Manufacturing Logistics for the 21st Century

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Eight major external influences in global trade, manufacturing methods, and public policy are identified that are likely to have profound effects on logistics as the 21st century begins. These forces are discussed and general conclusions are reached on likely results in the logistics system. Finally, a set of ideas that could help the freight transportation sector adapt to the changing logistics system is described.

What are the changes in manufacturing and the global economy that will force fundamental changes in logistics as we enter the next century? What changes will result in logistics operations? How will this affect transportation providers? How does public policy with respect to transportation affect these changes? Lacking a functional crystal ball, we are forced to speculate on the answers to these questions, but by looking carefully at both global economic changes and changes in manufacturing, we can make some educated guesses about changes in logistics that are likely to be coming over the next 10 years or so. By thinking about these changes now, transportation providers can begin to position themselves to take advantage of new opportunities that will arise. Further, by thinking about the interplay between private logistics decisions and public policy with respect to transportation, we can gain additional important insights.

From the perspective of the logistics system, changes in the global economy, in manufacturing methods, or in public policy are all external influences. Furthermore, they are of sufficient magnitude that they can force fundamental reorganization of logistics operations. The purpose of this paper is to identify important trends that will affect logistics operations in the future and to suggest some potential responses within the freight transportation system.

WHAT ARE THE MAJOR DRIVING FORCES?

At least eight major forces will influence the structure and function of logistics systems over the coming years and lead to dramatically different expectations for the freight transportation sector:

1. The growing importance of international trade and the emergence of large multinational trading blocs,
2. Changes in the nature of production and assembly operations in manufacturing,
3. Efforts by manufacturers to reduce the number of suppliers they deal with and to emphasize long-term relationships with the remaining supplier base,
4. Continuing emphasis by manufacturers on reducing overall logistics costs and improving service quality,
5. Increasing pressure on manufacturers to take responsibility for recycling their products after use as a part of worldwide environmental consciousness and efforts to reduce solid waste disposal problems,
6. Rapid increases in the scope and capacity of data networks for moving and organizing information,
7. Increasing levels of highway congestion in and around the urban areas of the United States, and
8. Changing perceptions and policies of the federal government concerning transportation systems in the United States.

In the following subsections, the nature of each of these influences will be discussed.

Growth in International Trade and Trading Blocs

Figure 1 shows U.S. merchandise imports and exports during the period between 1980 and 1990 (*1*). This clearly illustrates the growing importance of international trade in our economy. The recent breakup of the Soviet Union and the Warsaw Pact has removed another major set of barriers to globalization of the world economy and will result in even more rapid increases in U.S. trade volume in the years ahead.

The European community is forming an integrated trading bloc, and this has enormous implications for manufacturers, both in and outside of Europe (particularly in North America and Japan). A recent report by Andersen Consulting for the Council of Logistics Management (*2*) emphasizes movements toward both "integration" and "rationalization" in European logistics operations. Integration efforts are aimed at combining what previously have been separate national production and distribution systems into a coherent pan-European system. Rationalization efforts are aimed at cost reduction through elimination of duplicate or redundant facilities. Opportunities for rationalization are being created by efforts toward greater integration.

The recently negotiated North American Free Trade Agreement involving Canada, Mexico, and the United States is likely to have comparable significance, creating a free-trade zone spanning North America. The result of this agreement is likely to be a dramatic increase in the magnitude of north-south flow of goods, including raw materials, work-in-process, and finished goods. The predominant historic pattern for goods

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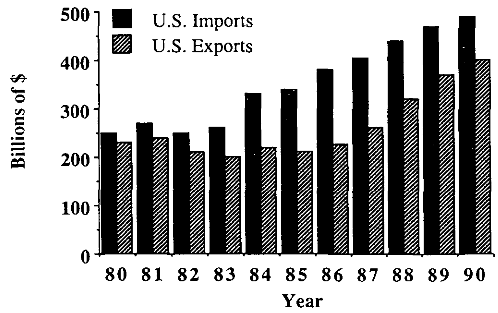

FIGURE 1 U.S. imports and exports, 1980–1990.

movement in both the United States and Canada has been east-west, and the increasing north-south flow is likely to require changing operations practices, investments in new capacity for both manufacturing and transportation, and changes in facility location decisions.

All of these changes will create both challenges and opportunities for manufacturing logistics and will reverberate through the freight transportation industries. The manufacturing process will become more decentralized, drawing on materials, resources, and labor in a wider variety of locations and depending on the logistics systems to bring all the pieces together at the right place at the right time. At the same time, markets for products (and hence distribution channels) are widening, but in a way that may require a variety of "regionally customized" products.

A simple, but illustrative, example of this regional customization issue is the manufacture of electrical appliances for European use. With the removal of tariffs among the European Community countries, the potential market for a manufacturer of appliances in France, for example, is now much larger. However, there are still several different standards for electrical plugs, and thus a slightly different model must be produced for each of those markets.

This variation in standards may affect the logistics system, because one strategy for dealing with these variations is to postpone the attachment of the electrical cord until the appliance reaches a distribution center within each country and at that point attach the correct cord for that country's use. This changes the logistics requirements because the cords and plugs, which may be produced by an outside supplier, now must be shipped in a pattern very different from that used in the past. In effect, the distribution center has become an assembly location, and that changes the way the logistics system must operate.

Changing Production Methods and Technology

Manufactured products are becoming increasingly complex, and the customers who buy those products have increasing expectations for product quality and reliability. As described in the previous section, manufacturers are also doing more and more "niche marketing"—producing several different variations on a product aimed at slightly different sets of consumers. The ever-growing emphasis on total quality management as a focus on meeting customer desires will also force companies to change their manufacturing methods. Among the likely changes in manufacturing as we enter the next century are the following:

- Greater use of smaller (cellular) production facilities capable of responding quickly to local market demands;
- Increased adoption of flexible production methods capable of making a wide variety of customized products, each in relatively low volumes;
- Shorter and shorter life cycles for products, which also will put pressure on manufacturing facilities to be more flexible and easily adaptable to production of new products.

These ideas (and others) have been proposed in the "Manufacturing 21" study sponsored by eight major Japanese companies and several universities in that country (*3*).

An early indication of the implementation of these ideas may be seen in Nissan's goal of five "anys": any volume, anywhere, any time, anything, anybody (*4*). Translated, Nissan wants to be able to make any one of its models, at any of its plants, anywhere in the world, at any volume level, and at any time demanded by local market conditions. Moreover, they want to do so with a production system capable of being run by anybody.

Another illustration of the ideas is the production of bicycles in Japan by a subsidiary of the electronics giant, Matsushita (*5*). In a small factory in Kobuku, in western Japan, 20 employees and a computer are ready to produce any of 11,231,862 variations on 18 models of racing, road, and mountain bikes. Production starts with a customer order faxed from a local retail store, and the bike is made to fit for a specific customer, with delivery in 2 weeks.

The implication of these examples is that in the future there are likely to be more production and assembly locations, each producing a wider variety of products in smaller volumes, and doing so on demand to meet customer orders rapidly. For transportation of materials and products, this means smaller lot sizes, more frequent orders, a more dispersed set of origins and destinations, and tighter standards for on-time delivery.

Changing Relationships with Suppliers

Many U.S. manufacturers are making major changes in their relationships with suppliers, and this includes suppliers of transportation services as well as suppliers of raw materials and component parts. The objective is to reduce the number of suppliers and to establish a longer-term cooperative relationship, or partnership, with the remaining supplier base.

An excellent example of this sort of change in the transportation services area is provided by Reynolds Metals Company (*6*). By reorganizing their logistics operations, they reduced the set of trucking carriers they dealt with from 200 to 14. Each of the remaining "core carriers" agreed to tailor specific services to meet Reynolds' needs and, in return, received a larger share of Reynolds' shipments.

Other examples of manufacturers that have made major changes in their relationship with transportation suppliers are Xerox (*7*), DuPont (*8*), and Olin (*9*). These companies are trend setters, and their lead is likely to be followed by many other manufacturing companies over the next few years. These changing relationships affect both the logistics operations of the manufacturing company and the operations of the transportation provider.

Emphasis on Reducing Logistics Costs

Statistics cited by Foster (*10*) indicate that in 1991, U.S. companies spent $655 billion on logistics, amounting to 11.6 percent of the entire gross domestic product (GDP). This is about the same amount as is spent on health care and twice what is spent on defense. Expressed as a percentage of GDP, logistics costs have been reduced from their high point (1981), when they reached 17.9 percent of GDP, largely as a result of deregulation in the transportation industries. However, further reductions are going to require more systematic analyses and structural changes in the logistics systems of most companies.

Systematic study of the full logistics chain has proven beneficial for several companies. Two excellent examples are the efforts at Reynolds Metals Company, cited previously, and at General Motors, documented by Blumenfeld et al. (*11*). The work at General Motors, in particular, has illustrated the close connections between production decisions (and costs) and logistics decisions (and costs).

Movements toward just-in-time (JIT) deliveries by many companies in the last 3 to 5 years have clearly reduced inventory carrying costs and are one illustration of attempts to tie production decisions and logistics decisions more closely together. However, careful study of the relationships between production and logistics decisions involves consideration of much broader issues than JIT deliveries of materials.

One of these broader issues is production of components and subassemblies in plants scattered literally around the world. Many major U.S. manufacturers are (or are at least considering) locating some production facilities outside the United States, primarily in a search for inexpensive labor. This lengthens the links in the logistics chain and increases logistics costs. Pressures to contain the total logistics bill for a company must be understood against the backdrop of a complex web of interrelated production and logistics decisions.

Responsibility for Product Recycling

Historically, manufacturers have worried only about putting their products in the hands of their customers. The logistics chain has been a one-way movement. However, the growing environmental consciousness in the major industrialized societies of the world is forcing some reconsideration of this assumption. Recycling and reprocessing of used products is growing in importance and is likely to become much more important by the early 21st century.

Some manufacturing industries, such as aluminum processing, already have made major changes in this regard. Others, such as manufacturers of plastics and lead-acid storage batteries, are beginning to use recycled materials more extensively. A wider variety of manufacturers is likely to follow over the next several years.

The resulting reverse flow in the logistics chain has implications for both the manufacturers and transportation providers. On the plus side, it may create backhaul opportunities that could lead to more efficient use of transportation resources. However, it also creates the need to integrate reprocessing facilities into the overall logistics system and to manage material flow patterns among an even wider set of origins and destinations.

Improved Information Management Capabilities

The processing speed, storage capacity, and networking ability of computer hardware have increased at a phenomenal rate in the last decade. These changes have provided opportunities for data exchange, processing, and organization in real time (or near real time) that only a few years ago would have been beyond our imaginations. Over the coming decade, we will see even more dramatic improvements, particularly in computer networking and distributed data base management, and these changes will open up even broader possibilities for managing the freight transportation system differently and more effectively.

Dertouzos (*12*) and Cerf (*13*) have outlined a variety of possible changes, ranging from installation of computer networks, which would become an "interstate data highway system" transmitting data at rates exceeding 2,400 million bits/sec, to "knowbots"—programs that could be launched into the network to look automatically for a variety of types of information relevant to a particular request, organize what is found, and return the results to the initiator.

Even in the relatively short run, increasing use of electronic data interchange will change the character of many logistics transactions and operations. For example, the widespread use of electronic point-of-sale terminals in retail outlets has allowed retailers to have virtually real-time information on sales and stock levels of products in their stores. Many retailers have used this information to their advantage by reducing in-store inventories, putting pressure on manufacturers for more frequent and smaller deliveries to retail outlets, and in some cases reorganizing their own inventory operations (*14*). All of the changes in information management that are used to reduce inventories in the overall logistics chain result in changes in shipment sizes, frequency, and composition that have consequences for both the manufacturer and the transportation service provider.

In the longer run, we can look forward to having much wider knowledge of shipment options, status of current shipments, equipment availability, and so forth easily accessible to shippers, carriers, and receivers. This should lead to increased responsiveness of the transportation system to demands placed on it and to improved utilization of resources in the system.

Increasing Highway Congestion

Rao et al. (*15*) have recently argued that highway congestion and JIT operations are both growing rapidly and are probably on a collision course. The smaller and more frequent shipments, shorter lead times, and precise scheduling called for by JIT can be severely impeded by travel times that are rising and becoming more uncertain as traffic congestion grows.

Extrapolation of current trends is certainly risky, but forecasts based on such extrapolation indicate that (a) total vehicle delay on urban freeways is expected to increase over 400 percent by 2005 (*16*) and (b) the intercity speed of an average railroad freight car will exceed that of an average tractor-trailer by 2010 (*17*).

Rao et al. (*15*) describe several potential strategies for alleviating some of the effects of congestion on JIT operations, including use of off-peak deliveries, computer-assisted routing and scheduling of movements, and consolidation strategies by either vendors or transportation companies. The last two of these strategies are dependent on better information organization and transmission and thus relate directly to the issues discussed in the previous subsection.

Changing Federal Transportation Policy

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) presents a new vision of the nation's transportation system—a concept in which the various modes form an integrated, closely coordinated system that provides "seamless" multimodal service for both passengers and freight. The individual modes are seen as different facets of a unified system that provides services appropriate to the needs and demands of the shipper or person being served.

This change in focus, from one dominated by differentiating the modes on the basis of technology to one emphasizing the services they can provide together, represents a fundamental shift in public policy at the federal level. This change will be played out in a variety of ways over the coming years, but the emphasis on improving intermodal connections surely will lead to new service offerings and should open additional opportunities for improving both service quality and resource utilization by transportation providers.

HOW WILL LOGISTICS CHANGE?

Bianco (*18*) has outlined a general model of logistics networks, including suppliers, parts production facilities, assembly facilities, distribution centers, warehouses, and markets. Figure 2, reproduced from his work, shows the basic connections. In this network diagram the logistics chain involves several stages of movement, connections between stages may bypass other stages, and at each stage there may be many locations (and potentially many different organizations) involved. Although Figure 2 shows the various stages with equal numbers of nodes (locations), we should not infer from that that the numbers of locations are really equal at the various stages. For the purposes of this paper, we can use the representation of the logistics network in Figure 2 as the basis for projecting potential changes in the logistics system that might be driven by the major forces described in the previous section. This perspective leads us to focus on changes in

1. The number and locations of facilities for suppliers, parts production, assembly, distribution centers, and warehouses;
2. The size or location of markets; and
3. The connections among the various stages of the process.

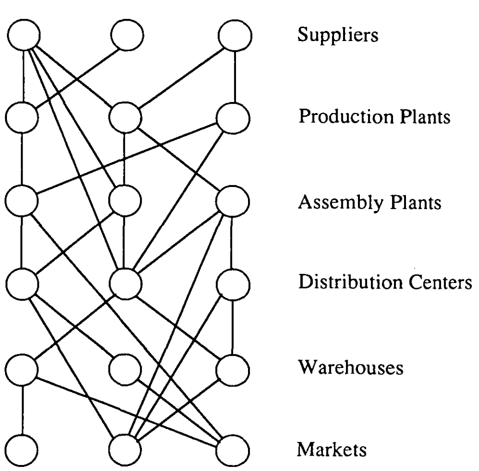

FIGURE 2 Representation of a general logistics network.

Figure 3 (again in an idealized sense) represents the general nature of changes in the logistics system under the influence of the driving forces described above. At least five major structural changes are likely.

First, the efforts of manufacturers to reduce their supplier base will "squeeze" the top (supplier) stage of the network. A smaller set of core suppliers will each be providing a wider range of raw materials or producing a wider range of parts and components. These suppliers will be asked to ship in mixed loads to meet JIT delivery schedules, and many manufacturers will expect their transportation providers to use multistop "milk runs" to collect shipments from several different suppliers for a single delivery to the destination plant.

Second, increasing globalization of the economy will "stretch" the bottom of the network, creating broader markets. However, those markets may have notable regional differences, requiring many customized variations in products.

Third, the competitive pressures to reduce logistics costs will compress the network from top to bottom, resulting in elimination of layers in the hierarchy of distribution inventories. This is shown in Figure 3 as the elimination of the "warehouse" stage. However, this top-to-bottom compression does not necessarily mean that the logistics links will become shorter. In fact, as production becomes more global the individual links are likely to become longer.

Fourth, the distinctions among the production, assembly, and distribution center stages will become less distinct. This change is a result of the combination of pressures to reduce logistics costs, the changing nature of production technology, and the desire to be more responsive to rapidly changing conditions in a wide range of markets.

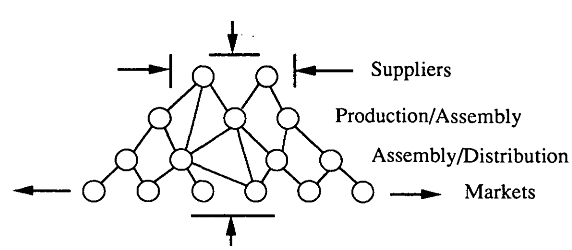

FIGURE 3 Response of a logistics network to external forces.

Finally, there will be greater flow of materials in the "reverse" direction, as a result of recycling used products. This also may create a new set of locations in the overall network, corresponding to reprocessing facilities in which materials from used products can be separated and prepared for reuse.

Perry (*19*) has argued that there are seven elements of strategic importance in adapting today's logistics systems to meet the future: asset productivity, horizontal management, selective risk (tailored, customer-driven service standards), postponement of resource commitments in the face of uncertainty, substitution of information for other resources (vehicles, materials, and labor), integrated planning, and system flexibility. His description of these seven ideas will not be repeated here, but the following section does illustrate, in a somewhat different way, a similar set of ideas about how we need to focus attention on the transportation elements of the logistics system.

NEW VIEW OF TRANSPORTATION SYSTEM OPERATIONS

Adaptation of transportation operations to the changing requirements placed on the logistics system requires new goals and objectives. Three critical goals for transportation operations are

- Coordination,
- Responsiveness, and
- Resource utilization.

These three goals do not make up an exhaustive list—certainly cost-effectiveness, safety, and reliability continue to be important, for example—but particular attention needs to be focused on these three. They point to total quality management for the transportation system—an emphasis on managing the performance of the whole system with constant attention to the customer. This focus on services provided is also the logical result of the public policy perspective expressed in ISTEA and reflects the influence of that force on changing the way the transportation system functions.

In an operational sense, coordination is the goal of bringing all the required pieces together in the right place at the right time. In a container port, for example, this means having gantry cranes, trucks (tractor and chassis) or railcars, and people available on the dock when the ship is ready to be unloaded, as well as having the required information for each container (contents, customs clearance, destination, tariff information, etc.).

The goal of improved system responsiveness stems from the fact that the system must be able to meet changing demands quickly and effectively. As markets shift from one place to another or commodity price changes cause changes in supplier locations, the system must be able to change delivery schedules or capacity requirements to meet new needs.

One way to meet the responsiveness goal is to provide excess capacity—to ensure that enough equipment and facilities will always be able to accommodate the demand that arises. But this leads to poor resource utilization and increased total cost, in contradiction to the third goal. Because responsiveness and utilization are conflicting goals, it is better to think about advancing the "responsiveness utilization" frontier, as shown in Figure 4. From a given operating point (combination of responsiveness and utilization), such as Point A in the graph, we want to move to a point at which improvement occurs in one or both objectives without a sacrifice in either.

Improvements in coordination, responsiveness, and utilization are intrinsically linked to information flow—the ability to provide more punctual and accurate information about system status and projected future events. The system needs an ability to complete operational transactions in a punctual, efficient, and accurate fashion, with "instantaneous" dissemination of pertinent information to all parties involved. Furthermore, improved quality of information offers the opportunity for effective real-time planning based on real-time data about present status and anticipated near-term demands.

Figure 5 shows a way of thinking about the related flows of goods, physical resources, and information, as we strive to achieve improvements in coordination, responsiveness, and resource utilization. Each of the three elements moves in its own "network"—goods move from vehicle to dock to vehicle on their way from origin to destination; trucks or railcars move from shipment to shipment as they are used and reused; and information moves from computer to computer (or person to person) through its own channels. However, these three networks can be treated as "layers" of a larger network, with connections among the layers that are necessary for processing steps. In the port example above, the container unloading process cannot begin until the ship with the containers, the crane, and the trucks or railcars are all present together, and the information about this shipment has also arrived, been assembled, and distributed to the necessary people.

The representation of connected layers of goods flow, resources flow, and information flow, as shown in Figure 5, emphasizes one of the major sources of delay in the transportation system. Delays occur when the layers are not tightly connected, and one or more of the elements required for a processing step are not present when needed. This delay lowers resource utilization, because those resources already assembled must wait for the missing elements, and also reduces overall service quality.

Figure 5 is also important because it places concern for information flow on an equal footing with concern for flows of goods and physical resources. As Perry (*19*) has suggested, the cost of information as a resource is falling relative to the costs of the other major resources (vehicles, labor, fuel, etc.)

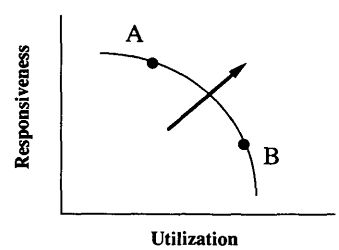

FIGURE 4 Responsiveness-utilization trade-off.

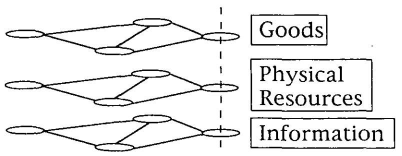

FIGURE 5 Connected layers in an overall network.

used in the logistics function. As rational managers, we should be trying to use more information and less of the resources it can replace. This will be vital as we enter the 21st century.

IMPLICATIONS FOR TRANSPORTATION SERVICE PROVIDERS

If the changes identified in this paper are occurring or accelerating, what should transportation providers do to preserve their existing business and create new opportunities for themselves? First and foremost, they must be aware that their customers' businesses are changing and that their logistics are likely to be changing as well. To reduce overall logistics costs and improve performance, the customers are likely to want to deal with fewer carriers, and the carriers they choose will have to understand their business. The implication is clear: transportation providers must get to know their customers better.

As manufacturing customers begin to rely on sources of materials and components from around the world, their inbound logistics problems get more difficult, and they are likely to be looking for carriers who can help them effectively manage the whole inbound supply chain. This may require joint ventures with other transportation companies so that together services over broader geographic areas and over multiple modes can be provided also. Similar pressures on expanding markets for finished products will create opportunities for similar joint ventures in the distribution end of the logistics chain.

Customers are likely to want more frequent shipments of goods, in smaller lot sizes, and with greater mixtures of commodities in each shipment. This is likely to mean greater use of containerization for domestic as well as international movements, and transportation providers need to be prepared to respond to that need.

Working more closely with customers, engaging in joint ventures with other carriers, and providing more complex services all will require mastery of the information flow that accompanies shipments. Transportation providers will need to exchange data with their customers, partners in joint ventures, and agencies such as Customs. Gaining the ability to do this effectively will require investments in both information technology and the people who will need to learn to use the technology efficiently.

FINAL NOTE

It has often been said that the only thing true about forecasts is that they will be wrong. Peering into the future is tricky business, but failing to plan for the future is almost certainly worse than planning for an uncertain future. It is my hope that the picture of the future sketched out here, dim and clouded though it may be, will shed at least a little light on someone's planning efforts.

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