The Logistics Revolution and Transportation

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ABSTRACT: A third of a century ago, management guru Peter Drucker called logistics the last great unexplored continent of business. This is no longer true. While transportation is the largest component of logistics, ordering costs, carrying costs, warehousing costs, and administrative costs are nontrivial. Corporations and academics now have departments to handle the logistics functions. Transportation has been subsumed, in many cases, by these broader departments. Managing the supply chain—from raw material assembly, to work in progress, to the physical distribution of the final product or service—is the essence of business logistics. The field has its quantitative side, with many models that minimize costs and maximize profits. A growing area is the qualitative side, which emphasizes management awareness of the logistics chain.

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AS defined by the major professional association in logistics, the Council of Logistics Management (CLM), logistics is

> the process of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption for the purpose of conforming to customer requirements. This definition includes inbound, outbound, internal and external movements, and return of materials for environmental purposes.[1]

The definition needs some refining, however. An earlier CLM version modified the word "effective" with "cost." "Cost effective" means that X is to be accomplished in the cheapest possible way. However, X might not be the profit-maximizing thing for the firm to do. Many logistics models use objective functions that minimize costs; in general, however, this is not the same as maximizing profit. Thus the definition should be modified to replace "efficient, effective" with "profit-maximizing." The spirit of this is captured by Ballou: "The mission of logistics is to get the right goods or services to the right place at the right time, and in the desired (right) condition, while making the greatest contribution to the firm."[2]

HISTORY

Obviously, firms always had to deal with logistics, whether they called it logistics or not. Raw materials had to be assembled so that the production activities could combine them to make the firm's product. The marketing and sales function of the firm would sell this product to demanders. Then, in turn, the firm's product had to be distributed down the channels of distribution, ultimately into a buyer's hands. In this process, materials and goods had to be stored and transported.

The field of transportation and logistics was once described as the Rodney Dangerfield of the firm, that is, it "couldn't get no respect." It took engineering genius to produce the product, marketing skill to sell the product, but anyone could get it from point X to point Y. When transport was heavily regulated and rates were basically fixed, many managers viewed the transport and logistics function as a necessary evil and an area in which they did not want to be involved because of regulation's arcane set of rules that only a small set of people had mastered (and were willing to master). Since all of one's competitors had to play by the same set of rules and faced the same structure of rates, management was not overly concerned with transportation—one could predict one's competitors' rates with great accuracy. Needless to say, being in transportation or logistics was not being on the fast track for a top management position. The green-eye-shaded worker mulling over a tariff book became the stereotype of the transport manager.

In the 1950s, those with foresight planted a seed that the field of transport and logistics was important. The

1. Council of Logistics Management, *1996 Membership Roster* (Oak Brook, IL: Council of Logistics Management, 1996), p. 356.

2. R. H. Ballou, *Business Logistics Management and Control* (Upper Saddle River, NJ: Prentice Hall, 1992), p. 5.

Weeks report for President Truman and the Doyle report for President Eisenhower advised that transport regulation was holding back the economy. President Kennedy's transport message in 1962 said the same. The Johnson administration made similar statements. The advocacy of transport deregulation was bipartisan in nature. The seed was planted—the rules did not have to be the rules. Firms might compete on the basis of transportation. At the same time, the lessons of military logistics from World War II and the Korean conflict were not lost. You had to support the troops (the product) or the war effort would not be successful.

Additional events put pressure on the previous simple model of making something and then selling it. Consumers continued the tremendous migration from rural areas to urban areas—and subsequently to the suburban and exurban areas outside the central cities. No longer would they shop in the central business district; now they wanted to be served near their homes (where "near" was defined as automobile accessible). Consumers (and/or marketers) also discovered product differentiation (real or perceived) in a whole new way. For example, white goods (refrigerators, stoves, washing machines) did not have to be white anymore. Colors and model types proliferated—to serve the designer tastes governing the type of kitchen one wanted to create. The impacts on inventory were staggering.

Demand growth can hide a multitude of sins. If the demand curve is rapidly shifting rightward, hosts of operational inefficiencies are hidden or ignored. Transportation and other logistics concerns were neglected for many years because of the rapid economic growth sustained in the United States after World War II. Recessions in the 1950s and 1970s started the thought processes toward cost control. The impact of the first and second oil embargoes on the U.S. economy led to great cost inflation, transport rate increases, and interest rates over 20 percent. Suddenly, inventory carrying charges, which were ignored when the interest rate was 4 percent, became substantial—especially since demand was no longer growing rapidly and the concept of the opportunity cost of money tied up in inventory had finally sunk in. Following the lead of the Nixon and Ford administrations, the Carter administration heartily advocated transportation deregulation. In fact, Carter's 1980 reelection strategy was to fight for deregulation as a way to control inflation. The combination of high carrying costs and the promise of lower transportation costs gave logistics a major push in recognition as we entered the 1980s.

Finally, the green-eye-shade mentality, along with the individual, was replaced by the computer. To the extent that institutional knowledge is valuable, it can be heavily captured by artificial intelligence. Routine, repetitive calculations can be handled rapidly. Deregulation's multitude of new rates can be analyzed easily. Models—routing, location, allocation—that had been developed by academics and that could be run only by a computer specialist on a mainframe could now be run by a relative novice at a desktop computer.

Top management had read about all these events (deregulation, sophisticated modeling advances) and wanted to see results, as they were under pressure to cut costs. In addition, since their competitors were now operating under a new set of regulatory rules (that is, no rules), they needed to worry that they couldn't handle transportation and other logistics concerns in the old way because their opponents could be gaining on or outdistancing them.

Thus the 1990s are a good time for logistics. It does not have all the respect that Rodney Dangerfield would like to have—but, in the words of a once-popular cigarette commercial, it has "come a long way, baby."

RECENT CHANGES AND CURRENT STATUS

The field of logistics is evolving rapidly. Thirty-four years ago, management guru Peter Drucker stated that logistics was like Africa—the last great unexplored continent (of business).[3] Since that statement was made, logistics has become a recognized field in many academic institutions. Many firms now have a vice president of logistics. This is likely a position that would have been called vice president of transportation or manager of transportation in the past. However, not all firms have developed to the level of recognizing logistics, and, as in the academic field, not every firm is sure where logistics belongs in the company. The big difference since the time of Drucker's comment is that most everyone now agrees that logistics belongs.

The locus of logistics in academe can be very diverse. Faculty can reside in the arts and sciences in departments of economics, geography, regional science and sometimes even in sociology, political science, and history; in business schools in departments of marketing, public policy, management science, decision sciences, operations research; in city, regional, and urban planning schools and departments; and in engineering schools in departments of civil, industrial, and systems engineering. As a result, the treatment of transportation and other logistics matters can be quite different by department—because of the paradigm differences of each discipline.

The change in the name of the major professional logistics association demonstrates the evolution of the field. CLM was founded in 1962 as the National Council of Physical Distribution Management (NCPDM). CLM has over 11,500 members, an increase of 248 percent since 1985. Indicative of the size and diversity of logistics, CLM lists 179 "Logistics Publications and Organizations"[4] (many of which recently changed their names to reflect a broadening of their base from transportation to logistics) that frequently publish material of interest to logistics managers.[5]

The association changed its name from NCPDM to CLM in 1985 as a

3. Peter Drucker, "The Economy's Dark Continent," *Fortune*, pp. 72, 103-4 (Apr. 1962).

4. Council of Logistics Management, *1996 Membership Roster*, pp. 348-55.

5. The evolution of the field is shown in changes in titles of publications and names of other professional or academic associations. The weekly magazine *Traffic World* has recently started to bill itself as the transportation and logistics weekly. The American Society of

recognition that "logistics" was the most encompassing term that described the management of firms' acquiring and distributing activities over space. "Physical distribution management" implied merely the managing of the production output of the firm through the channels of distribution (production to warehouse to distribution center to wholesaler to retailer to customer—not all steps relevant to all firms). Others worried about materials management (the purchasing, transporting, and storing of the raw materials necessary for the production of the product) and the management of work in process. Materials management activities are now described by many as "inbound logistics"—a further recognition of the unifying trend around the word "logistics."

Logistics, thus, is like a cradle-to-grave analysis of the ordering, transport, and storage of the product or service being produced and of the inputs required to produce it. Transportation is just one—albeit quantitatively the largest—of many functions that make up logistics. In addition, there are interfaces with other activities of the firm, such as marketing, finance, production, management information systems, and so on. Logistics is seen by its practitioners as the common link that weaves all the traditional functions of the firm together to meet customer requirements.

In fact, when firms are not managed as an entity and instead are managed as individual profit centers or as cost centers, suboptimization (from a profit maximization standpoint of the whole firm) is likely to happen. For example, marketing and sales generally would like a large amount of each product the firm produces in inventory at many locations. This enables them to provide very fast service for a customer order of any magnitude. Production would generally also like very large inventories—of raw materials (so they never run out) and of final production. Long production runs minimize the downtime of the production line for retooling and are simpler to manage.

Finished goods or raw materials held in inventory, however, are just dollar bills in disguise being warehoused. As dollar bills, they could earn a return, for example, as interest on a government bond, for the risk averse. With respect to long production runs, trade-offs exist as to increased costs for customer service and marketing, decreased costs for production, decreased costs for transportation (quantity discounts when shipping in large increments), but increased costs associated with high inventory. The secret is finding the right combination of inventory, length of production run, level of customer service, and so forth to maximize the profit of the firm as an entity: that is, a systems approach.

The logistics costs of a typical firm entail transportation, inventory carrying, customer service, order processing, warehousing, packaging, information or data costs associated with the foregoing, and administration of the logistics function. Trans-

Traffic and Transportation changed its name to the "American Society of Transportation and Logistics," and the Association for Transportation Law, Logistics, and Policy added "logistics" to its title in 1994.

TABLE 1
DAVIS AND DRUMM'S LOGISTICS COSTS AS A PERCENTAGE OF TOTAL REVENUES

Logistics Component	Percentage
Transportation	3.53
Warehousing	2.10
Carrying cost	1.70
Customer service or order processing	0.44
Administration	0.39
Total distribution cost	7.94

SOURCE: Herbert Davis and William Drumm, "Physical Distribution Cost and Service," in *Annual Conference Proceedings* (Oak Brook, IL: Council of Logistics Management, 1995), p. 211.

NOTE: The percentages do not add up to the total because not all firms responded to all the survey questions.

portation is typically the largest of these costs. Herbert Davis and Company surveys firms to ascertain the values of some of the components of logistics costs. Davis and William Drumm measure only the physical distribution cost components and find the cost items as a percentage of the total revenues (sales) of the firm as shown in Table 1.[6]

As can be estimated, transportation is more than 40 percent of the distribution cost. The total of warehousing and inventory carrying cost is slightly more than transportation cost. Davis and Drumm show that distribution costs as a percentage of revenues vary from industry to industry, from a low of 3.85 percent for high-value pharmaceuticals to a high of 10.2 percent for low-value processed food.

Robert Delaney of Cass Information Systems (formerly Cass Logistics) presents an annual "state of logistics report." In this report, he carries out a calculation analogous to Davis and Drumm's but using aggregate U.S. data. He compares physical distribution cost to the gross national product and, in addition, calculates the logistics supply-chain costs (which adds the materials management component to the physical distribution component) relative to the gross domestic product.[7] The results are shown in Table 2.

Transportation is by far and away the largest component of distribution or logistics costs, followed by things that can happen to inventory while in storage—it can be taxed, it can become obsolete, and it will depreciate. Warehousing and carrying costs combined (which exceeded transportation in the Davis and Drum analysis) are only a quarter of transportation costs in the Delaney analysis. This can be partially explained by noting that transportation costs did not change from Delaney's physical distribution calculation to his logistics supply-chain calculation. Clearly, transport was needed to support the movement of raw materials. Thus the transport component of the physical distribution calculation is overstated.

The $660 billion is 9.8 percent of the gross national product. Delaney also presents a time series of this calculation since 1971, when the per-

6. Herbert Davis and William Drumm, "Physical Distribution Cost and Service," in *Annual Conference Proceedings* (Oak Brook, IL: Council of Logistics Management, 1995), p. 211.

7. Robert V. Delaney, "Is Logistics Productivity at a Crossroads? Simple Facts, Plain Arguments, and Common Sense," in *Sixth Annual State of Logistics Report* (St. Louis: Cass Information Systems, 1995), figs. 8, 11.

TABLE 2

DELANEY'S PHYSICAL DISTRIBUTION COSTS AND LOGISTICS SUPPLY-CHAIN COSTS: AGGREGATE U.S. DATA (Billions of 1994 dollars)

Logistics Component	Physical Distribution		Supply Chain	
	Cost	As a percentage of gross national product	Cost	As a percentage of gross domestic product
Transportation	$420	63.6%	$420	57.5%
Warehousing	$60	9.1%	$63	8.6%
Carrying cost	$40	6.1%	$53	7.3%
Shipper-related cost	$5	0.8%	$5	0.7%
Administration	$25	3.8%	$28	3.8%
Taxes, obsolescence, and depreciation	$110	16.7%	$161	22.1%
Total costs	$660	100.0%	$730	100.0%

SOURCE: Robert V. Delaney, "Is Logistics Productivity at a Crossroads? Simple Facts, Plain Arguments, and Common Sense," in *Sixth Annual State of Logistics Report* (St. Louis: Cass Information Systems, 1995), figs. 8, 11.

NOTE: Davis and Drumm use 18% as the carrying cost, while Delaney uses 23.5%. Davis and Drumm's numbers are for 1995, and Delaney's are for 1994.

centage was 13.2 percent. The percentage peaked in 1981 at 14.7 percent and has fallen more or less monotonically since then (attributed by Delaney to the deregulation of the transportation modes). The logistics supply chain was 10.8 percent of GNP in 1994. This also peaked in 1981 at 17.9 percent and has fallen more or less monotonically since then. Thus, by any account, logistics costs are quite large.

In addition, since the calculations include the expenditures of all firms (in the case of Delaney) and the responding firms (in the case of Davis and Drumm), to the extent that firms are less than perfectly efficient, these costs will be overstated. Also, these percentages may be higher for some firms than for others because for those firms, the high customer service levels desired by marketing and/or the long production runs desired by operations are the profit-maximizing strategies for the firm (despite their increase in transportation costs, inventory carrying costs, and warehousing costs).

An interesting trend today is the proliferation of third-party logistics providers. They argue that firms should stick to their core competencies and outsource the logistics function. These third parties are primarily the transport modes that would move the product, previous transportation or logistics departments of firms that have been downsized, and consulting firms. Firms that use third-party providers would have none of the breakdowns shown in Tables 1 and 2.

MILESTONES IN TRANSFORMING TRANSPORTATION TO A LOGISTICS ORIENTATION

Two early studies in transportation encouraged thinking away from simply transportation costs and introduced the field to logistics concepts. While even earlier studies ex-

ist, none have had more impact on modern logistics than these two. The first related to the marketing of air freight. To move a given product by air from point A to point B can cost more than twice as much as by truck. Thus, if the shipper made the modal choice (the shipper or receiver's choice of transport mode) based on a comparison of transport rates alone, air would not win much traffic.

In order to sell air freight services, a full distribution cost approach was utilized in 1956 by Lewis, Culliton, and Steel.[8] This approach integrated some of the other logistics costs into the analysis of modal choice, so that high transport costs could be traded off against faster response to customer demands; smaller, more centralized inventories; lower carrying costs; lower warehousing costs; less loss and damage; more reliable service; and so on. Since no one would choose air on the basis of its transport rates alone, air had to argue that, from a total cost perspective, it was cheaper than alternative modes (for some shipments). The intent of the study was to suggest that all shippers should evaluate their modal choices based on several logistics variables, not only transport rates.

Trade-offs are a hallmark of logistics analysis. These trade-offs all exist but on a multidimensional basis—all of which should be driven by a standard of profit maximization. The optimal trade-off is not defined ex ante but rather ex post, that is, the profit-maximizing way of doing things will define the precise trade-off between X and Y, between X, Y, and Z, and so on, that one should have made.

Nevertheless, managers need ex ante rules and are governed by salaries or bonuses or both that are driven by their taking a number of things as given and optimizing against those constraints. Thus, minimizing costs subject to externally given amounts to ship, origins and destinations, and customer service standards may serve an intermediate manager well. One would hope, however, a higher-level manager is viewing the big picture.

The second major introduction of the other logistics costs came in the classic work of Meyer, Peck, Stenason, and Zwick.[9] Prior to Meyer et al., the typical way to view modal comparative advantage over distance was to perform a break-even analysis by plotting the transportation bill versus distance for each mode. Meyer et al. argued that the modal comparison should include inventory costs based on the time required by each mode and the shipment size moved by each mode. Since Meyer et al., numerous articles on the demand for transportation have appeared that include the transport rate and other logistics elements.[10] While the logistics texts all refer to Lewis et al.,

8. H. T. Lewis, J. W. Culliton, and J. D. Steel, *The Role of Air Freight in Physical Distribution* (Boston: Harvard University, Graduate School of Business Administration, Division of Research, 1956).

9. J. R. Meyer et al., *The Economics of Competition in the Transportation Industries* (Cambridge, MA: Harvard University Press, 1959), pp. 161-62, 164, 188-96, 348-53.

10. For a summary, see C. Winston, "The Demand for Freight Transportation: Models and Application," *Transportation Research A*, 17A(6):419-27 (1983).

Meyer et al. get no mention. Meyer et al., however, received considerable attention from economists.

Both the Meyer et al. and the Lewis et al. approaches were ones of cost minimization, however, and not profit maximization. The typical analysis would be: x tons of widgets must be shipped from A to B; what is the cheapest full-distribution cost mode to ship by? A profit-maximizing approach would ask questions of whether x was the best amount to ship and whether to ship from point A to point B was the proper origin-destination pair.

THE HEART OF LOGISTICS MODELING

The quantitative logistics field is centered around several models. One basic model is the economic order quantity (EOQ) and its variations. Interestingly, the simplest EOQ model (that used to introduce the EOQ concept) assumes that transportation is neutral, that is, that it does not influence the optimal behavior of the firm. A constant amount of the product is to be shipped from A to B during a time period, and a constant transport cost per unit shipped is assumed. The simple EOQ model finds the output that minimizes the sum of ordering costs and inventory carrying costs. The trade-off between ordering costs (which decline as the EOQ increases) and carrying costs (which increase as the EOQ increases) is easily shown.

If the transport rate is a function of the amount shipped (quantity discounts), then transportation influences the EOQ. Alternatively, the EOQ can be made a function of the transportation characteristic of time if transport time is not known with perfect certainty.

The classic linear programming model has a fixed supply of product available to be distributed from m origins to serve the demands at n destinations. Overall demand may equal supply, or excess demand or excess supply may exist. Transshipment (the movement from m to n through another location, r) may or may not be possible. The optimal distribution pattern minimizes total transportation costs and gives the amount of shipment from each origin i to each destination j given the unit transportation costs from i to j, subject to the constraints on total demand and supply.

Another model determines the optimal location of a facility (which could be a plant or distribution center, for example) by minimizing the total transportation costs of assembling the raw materials and distributing the final product. Other variables that could influence location are assumed equal at all locations or are handled as cost deviations from the minimal-transportation-cost location. For example, if the transportation cost at the minimum-transportation-cost location is x and it is y at an alternative location that is being considered because of a cost saving in a nontransport variable, the optimal location would change from the transport-cost-minimizing location only if the other variable offered savings greater than $y - x$.

Optimal routing models also minimize transportation cost. One of the simplest is the savings method. If A and B must be served from location X

and if they were served on a single run, one would travel $d_{XA} + d_{AB} + d_{BX}$, where d_{ij} is the distance from i to j. If the two destinations were served on separate runs on an out-and-back basis, the total distance traveled would be $2d_{XA} + 2d_{XB}$. Combining the two routes saves $d_{XA} + d_{XB} - d_{AB}$ in distance. If transport costs are proportional to distance, then minimizing distance will minimize transport costs.

Using the savings concept, a method exists that will often minimize and most times come very close to minimizing transport costs by building routes incrementally by adding stops that yield the highest level of savings of stops not already assigned to a route. A single route or multiple routes may be built by this method. Capacity of vehicle constraints, time of delivery constraints, and other factors can be added to the model.

All of these models can be made very sophisticated.

Despite the dominant role played by transport costs in the foregoing models, transport economists have not played a major role in their development, nor have such models been taught or utilized by many transport economists. Rather, they have become the domain of the operations research and engineering side of transportation. It is in the areas of transportation demand models and their linkages to other areas of logistics (such as inventory) that the social scientists have shown their interest in logistics (although many would not recognize it as such but as an application of their economics training in demand analysis).

Another major field of logistics has evolved today—the management of the previously mentioned processes—called supply-chain management. Many business schools are now devoting more time to this soft approach than to the quantitative approach. Some business schools have even dropped the quantitative material from their core curriculum.

THE DOMAIN OF LOGISTICS TODAY VIS-À-VIS TRANSPORTATION

What would be the typical domain of a logistician today? One way of obtaining a feel for this would be to look at the coverage in a logistics textbook. Overall logistics is a way of organizing in a more comprehensive format what many had called transportation and its ancillary and interrelated aspects. A table of contents of a transport text could have many of the same topics covered by the logistics text, but the level of detail emphasized in the texts would differ. In practice, however, there is little overlap in the tables of contents of the two types of textbooks.

Because good transport economists will always recognize that a systems approach is necessary, they could de facto practice much of what is recognized as the field of logistics today, whether they call what they do transportation, economics, operations management, or logistics.

CONCLUSION

Logistics will never likely cut into the domain of the true transport economist because of the concern in logistics with organizational design, on the one hand, and with operations

research on the other. Transport economists will continue to pick niche topics that interest them (perhaps in ignorance of what logisticians are doing, perhaps not). Likewise, operations researchers will not be interested in the bigger managerial pictures and will continue to work on models applied to particular problems. The overall integration will be in the business schools that combine economists, operations researchers, and the management disciplines. Some of the business types will be more quantitative and others will be more verbal or organization-design in nature. The essence of the business school is to bring multiple disciplines together, and that epitomizes what logistics is—a multidisciplinary approach concerned with how to coordinate all purchasing, selling, and producing activities together in order to assemble and distribute the right products in the right amounts to the right locations in the right condition so as to maximize profits for the firm.