamentally different design principles (e.g., microcomputers) eat away at its market. Even highly efficient firms can be put at a large cost disadvantage by currency fluctuations or subsidies from foreign competitors' home governments.

Although it predates real understanding of the new paradigm in the United States, Porter's (1980, 1985) competitive strategy framework remains very useful in explaining how environmental factors affect the performance benefits of implementing new practices. Based on his training in industrial organization economics, Porter elaborates a model for evaluating five threats to a firm's competitive position: existing competitors, potential new entrants to the industry, existing or potential substitute products, supplier bargaining power, and buyer bargaining power.

Internal Factors. Factors internal to a firm can increase or decrease the likelihood of successfully implementing new practices. For example, USAA's history of training and respecting employees created an environment conducive to implementing work process changes and information technology. In contrast, Douglas Aircraft's long record of heavy-handed management and adversarial relations with workers first undermined and then led to the failure of its TQM program (Vartabedian, 1991).

Research shows that the nature of the implementation process itself is one of the most important internal success factors. Although this research focuses on information technology, it is relevant to the present question because introducing information technology into an organization can precipitate the same kinds of changes in work processes, organization structures, and interpersonal relationships as the new business practices we have described. Bikson, Gutek, and Mankin (1987) found that variables describing implementation were better predictors of information technology implementation success than those that

described the technology itself or the organization in which it was implemented. Particularly important variables were the degree to which implementation addressed work group social issues, the amount of learning support the organization provided, and the perception by work groups that their efforts would affect the diffusion of the technology throughout the organization. Bikson, Stasz, and Mankin (1985) highlighted several important elements in one successful information technology implementation: a CEO involved from its inception, careful implementation planning, allocation of resources adequate to implementation (including training), system users' involvement, and the existence of procedures for sustaining improvements after formal implementation ended.

Potential Drawbacks to Adopting the New Management Paradigm

A firm that adopts the practices described in this report can reduce slack in all its processes and mesh them with those of its suppliers and customers. At the same time, it opens itself to disruption from unexpected supplier or buyer behavior; a strike or persistent quality problem at a single key supplier can halt production in a JIT factory. Sudden drops in buyer orders caused by recessions can create serious cash flow problems for firms whose capacity is carefully balanced to meet demand. In such a situation, laying off workers can erode the trust necessary for synchronized processes to run properly (Faltermayer, 1992). Even a leveling off of growth can test a firm that wishes to balance a no-layoff policy with incremental productivity improvements. While the current recession in Japan is forcing firms to confront such problems, it is not at all clear what long-run steps they will—or can—take to address them (Thornton, 1993). Retaining the trust and capabilities of workers, suppliers, and unions during market downturns is probably the greatest long-run challenge that firms adopting the new paradigm face (Niven, 1993).

A larger social concern is the fate of workers laid off by firms that see large productivity jumps from reengineering. The first firms in an industry to reengineer themselves can often avoid layoffs by taking business from less innovative competitors (Davenport, 1993a). But once only reengineered firms remain, many fewer workers will be needed in the industry than before, unless total industry output increases significantly. Will those workers be able to find employment in other industries, especially if the workers whose jobs are reengineered away were those least-educated in the firm to begin with? Individual firms may be forced to reengineer to survive, and consumers will benefit from their increased productivity, but government will probably be left to assist displaced workers in finding new employment.

Implementation Lessons

This report has described the new paradigm in some detail and contrasted firms that adopt it with more traditionally organized ones. However, changing from the traditional to the new paradigm state is as challenging a transformation as any an organization is likely to have to make. The literature surveyed for this report provides a few key suggestions for navigating that transition.

Focus on Changing What Matters to Customers

The implementation of new paradigm practices will not work unless senior managers invest their time and resources in making these practices work. Given the scarcity of these resources, implementations that do not affect the core processes that produce improvements in market share or customer satisfaction can be seen as failures, even if some real short-term efficiency gains result (Hall, Rosenthal, and Wade, 1993; Goodman, Bargatze, and Grimm, 1994). For example, a firm may focus on refining the manufacturing process for existing products, when what it really needs are new designs that are more easily manufacturable or more suited to current customer requirements.

Careful surveys of customers (see Section 4) are one way for firms to decide the processes to change to produce maximum performance benefits. Benchmarking the products and services of competitors is another way to find out what customers expect and where improvements can lead to superiority over competitors. It may turn out, though, that certain practices are necessary just to survive in an industry, let alone create unique competitive advantage. For instance, parts makers increasingly must pass rigorous quality certification standards just to be considered for contracts by automobile assemblers.

Although we have found little systematic research to support it, there are many stories of firms that used major crises to focus on what mattered to customers. A particularly graphic example is the Rockwell International division that produces Hellfire missiles. After Army auditors gave it one of the lowest scores ever given to any contractor, the plant implemented a comprehensive TQM program. Within three years, the resulting dramatic increases in quality and productivity led to the division's receiving a contract for 100 percent of the Army's Hellfire requirements (Velocci, 1991).

An Active Role for Top Management

The literature we surveyed is virtually unanimous in emphasizing the role of top management in successful implementation of new paradigm practices. Only top management has the authority to ensure that sufficient resources are allocated to the implementation program and to step in to resolve the interdepartmental disagreements that can arise when cross-functional processes are redesigned. And charismatic CEOs like Jack Welch of General Electric and Lawrence Bossidy of Allied Signal can provide the leadership to begin and sustain the change process (Welch et al., 1993).

This role is consistent with an emerging new view of corporate strategy,¹⁰ according to which top management should concentrate less on refining detailed strategic plans that they pass down to operating units for implementation than on creating an environment that expands the capabilities of workers and managers to satisfy customer needs.¹¹ One CEO (Stata, 1989) notes that top managers can no longer be "captains" who just steer their organizations but instead must devote most of their efforts to designing those organizations.

Top-down implementation must be tempered by sensitivity to reactions from workers and middle managers. At worst, lack of such sensitivity can lead to the kind of worker alienation that Mazda experienced in starting up its JIT factory in Michigan (Fucini and Fucini, 1990). But at best, innovative middle managers¹² with leadership abilities and authority over processes can guide the pilot efforts that often underlie the successful diffusion of new practices throughout an organization. A department or unit in an organization may innovate from the bottom and then be brought to management's attention by their success.

Choose a New Philosophy Carefully

An important task for top management is to choose an overall change philosophy that most closely targets the needs identified by the customer assessment and competitor benchmarking rather than trying to implement all new practices at once. Over time, more new practices can be added to the repertoire to build on previous successes. But to start out, a firm whose most pressing priority is

¹⁰See Hamel and Prahalad (1989), Prahalad and Hamel (1990), Williamson (1991), Schonberger (1992), Stalk, Evans, and Shulman (1992), Mintzberg (1994), and Hayes and Pisano (1994).

¹¹Top managers must, of course, understand their firm's customers and processes well enough to set in motion change programs that will yield significant competitive advantage. However, top U.S. managers are castigated for having a poor understanding of their firms' operations, concentrating instead on financial management (Hayes and Abernathy, 1980; Hise and McDaniel, 1988).

¹²Often referred to as "champions."

improving quality might choose TQM. If reducing order response times is critical, JIT would be a candidate. If faster new product introductions are essential, the firm could look to time-based competition. If meeting the needs of diverse customers or fast-changing markets is paramount, teams could be the place to start. If the efficiency of transaction processes must be upgraded, reengineering could be the method of choice.

In choosing a philosophy, management should ask whether incremental or radical changes to processes are needed (Davenport, 1993b). If a steady, incremental approach appears sufficient, then TQM methods would be appropriate. But if the firm must quickly make quantum leaps on some performance criteria, reengineering would be a likely candidate.

For each philosophy, many books and articles can provide implementation guidance. The American Society for Quality Control (ASQC) in Milwaukee, Wisconsin, publishes an extensive catalog of TQM-related materials. The American Production and Inventory Control Society (APICS) in Falls Church, Virginia, offers a similar catalog covering JIT, MRP II, and other manufacturing management subjects. Stalk and Hout (1990) is a good source regarding time-based competition. There are numerous books on setting up teams, such as Katzenbach and Smith (1993). Davenport (1993b), Hammer and Champy (1993), and a series of articles by McKinsey consultants¹³ give guidelines for reengineering efforts.

Since many of these books and articles are written by consultants who derive their revenues from helping firms through implementation programs, they often do not contain sufficient detail about organizational aspects of implementation. Engaging one of these consultants can give a firm the benefit of the consultant's experience in previous implementations. But the firm should be an informed consumer so as not to become overly dependent on the consultant or accept advice not sufficiently tailored to the firm's own circumstances.

For firms that do not wish to hire consultants or that want to become more informed consumers of their services, the organizational change literature can fill in some of the gaps in books about particular groups of practices. For example, a recent article by Duck (1993) describes some common pitfalls encountered by change programs and suggests steps to avoid them.¹⁴ Books on the subject include Jick (1993), Mohrman et al. (1989), and Tichy and Sherman (1993).

¹³Kaplan and Murdock (1991), Heygate (1993), and Hagel (1993).

¹⁴Other articles about managing change appeared in the same *Harvard Business Review* issue as Duck's, including Martin (1993) and Goss (1993). Dichter, Gagnon, and Alexander (1993), Schein (1993), and Schaffer and Thomson (1992) also discuss the subject.

Yet none of these texts provides anything like a recipe for successfully implementing new business practices. The literature on which we have drawn indicates quite clearly that the transformation of individual businesses and entire industries can be lengthy and demanding and that success is by no means assured. The incentive to change is not simply that the adoption of new business practices can lead to better products and services, produced in less time and at lower cost. It is, rather, that firms losing competitiveness are more likely to risk the organizational pain that comes with adopting the paradigm. In fact, this conclusion may well be the most important to which a review of the management literature leads.

Appendix

Improvement Tools

This appendix describes some of the basic tools used for process analysis, quality improvement, and quality control, and one sequence in which they may be employed.¹

Process Mapping

Process flowcharts (or process maps) are simply graphical representations of the flow of components, information, or products through the kinds of manufacturing, business, or distribution processes described in Section III (Burr, 1990a). They are essentially horizontal maps of an organization's activities, in contrast to the vertical maps of organization charts. Flowcharts can, therefore, highlight information feedback loops between departments, multiple handoffs of the items being processed, waiting time, and other sources of possible wasted effort or potential mistakes.

Process maps are most complete and useful when developed by the team that actually carries out the process. If the process crosses department lines, representatives from all affected departments are included in the process improvement team. The team first concentrates on drawing the *as is* process map, to ensure that all data about the process are accurately reflected in the map. Only then does the team begin to apply the other quality improvement tools to begin designing the *should be* process map (Rummler and Brache, 1991).

Managers should take a broad perspective so as not to expend effort on optimizing inherently NVA work. A team of supervisors and workers analyzing its own process may not realize that much of their work duplicates work done elsewhere (e.g., multiple entries of the same data) or can perhaps be eliminated altogether (e.g., expediting, which is unnecessary in a synchronized process flow environment).

¹In addition to the references in the text, discussions of process improvement tools are in Ishikawa (1986), Juran (1962, 1988), Feigenbaum (1961), and Sherkenbach (1988).

Cause-and-Effect Analysis

Once a particular problem area of a process map (or source of variation), such as a recurring manufacturing defect or miscommunication between departments, is selected as a focus for analysis and improvement, other tools are brought to bear. Cause-and-effect diagrams (also known as Ishikawa or fishbone diagrams) list all possible causes for the problem in question and the hypothesized causal relationships (Sarazen, 1990). These diagrams are often developed at one or more brainstorming sessions of the process improvement team; a generic example is shown in Figure A.1.

Data Gathering, Analysis, and Presentation

Cause-and-effect diagrams may disclose many possible targets for correction, but they do not show the relative importance of the various possible causes. The next step is, therefore, to gather data, either historical or in real time, about the relative frequency of various causes and the relationships between them. Check sheets are simple tabulations of data, in a format devised by the team to suit the needs of its particular situation (Juran Institute, 1990b). Histograms show the relative frequency of various events (Juran Institute, 1990a). Scatter diagrams are x - y plots that show potential correlations between different causes or between causes and effects (Burr, 1990c).

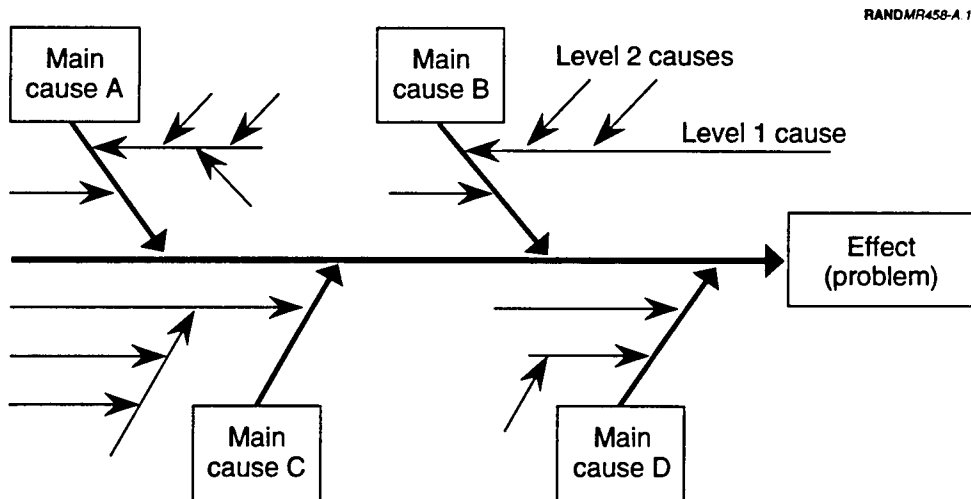


Figure A.1—Cause-and-Effect Diagram

One particularly useful format (shown in Figure A.2) for presenting data is the Pareto chart, which ranks causes in order of descending frequency (Burr, 1990b). In many cases, a small percentage of the causes accounts for a large majority of the problem (effect). Juran formulated this concept into the Pareto Principle: approximately 80 percent of a given problem is likely caused by only 20 percent of the causes. Corrective actions can thus be aimed first at the identified causes that will lead to the greatest reduction in the problem being addressed.

Continuous Improvement Cycle

Corrective actions, whether taken by the firm or its suppliers, are often familiar ones—improving training, clarifying procedures, reorganizing the sequence of tasks, modifying tooling, updating software, etc. But the effect of a given corrective action is carefully monitored using the same data-gathering and analysis tools just described. If its projected results are achieved, it is made part of standard practice, and problem-solving efforts are focused on the next most important cause. If not, new corrective actions are tested until an effective one is found. This cycle of (1) *planning* a corrective action, (2) *doing* it on a test basis, (3) *checking* the results, and (4) *acting* to make it a part of standard practice can be repeated continuously. As more and more causes of problems and variation are eliminated, process performance approaches closer and closer to nominal. This

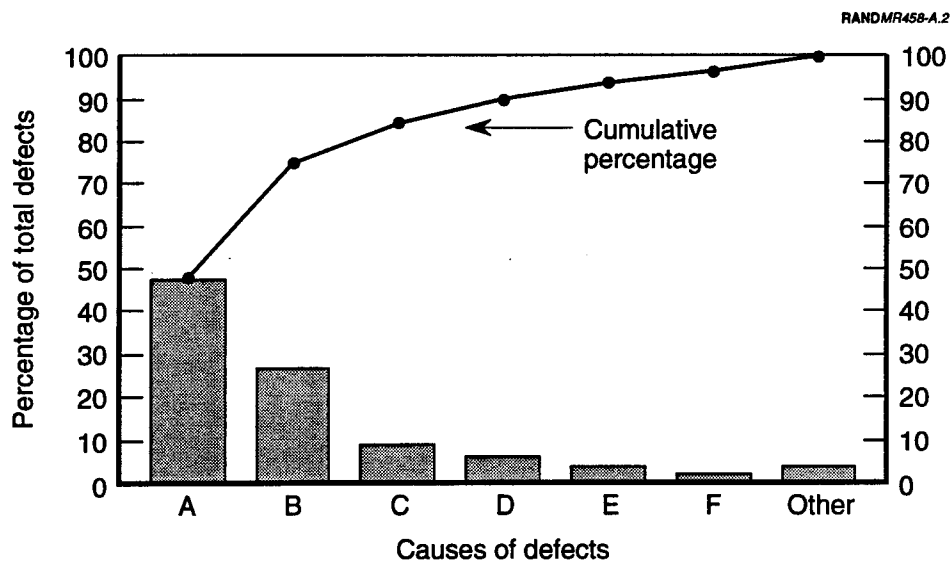


Figure A.2—Pareto Chart

PDCA cycle,² illustrated in Figure A.3, is the foundation of continuous improvement efforts (Carr and Littman, 1990).

Quality Control Following Process Improvements

Statistical methods can also be used to maintain the performance of an improved process. The last of the seven tools, control charts, are a means to record the performance of a process over time (Shainin, 1990). Critical parameters for the process being controlled, such as the diameter of machined parts or the accuracy of data records, are defined and measured periodically for samples of the process's output. The average of measurements for each sample is plotted on a chart as shown in Figure A.4. Upper and lower allowable (control) limits are set for the average of each parameter, such that if any sample reading goes outside those limits, there is a likelihood that a special cause of variation has occurred,³ i.e., that the process is out of control. If the process is indeed out of control, the special cause is immediately identified and corrected; the process may be shut down in the meantime. A nonrandom trend across samples, even if all are

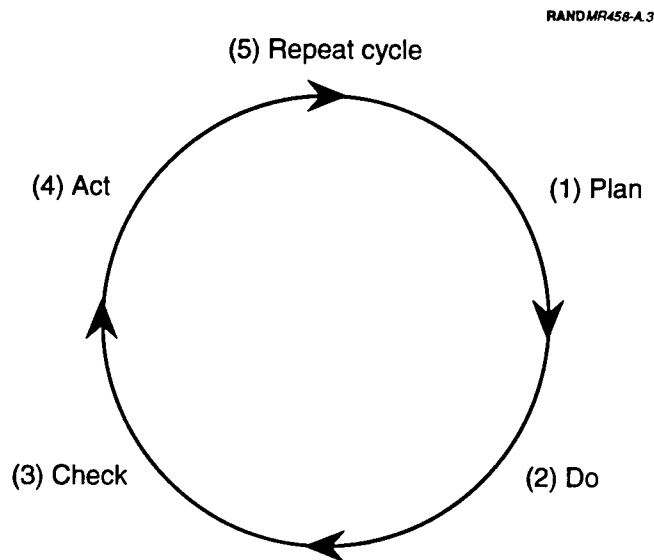


Figure A.3—PDCA Cycle

²The PDCA cycle has some similarity to the Observation, Orientation, Decision, Action (OODA) loop used by fighter pilots. The users of such loops become more proficient with practice, which provides them a competitive advantage in combat or business (Bower and Hout, 1988).

³Each sample is essentially a graphical hypothesis test. If control limits are set at $\pm 3\sigma$ and the process is in control, the probability of a sample falling outside the limits is only 0.26 percent.

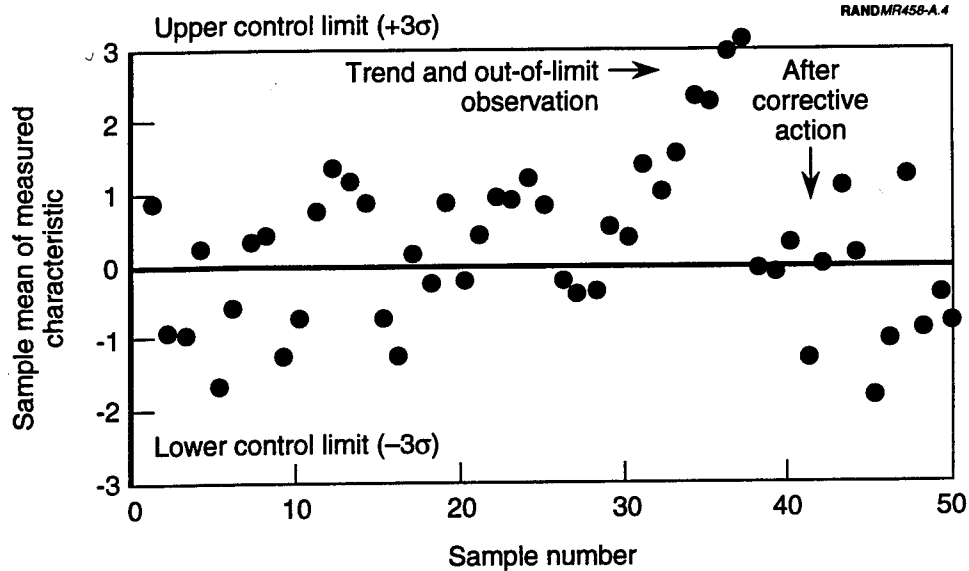


Figure A.4—Control Chart

within limits, may also be cause for evaluating whether the process is still in control. Other measured quantities can be monitored with control charts, including the range of measurements within each sample.

Mechanisms to prevent defects can also be built into the process itself; the Japanese name for these mechanisms is *poka yoke*, or mistake-proofing (Shingo, 1986). For example, fixtures that hold components during machining can be modified so that the part will not fit unless it is aligned exactly. Workers can design such mechanisms themselves, based on their knowledge of the most common sources of error. In business processes, automatic consistency checks on data entry can flag errors for immediate correction. An interesting logistics example was developed by McKesson, a drug distributor, in collaboration with defense Electronic Data Systems. A wearable bar code reader automatically compares the item just picked by the warehouse employee to the order; as a result, order errors dropped 70 percent in 6 months (Magnet, 1992b).

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