Enterprise Logistics in the Information Era

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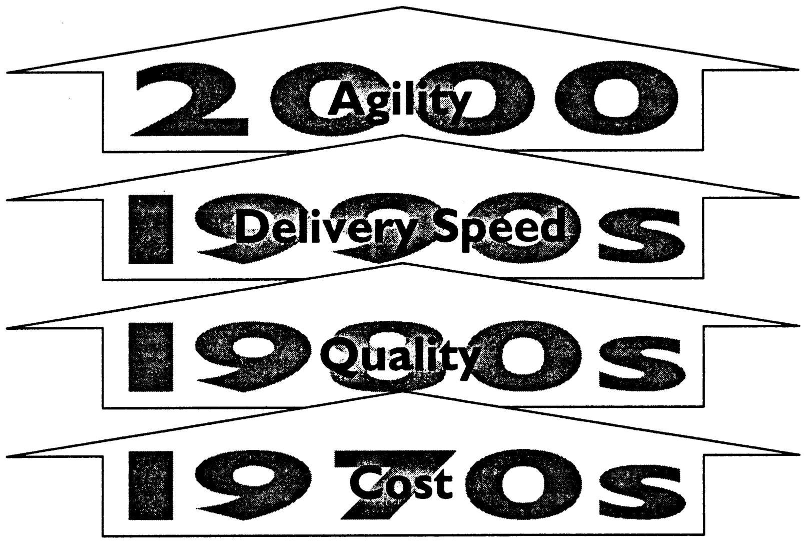
Today's competitive pressures require goods-producing firms to simultaneously manage multiple cross-organizational information and material flows in order to source, manufacture, and deliver their products better, faster, and cheaper. This change has precipitated a radical shift in our thinking about the architecture of production, the importance of traditional supply chain relationships, and, most importantly, the role of logistics. For as long as it has been recognized as a distinct function within an organization, logistics' primary role has been the movement of goods and materials from point to point along the production supply chain. Information about customer requirements was captured in aggregate long-range forecasts that drove the production cycle. However, forecast-based production systems are no longer adequate to meet the rapidly changing demands of the marketplace. Firms must increasingly organize their operations around real-time information about shifting customer needs and about the availability of their productive capacity. They require not only up-to-date and immediate information about the location and disposition of all productive assets, but also information linking the location of the asset with available transportation opportunities. Under such conditions, logistics is becoming a primary enabler of real-time response to customer needs.

As companies strive to meet the challenges of rapid and flexible customer response, new organizational forms are evolving. One emerging form is the extended enterprise, a group of strategically aligned companies focused on specific market opportunities. The advantage of the extended enterprise derives from a firm's ability to quickly exploit not only its internal resources, but also the collective resources of the entire extended network of suppliers, vendors, buyers, and customers. The emergence of the extended enterprise presents

FIGURE 1. Shifting Competitive Priorities



logistical challenges as well as opportunities. Information must now traverse both the organizational boundaries and great distances that separate and span the entire enterprise. At the same time, expanded information flows provide an unprecedented opportunity to build new logistical systems and knowledge-based tools. The power of the extended enterprise lies in its capacity for bringing together previously unlinked information across the entire production supply chain and, in turn, for building more effective tools to manage complex flows of information and materials.

Shifting Competitive Priorities

The extended enterprise is a response to a distinct set of global competitive realities. We have entered a new speed-driven global economic era that is altering the production and operations strategies of companies. In this era, competitive price and high quality are necessary but not sufficient determinants of commercial success. Speed to market and quick, flexible customer response are increasingly pivotal.[1] The increased importance of speed and agility caps a succession of competitive priorities that have marked manufacturing over the last quarter century, as depicted in Figure 1. This rapid succession of cost, quality, delivery speed, and agility as strategic imperatives reflects the continuous search for differentiating capabilities that provide firms with competitive advantage in the marketplace.

From the start of the Industrial Revolution through the post-World War II era, firms sought to bring down the cost of their products to make them affordable to a larger portion of their domestic markets and, as domestic markets saturated, to markets abroad. In the early part of this period, cost advantages were obtained through economies of scale in mass production. By the 1970s, however, Japanese manufacturers were able to gain further advantages over mass production firms through the application of lean manufacturing principles.[2] As the ability to manufacture at low cost diffused across industries and countries, quality emerged as a competitive focus. This shift was signaled by the increasing number of companies that adopted total quality management and other quality control strategies in the 1980s, beginning with statistical process control and moving through a number of different programs such as quality circles, continuous improvement, and business process engineering.

By the late 1980s and early 1990s, the ability to produce quality products at competitive prices became a qualifier and not a guarantor of commercial success. Orders increasingly went to those firms that could get their competitively priced quality products to the customer before others. Today, the drive for speed pervades all aspects of an organization, from the product development process, to the customer service function, to the delivery of product to the customer. In recognition of the fact that delivery speed, not price, often wins the sale, many companies are focusing attention on logistics as the next management frontier. Take PC Connection Inc. of Marlow, New Hampshire, the nation's largest mail order and catalogue PC and peripherals company. The company guarantees noon delivery of its computer software and peripherals for telephone orders received by 2 A.M. that day. PC Connection accomplishes this feat by relaying orders electronically to the company's distribution warehouse at the Airborne Express complex in Wilmington, Ohio. PC Connection currently does more than $200 in annual sales and is growing more than 10% annually, despite charging a premium price.

As we move into the next century, delivery speed alone will not be sufficient for market success. Customer willingness to accept standard products is being supplanted by their demand for products that contain personalized features, point-of-delivery customization, and value-added services. For example, logistics has transformed how Apple Computer handles customer service and repair. Customers can now receive overnight delivery of replacement machines by Federal Express. At the same time, the broken computer is repaired at the FedEx warehouse so that it can be shipped to the next repair customer.

High-tech companies aren't the only companies building speed and agility into their organizations. Recognizing that most consumers buy off-the-rack clothing that doesn't fit very well, Levi Strauss has launched its "Personal Pair Jeans" strategy that could revolutionize the way people shop for clothes. Electronically scanned customer measurements from a company store are relayed to Levi's factory in Mountain City, Tennessee, for sewing, followed by express delivery to the customer's home—all for a premium of fifteen dollars. These companies are among the growing number of innovative global enterprises using logistics to get goods to customers faster while, at the same time, responding to unique and varied customer needs.

The Emerging Extended Enterprise

Growing demand for delivery speed and agility has stimulated a search for new architectures of production that are better equipped to assemble organizational resources quickly in response to market opportunities. A more recent strategy is to redefine a company's operational environment so that it includes not only itself but also the organizations with which it interacts in creating and delivering a product to a customer. Such an extended enterprise might include manufacturers, suppliers, and logistics providers in a confederation that differs from a traditional strategic alliance or joint venture in the fluidity of its underlying nature and a tacit acknowledgment of its transient existence.

The notion of the extended enterprise is in direct contrast to the hierarchically controlled organizations that have dominated American manufacturing for more than one hundred years. In the mass production environment, a company's survival often depended on its ability to manage the entire supply chain within a large vertically integrated organization. As we move to a speed-driven environment, an organization's instinctive desire to manage all the assets of production within a single organization is increasingly at loggerheads with the need to be fast and flexible. Managers have begun to realize that their companies can be even more successful by relinquishing total control of *all* production assets and, instead, by assembling assets and expertise across organizations as opportunities arise.[3]

There are several names for this new arrangement of resources—the virtual organization, the agile enterprise, and the seamless enterprise are just a few. While each of these differs with respect to particular details, they all embody the notion of a set of legally separate but operationally interdependent companies focused on responding to a market opportunity. Since market opportunities are evanescent, the collective enterprise must be opportunity-driven and adaptable. Each extended enterprise member contributes to the collective enterprise by sharing facilities, resources, technology and know-how. In theory, and in practice, as market opportunities change, the extended enterprise can be reconfigured to assemble the right complement of resources more quickly than a single company can acquire or develop those resources internally. This collective enterprise has become especially important today because the complexity of today's products requires a much broader range of resources, skills, and technologies to produce than most organizations can support. The extended enterprise responsible for the development of the Boeing 777 included dozens of players, some selected for their technical expertise, some for their skills in concurrent production, and some to provide access to new markets.

A group of 19 small companies in eastern Pennsylvania known as the Agile Web provides another good example of the extended enterprise.[4] Brought together by the Ben Franklin Center at Lehigh University, these companies represent a wide range of manufacturing capabilities (including product development and design, CNC machining, metal fabrication, die casting, and plastic injection molding) necessary for the design and manufacture of electronic components. Depending on the requirements of a business opportunity, these companies team to assemble the right mix of capabilities and disband upon completion of the project. Profits generated by the project flow back to the participating companies on a project-by-project basis.

The idea of a collective enterprise based on mutual benefit requires cooperation and collaboration among partners, even when these partners are traditional competitors. In the heyday of mass production, the typical value chain was integrated vertically within one company or organized around a single dominant company and a few suppliers. Suppliers were smaller companies, easily substituted for one another as firms sought out lower costs. This arrangement provided companies complete control over their assets and, in a stable environment, helped assure their survival. In the extended enterprise model, the productive unit is less likely to be consonant with a single firm, but rather with a span of allied companies. Unlike the former model, however, the relationships are a collaborative partnering based on mutual goals rather than a hierarchical relationship in which a dominant organization controls a constellation of smaller suppliers. The personal computer industry is an often-cited example of competitors in collaboration—for example, IBM, Motorola, and Apple getting together to produce the Power PC chip.

The extended enterprise is a response to the recognition that organizational structures that were designed to operate in static environments are ill-equipped to manage unpredictable change.[5] Both mass production and lean manufacturing systems were designed to maintain stable processes in a relatively stable environment. The structure of lean organizations reflects the notion that weak links in the supply chain are a greater threat to organizational success than the vagaries of the competitive environment and the fickleness of the customer. The concept of the agile enterprise, in particular, arose in response to the concern that some companies had pursued leanness to an extreme, becoming fragile to the impact of change. In the future, however, the ability to be competitive will be determined more by how well an organization can respond to continuous, yet often unpredictable change. Successful companies must have the capability to reconfigure their technologies, products, and services quickly and efficiently—and even their partners.[6]

The extended enterprise is also characterized by a different approach to the governance of supply chain transactions. The character of supply chain transactions is traditionally viewed as a distinguishing characteristic of production systems. These transactions can be defined at one end by an open market system in which transactions are short-term, competitors are numerous (and often anonymous), and where prices convey all the information required to complete the transaction. At the other end, transactions are determined by a hierarchical system in which authority relationships substitute for completely specified, complex, and long-term contracts.[7] In these closed systems, management provides the primary informational link between an organization and its external environment.

Transactions within the extended enterprise represent a balance between markets and hierarchies. In a pure market system, companies come together transiently to execute contracts in a very brief period of mutual agreement. In a closed hierarchical system, the flow of information and materials is controlled by management rather than markets. In the extended enterprise, firms act rapidly and efficiently in concert to introduce new products and deliver them to customers. Coordination of activities persists for periods of time that greatly exceed the lead times associated with the frequent renegotiation of contracts in markets. Thus, the extended enterprise presents the possibility of strategic but flexible control without the overpowering and often stagnating features of hierarchy. At the same time, the longer-term partnering relationship is built around mutual goals that avoid the adversarial and competitive nature of relationships that typically characterize market transactions.[8]

A key feature of the extended enterprise is the alignment of production activities in a way that both encourages and demands the free exchange of information across organizational boundaries. Previously, individual companies managed large portions of the supply chain within the walls of their own organization, carefully monitoring and restricting information access. In the extended enterprise, companies operating at different points in the supply chain align their internal processes and information channels to create the speed and agility that more rigid organizations cannot. The collaborative and longer-term relationships among customers and suppliers in the collective enterprise is accompanied by a level of information-sharing that is deeper than that traditionally associated with the simple exchange of faxes or electronic mail to transact an order, transmit a technical drawing, or tally a bill. It is through the creation of new information exchange channels and the depth of information sharing that the extended enterprise sets itself apart from both markets and hierarchies.

In summary, changes in the organization of productive resources, in the relationships between traditional competitors, and in the governance of transactions have stimulated new thinking about inter-organizational information flows and the nature of competitive cooperation. The interdependent destinies of allied companies of the collective enterprise reflect the new environment in which supply chains compete against supply chains, and in which traditional competitors increasingly find themselves mutually beneficial collaborators. It has become cliché, but is nonetheless true, that a company's performance is determined by the weakest link in its supply chain. The dependence of the success of the extended enterprise on the collective performance of its members, rather than on the performance of individual companies, portends significant change in the role and importance of logistics. Logistics in the extended enterprise must bridge the geographical and organizational divides that have separated firms in the past so they can operate effectively as a single networked unit. The highest priority in the extended enterprise will be to speed up the expanded number of cross-organizational transactions and informational exchanges in a seamless delivery process in which value is continually being added to goods and materials as they traverse the network.

The Evolution Of Logistical Systems

To appreciate the significance of these changes in the new architecture of production, it is useful to examine the historical relationship between manufacturing and logistics. Logistics in the past has been viewed as a narrow functional activity concerned with transportation, warehousing, inventory, and materials management. These activities played a supporting role to manufacturing. Logistics functions within most organizations existed as ancillary silos that were linked only loosely with the major value-adding operations of the organization. However, as organizations have reconfigured themselves in response to new competitive pressures, we have observed dramatic changes in the relationship between manufacturing and logistics. These shifts have been characterized by the increasing coordination and synchrony of manufacturing and logistics activities through information exchange.

Logistics, originally a military construct, emerged as a distinct organizational function during the mass production era. In order to meet the steady demand for affordable products by the new affluent middle class, factories were designed to create large volumes of standard products using machines with standardized, interchangeable parts. This mechanization of production brought marked economies of scale and profits to American companies. The shift to mass production was complete when, around 1900, Frederick Taylor applied the same principles to labor that had been applied to machines. He broke down manual labor into its component steps in order to make it more efficient, specialized, and interchangeable. This specialization of tasks led to the concept of the production supply chain that still dominates much thinking about how to organize production. The basic logistics functions that are recognized today, such as transportation, warehousing, and inventory management arose, then, as key supporting elements of the Taylor Scientific Management System.

The persistence of the mass production era through the 1970s can be attributed to success of companies in achieving economies of scale in large-volume production and the relative stability of the competitive environment. Economies of scale are reductions in average and marginal cost that result from the increased size of an operating unit or batch. Savings result from factors such as the ability to divide tasks into ever smaller segments, savings in quantity purchases of raw materials or components, the ability to justify expensive process equipment over larger production units, and the spreading of fixed costs over ever larger volumes of output. However, the focus on economies of scale, combined with a trend toward vertical integration, led to ever larger inefficient companies that could not manage information and were not flexible enough to respond to changing markets. Lean manufacturing offered a palliative to these problems. The overriding philosophy of lean is to eliminate any part of the production system that does not add value. Its primary goal is to analyze and focus the activities of the value chain to create the maximum value for the customer with the fewest resources.

The close and determining relationship between manufacturing and logistics is well illustrated by the shift from mass production to lean manufacturing. Lean was successful because manufacturing goals were supported by new logistical arrangements. The development of the just-in-time delivery system assured continuity of production but required continuous delivery of small batches of parts precisely as they were needed in the assembly process. Continuous delivery of parts eliminated the need for costly inventory, but made it necessary for suppliers to locate within easy trucking distance of the manufacturing site. Overall, lean plants have shown significant productivity and quality gains (and ultimately cost advantages) over their mass production counterparts largely through shared information about production schedules among supplier, customer, and logistics provider. The International Motor Vehicle Program World Assembly Plant Survey and the 1989 J. D. Power Initial Quality Study showed that lean Japanese-owned automotive plants in Japan required, on average, 16.8 hours per vehicle compared with 25.1 hours per vehicle for American-owned plants in the United States. Similarly, Japanese-owned plants in Japan produced cars with only 60.0 defects per 100 vehicles, compared with 82.5 defects per 100 vehicles for American plants in the United States.[9]

The transition from mass production to lean manufacturing can be characterized by the increasing integration of manufacturing and transportation, and by the increased reliance on information to link the production processes and transportation. Mass production systems can be thought of as systems of decoupled processes in which inventory serves as a buffer between adjacent manufacturing processes.[10] Since the processes are independent, there is little information sharing and processes operate on the basis of forecasts. The function of logistics is merely to schedule the transport of large batches of component parts to and from inventory as needed on the assembly line, and to deliver the final products to the retail outlet or finished goods warehouse. In lean systems, inventory has been eliminated or greatly reduced through the integration of adjacent processes. The sharing of information from process to process assures the fast and coordinated movement of materials on a just-in-time basis. Deliveries are frequent, small, and tightly scheduled.

Both the mass production system and the lean system, however, are tuned to work in stable environments. They are not, therefore, able to respond quickly to changes in demand—for example, in the number and variety of products. The extended enterprise model is capable of providing the speed and agility that neither mass production nor lean manufacturing can. What is required is the further integration of manufacturing and transportation processes and deeper information sharing across the organizations of the enterprise. Increased integration and information sharing lead to a new type of logistical environment, described below, that is based on a rethinking of accepted ideas about how supply chains operate.

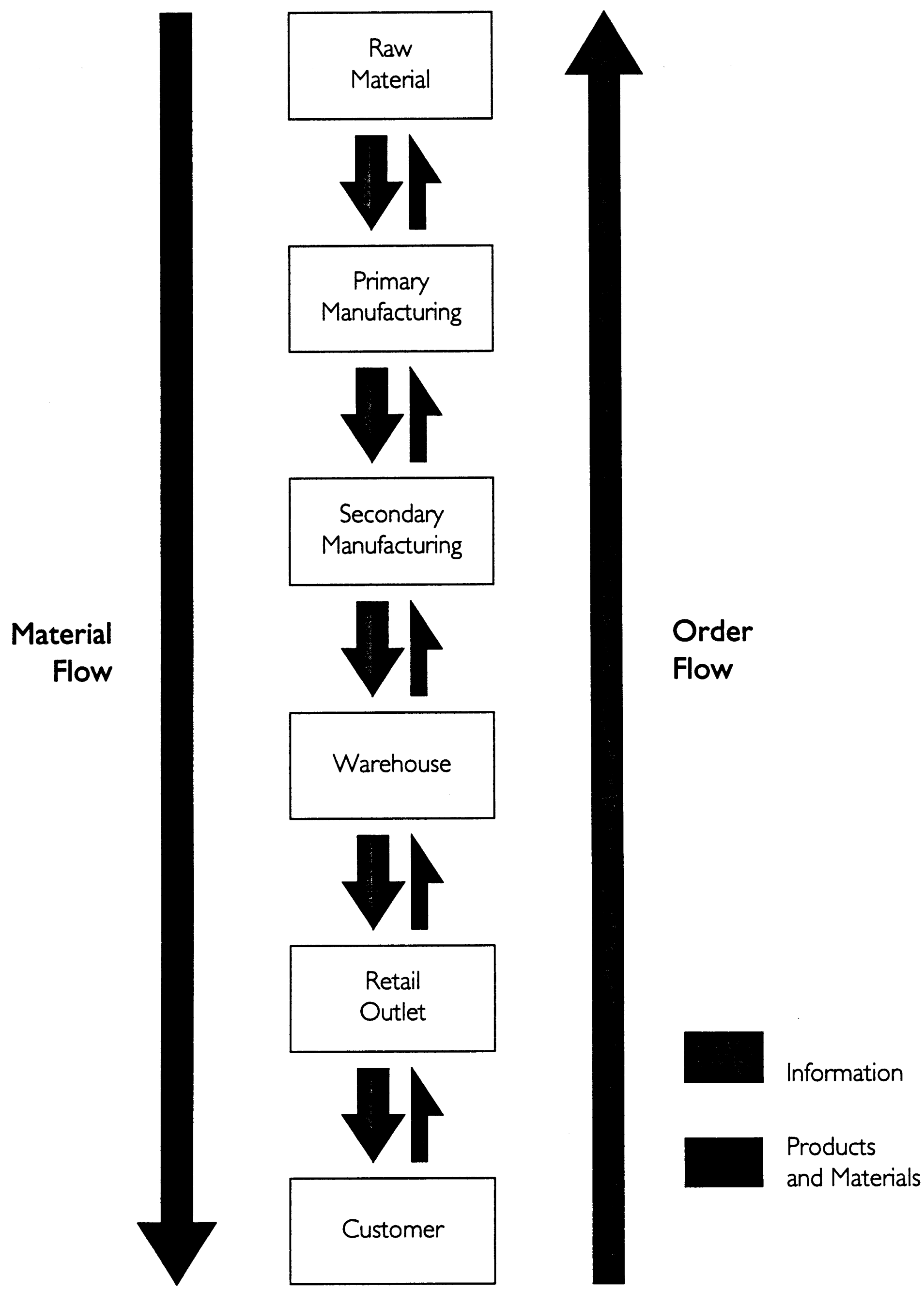
Rethinking the Logistics Supply Chain

The notion of a supply chain, or value chain, has been a pervasive and useful concept for explaining how organizations marshal their resources in both the mass production and lean environments. However, the familiar link-and-node supply chain models of production no longer capture the way information and material flows are currently managed or soon will be managed in the extended enterprise. These models are better suited for organizations that are driven by manufacturing schedules and forecasts in a production-push environment, and situations where organizations along the supply chain operate more or less as autonomous units, often in close proximity to one another. The relationships that drove this model of production were simple, sequential, stable, and often slow. None of these attributes describe the logistical environment needed to compete in today's customer-pull markets.

A schematic view of the familiar link-and-node supply chain is provided in Figure 2. Information about orders flows up the supply chain, and order-filling quantities of finished goods flow back in discrete batches. Batch size is determined by forecasts of future demand or derived production schedules. The system operates as a set of discrete and autonomous organizations passing information and materials from point to point, but exchanging information and materials with only their nearest neighbors. Because information is shared only with nearest neighbors in a sequential manner, opportunities for reducing the total product delivery time and the ability to respond to customers in real time are limited.

Current models of production are based on certain implicit assumptions that are barriers to designing a logistical system for the extended enterprise. The first is the single-minded focus on activities such as parts manufacture, assembly, and distribution as the principle organizing elements of production. The tendency is to think of these activities, or the companies that perform them, as individual nodes in a sequence of steps that we refer to as the supply chain. Thus, raw materials are obtained and shaped into component parts during primary manufacturing and then assembled into final products in secondary manufacturing or assembly. Finished products are distributed from a retail center or placed in inventory for ultimate distribution to the end customer. To achieve speed and agility of response, our conceptualization of the supply chain must first be turned inside out so that the chain is seen as a set of interfaces between

FIGURE 2. Traditional Logistics Supply Chain



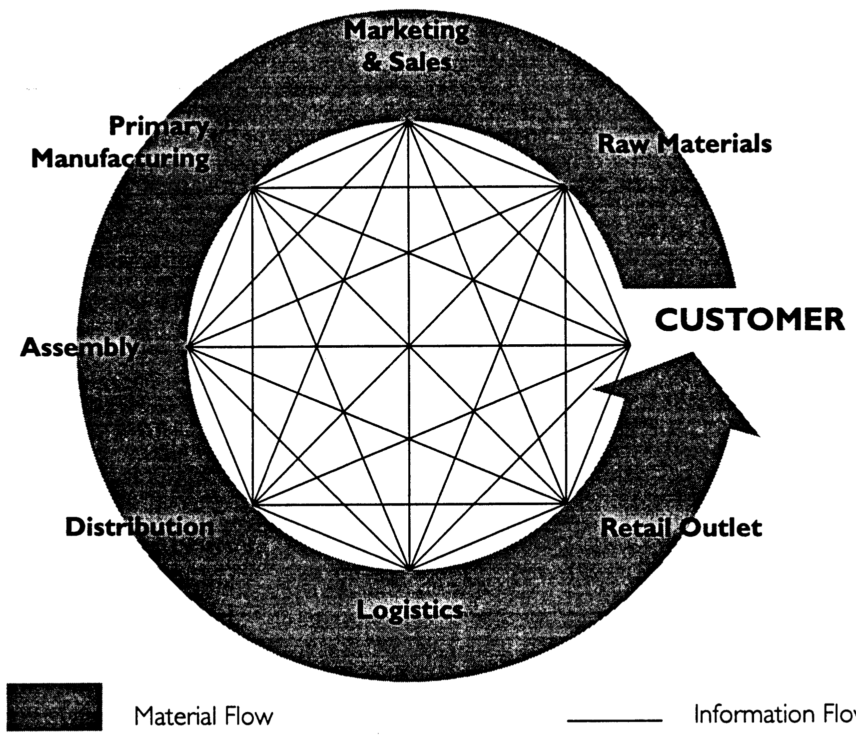
manufacturing and transportation that must be managed rather than a set of activities that must be accomplished.

Second, we have been trained to think of this set of activities as the primary sources of a company's competitive advantage. Thus, for example, a company's particular technical expertise in product manufacture or it's skill in marketing are seen as primary sources of added value. Equally important, but insufficiently appreciated, is the value of speedy and reliable product delivery. Fast and efficient delivery is possible only by managing the hand-off of materials and information from node to node as they flow along the traditional supply chain. In the new enterprise, then, value is created not only at the nodes, but also in the transport of materials between nodes *and* in managing the transitions at the interfaces linking manufacturing and transportation. At these interfaces are found the formerly transparent activities of materials handling, packing, and consolidation.

Finally, the traditional supply chain suggests a sequence of information flow and material movement that is well-ordered and sequential. Increasingly, this model does not reflect the complex, fast-paced global movement of materials and information. Today, information and materials no longer flow in simple linear fashion from supplier to customer. The flow of information resembles more a complex web of exchanges rather than a chain. Material and information often loop around the enterprise or the world several times before the finished product arrives at the customer's doorstep. In one example, computer equipment from a single manufacturer was shipped back and forth across the Pacific four times before beginning its final journey to the customer location. For complex products like automobiles, the journeys of parts, materials, and finished products can be even more tangled.

In contrast to Figure 2, the model shown in Figure 3 is a more appropriate model for thinking about the movement of information and materials in the information-based extended enterprise. This model is a distinct departure from the sequential production-driven model of Figure 2. Seamless material flows are achieved by replacing the notion of a sequential and linear chain of information exchange with a set of simultaneous information exchanges that span the members of the extended enterprise. As depicted in the figure, information flows electronically around the collective enterprise in what can be called a transaction web. The transaction web includes the myriad arrangements and transfers of information necessary to actually design, produce, and deliver an order in a time-based and collaborative environment. By providing this cloud of interconnectivity, material flows from multiple sites can be coordinated spatially and temporally. For example, shipments of customized components produced by suppliers at several locations can be arranged for concurrent delivery as required as the customer. Or, information about the status of orders can be monitored continuously by multiple parties, including the customer.

FIGURE 3. Rethinking the Logistics Supply Chain



Economies of Conjunction

The creation of the transaction web represents the next step beyond electronic data interchange (EDI) in the evolution of information exchange. Like a medieval fair or marketplace, this electronic transaction web brings all buyers and sellers together directly with all the commercial and knowledge support required to complete the transaction. It is not sufficient merely to be able to receive and transmit information to nearest neighbors. It is essential to be able to interconnect simultaneously with a network of suppliers, buyers, and sellers and the information necessary to transact a deal.

These transaction webs create opportunities for economies of conjunction.[11] Economies of conjunction derive from the occurrence of multiple events or transactions in a single time and place. The analogy is made to the celestial conjunction of two or more planetary bodies at their moment of least separation, in time and space. In the transaction web, different transactions—ordering, paying, shipping, and so forth—can be performed in one place and at one time, thereby creating value by reducing costs. The only difference between the medieval fair and the electronic space is that, in the middle ages, the transacting space was a physical place. Now it is an electronic network that is no longer confined by organizational boundaries or geography.

This logistical environment of the extended enterprise will be organized around economies of conjunction in the same way that large-volume mass production factories are organized around economies of scale, and in the same way that agile manufacturing depends on economies of scope. Economies of scope refer to the ability to achieve comparable unit costs whether products are manufactured in lot sizes of one or one thousand. Unlike economies of scale and economies of scope, however, economies of conjunction are not just about how manufacturing is organized. Rather economies of conjunction reflect a new source of speed and efficiency that derive from how an organization manages information and its business transactions. It is precisely the imperative to integrate geographically dispersed resources without relocation that places a premium on the ability to achieve transactional economies of conjunction. Through a shared information system, the numerous members of the extended enterprise transact business in a "one-stop-shopping" environment, through they may be physically separated by great distances.

Economies of conjunction can be achieved through a wide variety of transactions involving those with direct participation in product design and manufacture, as well as delivery. Clearly, transactions involving the movement of materials are a major opportunity for achieving economies. Production schedules can be shared with transportation providers so that capacity is available at the moment needed. Another example would be the cycle time compression and cost savings that result when product designers, packaging designers, and planners interact early in the product development cycle. Alternatively, early warning about quality problems at a major supplier can be accommodated by locating alternative suppliers or rescheduling production runs.

Economies of conjunction can be realized in transactions with organizations external to the enterprise, such as financial institutions or providers of legal services, or through trade regulations and tariffs. Economies of conjunction also accrue when members of the extended enterprise are provided electronic access to technical expertise at national laboratories and research centers or to other sources of expertise required to trouble-shoot the production process. Economies of conjunction are of particular importance to small and mid-sized firms that lack the resources to maintain financial, legal, or research staffs within their own organizational boundaries but can access these external resources electronically.

A Logistics Environment for the Extended Enterprise

The organization of a logistical system for the extended enterprise should follow from the efficient configuration of its supply chain and the economics of its organizing principle. The most significant implication of the extended

TABLE 1. Logistics Environment for the Enterprise: Attributes and Elements

Competitive Need	Enterprise Logistics Attribute	Elements
Speed in Development, Manufacture and Delivery of Customized Products	**Time-Based**	Rapid Delivery through Seamless Transportation Network
Dynamic Reconfigurability of the Extended Enterprise	**Collaborative**	Electronic Interconnectivity through "Plug-in" Access to Shared Information Network and Knowledge Support
Real-Time Response to Changes in Logistics Requirements	**Flexible**	Multimodal and Intermodal Transportation Network with Information Access

enterprise for logistics is that productive resources are no longer co-located or located at nearby facilities, but are widely dispersed around the world. The logistical system for the extended enterprise must create a single coherent production system by aggregating, but not relocating, a complementary set of dispersed resources that might include entire organizations, divisions of larger corporations, or even individuals.[12]

Thus, it is no longer possible to think of logistics as a discrete set of shipping and delivery operations within organizational boundaries. In the extended enterprise, the notion of logistics as a set of functions is being replaced by the emergent "logistics environment" that is time-based, collaborative, and flexible. These attributes are a response to three competitive needs—the need for quick response, the need for dynamic reconfigurability of the enterprise, and the need to respond to unexpected changes in demand or supply—as shown in Table 1. In this environment, the focus of logistics shifts from production support to the task of coordinating and driving the production process through the fast and flexible movement of information.

In order to build a time-based, collaborative, and flexible logistical environment, manufacturing and transportation processes must be fully integrated across the extended enterprise to support a broad range of production and sourcing strategies. As noted earlier, the close linkage of manufacturing and transportation began in the lean environment with just-in-time delivery. Just-in-time systems in the lean environment, however, are suited to high-quality, identifiable goods whose volume is determined by a regular production program that can be accurately predicted. In such an environment, shipments can be controlled as precisely as manufacturing processes. The objective of just-in-time strategies in lean systems was to reduce throughput time and inventory.

In today's competitive market, speed and reduced inventory are still important priorities. But just-in-time systems in the new logistics environment must have up-to-date information about customer demand and resource availability so that the same economies can be achieved for customized parts and products which may not be identifiable with long lead times, and in situations where the required numbers cannot be determined and controlled. In short, through further integration of information, manufacturing, and transportation, the new logistics environment will provide just-in-time advantages for the fast and flexible delivery of nonstandard custom parts that are not the usual candidates for such a system.

A second essential feature of this new logistics environment is a shared information system that connects all parties of the extended enterprise through direct information exchange. Data interchange as we know it today will be replaced by a shared communications system and transparent user interface that can manage the multiple simultaneous transactions of the transaction web. The flexibility and reconfigurability upon which the enterprise depends cannot occur unless communication and information exchange technologies and practices are in place to support all the interconnections required to achieve transaction economies. Customer orders must be sent, received, and acted upon simultaneously by upstream suppliers of components and raw materials, downstream customers, as well as logistics providers and others tied to the product delivery process. The system must be transparent to its users and able to support the disparate organizational interfaces while protecting sensitive information. This communications infrastructure will be based on message standards and open architectures, with separation capabilities to maintain security over those data that are proprietary.

This shared information system should not be mistaken for electronic data interchange as currently practiced. Although the use of electronic data interchange in becoming increasingly common, these systems are typically customized and dedicated links between individual pairs of trading partners. What has evolved, in effect, is a system of customized interfaces between trading partners where the format of the transaction is typically specified by the customer or manufacturer. Thus, a supplier of standard component parts might have to accommodate a large number of electronic formats for its many customers. While this system has provided advantage in a stable environment, it is not easily workable in a dynamic environment where members of the collective enterprise might change frequently.

Finally, the new logistics environment must feature a multimodal transportation network capable of rapid and uninterrupted delivery of products and materials across the supply network. In order to support the geographically diverse resources of the extended enterprise, this multimodal network must be global in reach and seamlessly connected across multiple modes of transport. The success of just-in-time delivery systems and lean manufacturing has underscored the key role that transportation plays in competitive success. As pressures for speed and quick response mount, air freight will increasingly be used to move materials around the world.

However, speed and agility cannot be achieved by air transport alone. Shippers must be able to switch modes of transport for shipments moving through the network—for example from one air route to another, or intermodally from truck to rail or air to truck. The shipper must be able to select from an array of transportation modes and must be able to mix modes optimally as shipments and conditions change. Transitions between modes must be quick, easy to use, and transparent to the user. Smooth transitions at the seams of the logistical system—when goods move from one mode of transportation to another or from factory to air freighter—cannot occur without simultaneous and real-time information sharing throughout the transaction web.

Emergent Properties of Enterprise Logistics

Speed of product delivery and flexibility are not inherent properties of a particular mode of transportation or a particular type of production process. Rather, these attributes result from the interaction of the emergent features of the logistics environment. Three emergent properties of this new environment derive from the integration of manufacturing, transportation, and information in global production networks: continuous value creation during the product delivery process; asset tracking and real-time control of materials and information; and the provision of customized or "discrete" logistical services. It is the set of logistics practices and strategies that is being built around these emergent properties of the new logistics environment that we refer to as enterprise logistics.

Continuous Value Creation

The first emergent property is the ability to eliminate non-value-added time in the product delivery process so that material flows uninterrupted to the customer. A basic goal is that value be continuously added to a product, either through "hands-on" transformations or by providing place utility in shipping and distribution. We are accustomed to associating non-value-added time with work-in-process inventory or, more generally, with time material spends waiting to be transformed or otherwise acted upon in a production process. Often forgotten is the time material spends waiting somewhere in transit. Considerable time is frequently lost waiting for approvals, customs clearance, or available capacity. The air express company FedEx is well known for speed and delivery reliability. By integrating surface and air transport modes through their national and global network, FedEx has achieved a reputation that is the model for other express companies. Yet, internal studies at FedEx have revealed that, from the time delivery orders are placed, material is actually "moving" through their system less than 25 percent of the time. Packages may be sitting on secretaries desks waiting for pick-up, on a warehouse dock, in customs, or stuck in traffic. The exchange of real-time information about customer orders and resource availability can reduce such delays. Advance notice of the intended disposition of materials through simultaneous information exchange assures that preparations can be made in advance of their arrival, eliminating non-value-added wait time at the nodes. FedEx, among other companies, has recognized that significant profits can be achieved with even small reductions in non-value-adding time.

Asset Tracking and Real-Time Control

The second emergent property is the ability to track materials on a global basis—to "see" materials as they move. Asset visibility is necessary to achieve the speedy hand-off of products and materials from supplier to customer at the nodes of the delivery network. The ability to track assets will be a required standard of doing business in the future. The kind of seamless material flow that characterizes the new logistics environment will depend on the ability to count, track, and divert assets in motion. Today, most all express air delivery services such as DHL Worldwide, Airborne, and FedEx offer tracking through websites on the Internet. However, while many companies can monitor the movement of materials within their organizational walls, few have the ability to track their products outside those walls because they lack the shared information system for executing this kind of information exchange.

Today, asset accounting happens where people *are* since it takes people to input information into a computer. In the new logistics environment, information updating will happen where people *are not* through the use of remote tagging systems that electronically relay information about the status of customer orders. The integration of global positioning and geographic information systems with automatic identification technologies can report the location of material in transit and can assign this information to a particular customer and a particular set of delivery requirements. In addition to tracking shipments as they move from one organization to another, organizations must be able to track products to assure compliance with customs regulations or other import/export regulations—for example, regulations for perishable food products or high-technology products monitored for national security reasons.

Discrete Logistics

The third emergent property of the new logistics environment is the ability to tailor transportation arrangements to particular customer orders. Most factory managers have grasped the implications of mass customization for their manufacturing operations. In general, the logistical implications have yet to be addressed. Discrete logistics involves a reconfiguration of information flows to accommodate unit deliveries on a time-definite basis just as easily as large batch orders. Deliveries of customized products are still often scheduled around production runs, and the customer may not receive his or her product until a sufficient number of shipments have been collected for the same destination. Through real-time information exchange between the manufacturing and transportation processes, specific customer requests with respect to the packaging, handling, and transport of shipments can be relayed to logistics providers and acted upon. When these shipments are linked to an intermodal global delivery network, unit orders from disparate locations and organizational entities can be integrated and consolidated for global delivery in a cost-effective and routine manner. Air express companies have derived their competitive advantage from the ability to consolidate the shipments of packages and to route them through their hubs. But these systems operate only within corporate boundaries. The ability to bundle orders from separate companies according to their geographic destination makes it possible to achieve the large-volume efficiencies that would have otherwise been lost through individualized response. Routing and consolidation decisions can be made in real-time depending on route volumes, further reducing costs.

An excellent example of how all three of these emergent properties can be integrated to provide a new logistical service is what we refer to as "in-transit material merger." In this case, an order for a customized product is fulfilled in real-time by the synchronization of the arrival of custom components at the factory for immediate final assembly and shipment to the customer. Materials merger can be implemented by information management systems located at sites across the global delivery system with the capability to integrate the flow of goods and materials from various geographical locations and organizations. Inacom Corporation, provider of customized personal computers to customers worldwide, has engaged Skyway (Union Pacific Corporation's logistics subsidiary) to coordinate the pick-up of monitors, modems, and other peripherals from Inacom suppliers around the country. Skyway delivers them to four Skyway-owned distribution centers in the U.S., where they are packaged with Inacom computers for direct shipment to the customer. It is likely that new applications of these properties will accelerate as information technology costs continue to fall and as customers begin to expect rapid customized service as an essential, rather than a premium, level of service.[13]

These emergent properties are also being used to reduce complexity in the supply network. For example, warehouses and distribution centers can be eliminated when just-in-time delivery is available overnight to most places in the world; or companies can develop creative strategies for sharing facilities and assets. National Semiconductor operates six silicon wafer fabrication plants that supply wafers to seven assembly plants, mostly in Southeast Asia. Until recently, National Semiconductor's customers around the globe were supplied from these seven assembly plants. National's solution to rising complexity in its supply chain was to serve all customers from a single new facility in Singapore—run by FedEx. Delivery times plummeted from 45 days to four days while distribution costs as a percent of revenue fell nearly 40 percent.[14]

Creating Knowledge from Information

The extended enterprise is emerging as a viable organizational model just as we are moving from an economy based on information to one based on knowledge, where knowledge means the application and productive use of information.[15] In traditional customer-supplier relationships, inter-organizational information exchanges were controlled by functions located at the periphery of the organization such as sales and marketing. As we have noted, information sharing in the mass production environment was minimal. The organization of the mass production system around large-size batches masked true information about demand and its variability. Lean production required logistics arrangements that were more closely tuned to the rhythm of the manufacturing floor, but true information-sharing for the joint benefit of supplier and customer did not occur. In the extended enterprise, deep and wide sharing of information offers the possibility of powerful knowledge-based tools that can intelligently navigate in the new logistical environment.

The availability of knowledge-based logistical tools has the potential to revolutionize the business of logistics just as it has revolutionized a range of industries. The creation of computer-generated airline guides and reservation systems such as American Airline's SABRE is an often-cited example of how information-based tools have transformed an industry. Sharing schedule and booking information resulted in better control of passenger volumes. In the case of SABRE, information about flight schedules, routing and seat availability ultimately became as profitable, if not more profitable, than the core business it was created to serve. A further development, yield management, used information systems like SABRE to build knowledge-based tools for creating additional profits. In the case of yield management, information about passenger demand, flight availability, and seat capacity was synthesized to create a pricing tool for maximizing revenue.

A variety of knowledge-based logistical tools that leverage the information management capabilities of the extended enterprise are beginning to emerge. Capabilities such as product visibility and asset tracking, as well as concurrent delivery systems, are being embedded in software that filters and interprets information, thereby enabling more effective service to customers. The evolution of three such logistical tools is portrayed in Table 2.[16] The figure illustrates how each tool is able to transform routinely collected logistical data into information that can then be used to create knowledge. REROUTER provides customers with the geographic location of parts at any point along the supply chain and the capability to reroute on a real-time basis. The data that provide the foundation for this system are the geographic locations of parts that have been reported to a central location through radio tagging and tracking capabilities. Information is created when these data are gathered and analyzed to determine the least cost component location. Knowledge-based rules can then combine this information with routing schedules and available capacities to schedule deliveries and make real-time routing changes at customer request. The power of this system lies in its ability to roam the entire enterprise without constraint or concern for organizational boundaries. CONVERGE allows an assembler of electronics equipment to deliver customized equipment overnight by coordinating the arrival of component parts to within a one-hour window.

TABLE 2. Building Knowledge-Based Tools for Enterprise Logistics

	Rerouter	**Converge**	**Partmax**	**Key Features**
Data	Current Asset Location and Planned Route	Production Schedule and Component Requirements	Record of Received Orders	Intraorganizational Data Gathering
Information	Alternative Sources and Route Capacities	Coordinated Component Production Schedules	Trend Analysis of Part Demand	Collection and Analysis of Interorganizational Data
Knowledge	Creation of New Routing Patterns	Convergent Arrival of Components for Final Assembly	Optimized Inventory Holdings	Transformation of Information into Knowledge-Based Decision Tool

The arrival of parts is synchronized so that no part is held in inventory while ensuring that the customer receives the finished product within hours of ordering it. PARTMAX is a software program that tracks part usage over time to determine maximum and minimum inventory levels for automatic replenishment, and to identify parts that should be discontinued.

To realize the full potential of these knowledge-based tools, it will be necessary to leverage several key features of the new logistical environment. Consider the need to reroute goods and material in response to a quality problem at a major supplier. First, plug-in access to a shared communications infrastructure and knowledge-support systems that span the extended enterprise will assure that the customer is apprised of the problem *and* that alternative suppliers can be identified immediately. Second, in-transit material currently destined to another location can be quickly rerouted to replace the defective part. A seamless transportation network will allow for the shifting of routes and modes of transportation as required for door-to-door service. Accurate data about material location can be obtained through investment in radio-frequency tagging technology and the customer's own information system. An information map of the flow of goods across organizational borders, however, requires full information interconnectivity across the extended enterprise through common architectures and standard messages. Finally, the creation of a knowledge-based system for rerouting requires not only tie-ins to external databases with schedules and capacities for various transportation alternatives, but also decision rules for determining the "best" route to the customer through the intermodal and flexible transportation network.

Knowledge-based tools are being developed in a number of companies. Cisco Systems' customers depend on Cisco's ability to respond to emergency requests for routers and other products to avoid the tremendous costs of network downtime within their organizations. To assure quick response, Cisco has partnered with UPS Worldwide Logistics to develop a system for scheduling quick delivery of Cisco products to customers around the world. With UPS's help, Cisco can now track and reroute an order at any time. The ability to link product location with international plane, train, and trucking schedules has, according to Cisco, reduced delivery times dramatically. For example, European customers who used to wait three weeks for an urgent order now receive delivery within four days. With the systems currently in place, Cisco can let customers know exactly when the router will arrive.

In another example, FedEx was quick to recognize the potential of linking the ordering process to the delivery process through electronic commerce. FedEx's electronic commerce arm allows companies to create their own Web catalogues—complete with direct links to FedEx's cargo booking system. Of course, booking is limited to FedEx and doesn't allow customers to select among carriers, or even modes. One effort to provide universal on-line booking and tracking, Encompass, a joint venture of CSX Corporation and AMR Corporation, was recently abandoned. But other ventures, recognizing the potential market, are quickly trying to fill the gap left by the departure of Encompass.

Finally, office stationer Corporate Express, in a joint project with Hewlett-Packard Company, has connected HP's Intranet directly to its computer network. Hewlett-Packard employees can order supplies on-line, triggering next-day delivery in most of North America—made possible by Corporate Express's recent acquisition of U.S. Delivery Systems and United TransNet, the two largest same-day delivery services in the United States. Corporate Express is building, layer by later, client-server applications for their customers that will feature a range of value-added functions from inventory and warehouse management to financial services. Corporate Express's goal is to consolidate the industry, lower the cost of delivering products to its customers, and eliminate the wholesaler. In just five years, their revenue has shot from $30 million to $3 billion.[17]

In the examples above, information acquisition began as a byproduct of the core business of the organization. Companies routinely collect information about shipment patterns in traffic department for billing purposes. Similarly, marketing possesses broad knowledge about current customer orders. The key to becoming knowledge-based is putting these types of information to productive use in a way that creates a new service or product. For the extended enterprise, the key to competitive advantage lies in its ability to access and use real-time information in ways that enable it to adapt to changing customer needs and market conditions. Thus, the synthesis of information residing in different functions and organizations across the extended enterprise itself becomes an emergent process, adding further value to member units of the enterprise.

Conclusions

Logistics will play a crucial role in the information-driven extended enterprise of the future. Recent developments in logistics, notably the introduction of lean logistics and agile logistics, represent initial steps toward articulating the

TABLE 3. Summary of Logistical Systems Characteristics

	Mass Production Logistics	Lean Logistics	Enterprise Logistics
Competitive Environment	Static	Static	Dynamic
Information Sharing	Little	Nearest Neighbor	Enterprise-Wide
Process Linkage	None	Nearest Neighbor	Enterprise-Wide
Logistics Function	Production Support	Just-in-Time Component Delivery	Intelligent Management of Logistics Environment

capabilities of the next generation logistical system. But these concepts are only a partial response to the logistical requirements of the extended enterprise and do not fully recognize the extent of the linkages among manufacturing, information, and transportation that will be necessary. It is no longer possible to think of manufacturing and logistics as separate functions. Rather, the ability to move lean and agile concepts to the next level of production efficiency will require a new logistical environment in which manufacturing and logistics are fully integrated. This emergent process will be characterized by a deep enterprise-wide exchange of information that provides for the seamless, fast, and flexible flow of materials.

To date, companies have made great strides in integrating the flow of information and materials within their organizations and with their partners. However, full implementation of enterprise logistics remains a vision for the future. As illustrated in Table 3, the extended enterprise represents a new stage in the evolution of organizations predicated on process linkage and information sharing. The extended enterprise is a response to the needs of the new market environment in which a flexible, real-time response to unanticipated change will be a necessary condition for commercial success. In short, the extended enterprise is a production system in which the role of logistics is not merely the transportation of materials or the storage of goods, but the coordination of all production activities necessary to deliver a product to a customer. Unlike mass production and lean manufacturing systems, the extended enterprise is itself a dynamic organization, continually reconfiguring or re-inventing itself as new market opportunities arise. A key distinguishing feature of the extended enterprise is the integration of market conditions, manufacturing (not just order fulfillment from inventory), and distribution through the deep sharing of information. Because of its cross-organizational information gathering and real-time management capabilities, enterprise logistics provides a unique opportunity to create knowledge-based tools that can revolutionize supply chain management, as well as reveal new logistical products and services. This enables new organizational forms that are far less bound by space, yet more flexible and rapidly responsive to market change.

Notes

1. For a discussion of the role of logistics in industrial strategy, see John D. Kasarda, "Transportation Infrastructure for Competitive Success," *Transportation Quarterly*, 50/1 (Winter 1996): 35-50.
2. According to James Womack, Daniel Jones, and Daniel Roos [in *The Machine That Changed the World* (New York, NY: Rawson Associates, 1990)], the Japanese share of the world motor vehicle production increased from 0% to 30% over the period 1955 to 1980 through the application of lean principles. Their initial success in the U.S. market was due to the popularity of low cost cars that did not have anywhere near the quality that Japanese cars are known for today.
3. See Kenneth Preiss, Steven Goldman, and Roger Nagel, *Cooperate to Compete: Building Agile Business Relationships* (New York, NY: Van Nostrand Reinhold, 1996) for a discussion of how organizations can adapt to the pace of change in the competitive environment.
4. See "The Agile Web: A Model for the Future?" *Industry Week*, March 4, 1996, pp. 31-35.
5. Rick Dove of the Agility Forum has developed a model of eight kinds of agile change that capture the spectrum of change situations faced by companies today. These eight change domains (creation, capacity, capability, reconfiguration, migration, performance, improvement, and recovery) were developed as a tool for understanding and analyzing agile behavior in organizations. See Rick Dove, "Tools for Analyzing and Constructing Agility," Agility Forum, Bethlehem, PA, 1994.
6. A good discussion of agility is contained in Steven Goldman, Roger Nagel, and Kenneth Preiss, *Agile Competitors and Virtual Organizations* (New York, NY: Von Nostrand Reinhold, 1994).
7. For a further discussion of organizations as open and closed systems, and the ability of these concepts to explain how organizations change their shape, see Charles E. Bidwell and John D. Kasarda, *The Organization and Its Ecosystem: A Theory of Structuring in Organizations*, Monographs in Organizational Behavior and Industrial Relations (Greenwich, CT: JAI Press, 1985).
8. For a discussion of the enterprise as an alternative to pure markets and pure command structures, see J. S. Busby and I.-S. Fan, "The Extended Manufacturing Enterprise: Its Nature and Its Needs," *International Journal of Technology Management* (1993), pp. 294-308.
9. For further information about the International Motor Vehicle Program (IMVP), see Womack, Jones, and Roos, op. cit.
10. For an engineering perspective on the differences between mass, lean, and agile systems, see Kenneth Preiss, "A Systems Perspective of Lean and Agile Manufacturing," *Agility and Global Competition*, 1/1 (Winter 1997): 59-79.
11. Economies of conjunction are similar to economies of agglomeration or economies of aggregation. Economies of agglomeration are the benefits that derive from the spatial proximity and geographic concentration of similar organizations, e.g., the semiconductor industry in Silicon Valley. The geographic proximity of firms in a single "place" is thought to enhance collaboration, learning, and the generation of knowledge. Economies of conjunction combine both the economies of "place" with economies of "time."
12. See Steven Goldman, "The Era of the Virtual Enterprise," White Paper, Agility Forum, 1993.
13. See Scott Woolley, "Replacing Inventory with Information," *Forbes*, March 24, 1997.
14. See Ronald Henkoff, "Delivering the Goods," *Fortune*, November 28, 1994.

15. Aleda Roth describes a roadmap to strategic agility through the development of economies of knowledge. Roth defines economies of knowledge as a firm's ability to use business acumen, combined with skilled people and experience and advanced technology, to create an organization that consistently identifies, assimilates, and exploits new knowledge more efficiently and effectively than the competition. See Aleda Roth, "Achieving Strategic Agility through Economies of Knowledge," *Strategy and Leadership* (March/April 1996), pp. 30-37.
16. These knowledge-based tools are based on existing concepts currently in the marketplace in some form. REROUTER could be any of the asset tracking systems used by air express carriers for tracking the movement of packages within their organizational boundaries. CONVERGE is patterned after systems such as EMERGE offered by Federal Express. PARTMAX is patterned after software developed by Sonic Air, the logistic-services subsidiary of United Parcel Service, to help clients determine which parts to discontinue and which to keep.
17. For a discussion of Cisco Systems, see Woolley, op. cit.; for a discussion of FedEx's cargo booking systems, see Alan Abrams, "The Threat of the Net," *Air Commerce*, March 13, 1997; for details about Corporate Express and Hewlett-Packard, see William Cassidy, "An Intranet Connection," *trafficWORLD*, February 3, 1997.