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From the pages of Supply Chain Management Review

Demystifying Supply Chain Management

PETER J. METZ -- 1/1/1998

Integrated supply chain management is not rocket science. . .or is it? It relies on advanced, somewhat mysterious, techniques like mixed-integer programming and concurrent engineering. It uses the most sophisticated software and hardware available. But while the tools used may be rocket-science like, the basic concept is surprisingly simple. Supply chain management is the logical customer-focused progression of physical distribution and logistics management. It's challenging, it's fun, and it's here to stay.

Is supply chain management (SCM) just another business buzzword, a faddish term destined to be replaced by yet another buzzword? Despite its current widespread popularity, supply chain management remains a somewhat mysterious concept. Its basic precepts are not clearly understood, its origins puzzling, its concepts amorphous, its future fuzzy. Given these concerns, is supply chain management real?

My aim in this article is to show that supply chain management is, in fact, a logical development of lasting value. It boasts a future that is quite discernible-and quite exciting. And once you've heard my point of view, the hope is that you'll be able to explain supply chain management to your spouse-and maybe even your boss.

Supply Chain Basics-It *Is* Rocket Science

I contend that supply chain management is rocket science at its core. It uses advanced technology, information management, and operations research math to plan and control an expanding complexity of factors to better produce and deliver products and services in a customer-pleasing way. It uses sophisticated mixed-integer programming, relational databases, concurrent engineering, and similar mysteriously technical tools. Though the technology may be complex, SCM's essential concepts and its operational techniques are eminently understandable.

Here's the definition of supply chain management used at MIT:

> Integrated Supply Chain Management (ISCM) is a process-oriented, integrated approach to procuring, producing, and delivering products and services to customers. ISCM has a broad scope that includes sub-suppliers, suppliers, internal operations, trade customers, retail customers, and end users. ISCM covers the management of material, information, and funds flows.

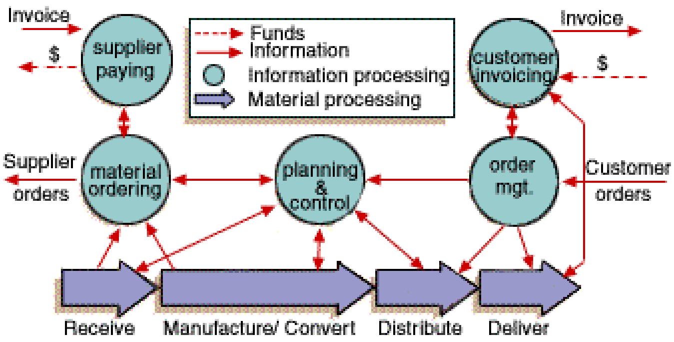
(Note that we add the word "integrated" to underscore the objective of integrating the many functions into the total process. See the accompanying sidebar on the MIT-Industry Integrated Supply Chain Management Program.)

Supply chains exist in manufacturing industries, in service industries, and in the home. Other terms are "demand chains" or "value chains." But whatever the term used, we mean the integrated process of producing value for an end user, the ultimate customer.

Supply chains come in different varieties of increasing complexity. **Exhibit 1** depicts a single-stage supply chain. It incorporates the material flow functions of receiving raw material or sub-assemblies, manufacturing, distributing, and delivering. It has many information-processing and decision-making functions, reflected in the many information-flow lines. And it includes funds-handling functions because working capital in the form of payables and receivables is just as important as working capital in the form of inventory and equipment. This single-stage supply chain, typically found in a single company, has been the primary focus of supply chain management to date.

EXHIBIT 1

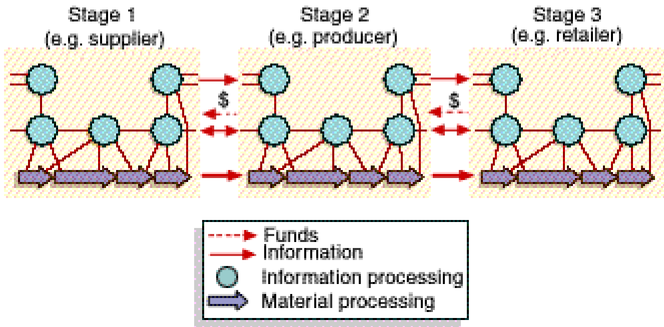
Basic Single-Stage Supply Chain



The multi-stage supply chain more fully embodies our SCM definition above. These are typically multi-company supply chains, but they are essentially multiple replications of the single-stage supply chain. **(See Exhibit 2.)** Volkswagen provides an example of a multi-stage supply chain. The automaker is working with its dealers to get advance order information and actual orders electronically and feed the data directly into the daily automobile production planning. VW also is working with its in-house supply plants and contract suppliers to issue electronic orders for parts and sub-assemblies to be delivered in a just-in-time mode according to the daily production schedule. VW plans to use this integrated supply chain operation to reduce its present order-to-delivery cycle time from many weeks to two weeks and eventually to a matter of days.

EXHIBIT 2

Multi-Stage Supply Chain



Supply Chain Past: The Roots of Supply Chain Management

Supply chain management is the logical progression of developments in logistics management. When the National Council of Physical Distribution Management (NCPDM) was founded in 1963, practitioners were discovering the inter-relationships between the warehousing and the transportation functions. **(See Exhibit 3.)** Physical distribution management integrated these two functions, providing inventory-reduction benefits from the use of faster, more frequent, and, especially, more reliable transportation. Shorter order response times via faster warehouse handling and faster transportation lessened the length of the forecast period, thereby increasing the accuracy of forecasts. Another integration advantage centered on the ability to consider transportation and warehousing together, thereby optimizing warehouse locations for better service and lower total cost.

Physical distribution management was enabled by improved data communications between the different levels of warehouses (plant, regional distribution center, local distribution center) and the more complex analyses (for example, total warehouse-transportation costs, optimization of the transportation/warehouse network). Better

EXHIBIT 3

Physical Distribution Stage

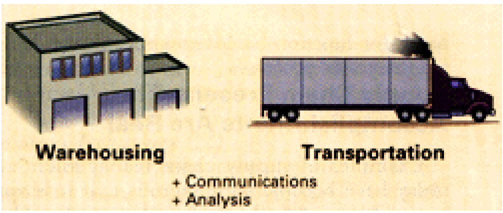


EXHIBIT 4

Logistics Stage

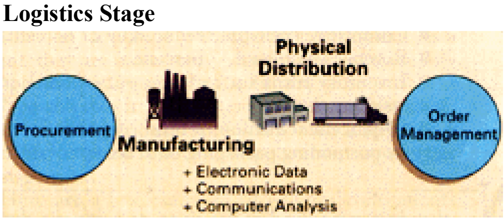
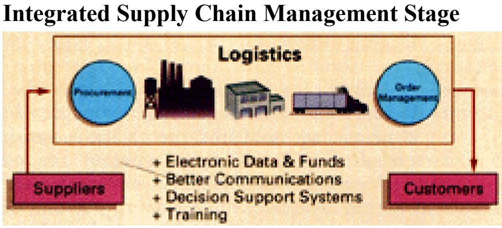


EXHIBIT 5

Integrated Supply Chain Management Stage

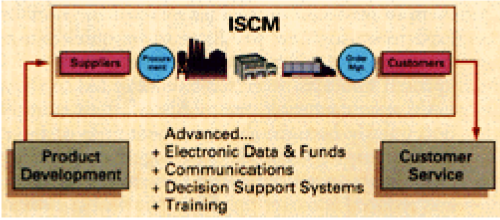


data and more advanced analytical techniques facilitated better decisions among a more complex set of factors. In fact, ever improving communications and analyses continually enhance our ability to make more complex decisions.

The second phase in SCM's development, the "logistics stage," saw the addition of the manufacturing, procurement, and order management functions. **(See Exhibit 4.)** This was aided by electronic data interchange, worldwide communications, and the growing availability of computers to store data and perform analyses.

EXHIBIT 6

"Super" Supply Chain Management



The third-and current-stage is the "integrated supply chain management stage." **(See Exhibit 5.)** To the lengthening chain of functions being integrated, we've added suppliers at one end and customers at the other. This has become a seven-function supply chain, vastly more complex than the two-function physical distribution chain. To handle this complexity, we rely on electronic data, electronic funds transfer, higher bandwidth communications, and computerized decision-support systems for planning and for execution. Training is a key component, too.

The next phase of supply chain management, "super-supply chain management" for want of a better term, will incorporate more functions such as product development, marketing, and customer service. **(See Exhibit 6.)** It will be enabled by even more advanced communications, better and more user-friendly computerized decision support systems, and increased training. Some examples of this already exist.

In this "super supply chain" product designers, as part of the supply chain team, will design the product to facilitate manufacture of customized versions that also can be more easily installed and serviced. Pre-order and order information will be sent to all supply chain participants so that they can respond more quickly and accurately. Manufacturing personnel will be part of the installation team, resulting in shortened installation times. Material receipt triggers invoice-less supplier payments. And improvements are continual as the supply chain team learns more about working in an integrated mode.

What's propelling this steady advance from a two-process supply chain, to a seven-process supply chain, and on to a future with 10 and more processes linked into one integrated process? The answer: The explosive development of computer technology and communications technology, the "information technology revolution." IT makes it possible to have more information, more accurately, more frequently, from more sources, from all over the globe. And IT makes it possible to digest, to understand, and to act on this growing abundance of information by giving us ever more sophisticated analysis, modeling, and decision-support capabilities. In short, advances in communications and computerized decision-support systems are making it possible to deal with the supply chain's growing complexity, to incorporate more factors and more people in the decision making, and to communicate the decisions and learn faster about the results.

The rise of "systems thinking" in business management has fostered the development of SCM. Engineers are trained to consider all the parts of an entity in examining how they interact with one another. Peter Senge's popular management book, *The Fifth Discipline* [1], is mostly about how to understand and exploit the fact that processes interact with one another. Total quality management (TQM) and business process reengineering (BPR) also have made important contributions. Both of these disciplines, in their own way, teach the power of understanding process interactions in order to design more efficient, more productive processes. The other important aid is the move toward activity-based costing (ABC), which has given us process-based financial information that is much more useful than the traditional organization-based (or function-based) cost accounting in designing integrated processes.

Supply Chain Present: The Accomplishments Are Real

Examples of supply chain management results today have become so numerous that it is virtually impossible to compile comprehensive list. Here are just a few examples, each from different firms, we can cite:

- Inventory reduced by 50 percent.
- Supply chain total cost share of revenue reduced 20 percent.
- 40 percent increase in on-time deliveries.
- Cumulative cycle time reduced by 27 percent.
- Revenues increased 17 percent.
- Inventory turns up 2x while out-of-stock incidents down 9x.
- 50-percent reduction in finished-goods inventory by postponing packaging until receipt of orders.

These are all real improvements created by the better decision making made possible by integrated supply chain management. But there's also a non-intuitive result: Supply chain management can reduce costs, improve service, *and* enhance revenues *simultaneously!* For instance, the VF Corporation, which makes popular lines of clothing such as Jantzen, Vanity Fair, and Wrangler, achieved the 17-percent increase in revenues cited above. This came about within several years of installing computer-aided design (CAD) in its design centers, computer-aided manufacturing (CAM) at its world-dispersed plants, and a telecommunications network to interconnect them in near-real time. This enabled the initial sales experience for new products to be quickly used in CAD product redesign. These data, combined with updated forecasts, were electronically fed to the agile CAM manufacturing plants. Also, fast air transportation quickly brought the right quantities of the right product to the retail shelves. Together, these supply chain innovations improved sales in the peak season and reduced left-over product to be sold at a discount. So revenues rose, *and* the customers got better service, *and* inventory costs and resale costs went down.

Five key success factors enable these continuing supply chain management accomplishments:

- *An overriding, pervasive customer focus.* At every stage in the supply chain, the ultimate customer's needs are understood and factored into the decision making.
- *Advanced use of IT.* Data and information flow readily to all parts of the supply chain. Computer-aided decision-support systems use this complex information to enable better, faster decisions that then are quickly communicated throughout the supply chain.
- *Quantitatively based performance management.* Measurements of multiple performance factors occur frequently at each stage in the supply chain. Time and cost are key measures, but others are used as appropriate to the specific supply chain. All measures relate to the ultimate supply chain goals.
- *Use of cross-functional teams.* Teams of people from the interrelated functional operations working closely together can cut through the normal organizational barriers to find local and distributed improvements that benefit the overall supply chain performance.
- *Attention to human factors and organization dynamics.* Use of the best human and organization coordination/cooperation/measurement/reward techniques facilitates supply chain innovation and implementation. This level of attention is needed to offset the tendency of individual accountability and work-unit accountability to create barriers to supply chain cooperation.

Technology Is the Key Supply Chain Driver, Energized by Competition

No other factor has had as much to do with the development of supply chain management as the advance in key technologies: information, manufacturing, and transportation. The improvements have brought about agile manufacturing, cheaper and more reliable transportation, wide bandwidth global communication, and powerful information processing. And this, in turn, is enabling us to coordinate multiple supply chain functions, responding ever more frequently and rapidly to changes in the market, business environment, and product design. The competitive urge has inspired us to implement these technology advances swiftly. Thus, rapid technology advances have made SCM a fast-moving, sometimes breathtaking, field.

Before going on about technology, I want to point out two other key factors: improvements in financial accounting and improvements in organization management. In fact, both can be viewed as "soft technologies." Financial methods like activity-based costing give us process element costs and enable us to quantify the financial trade-offs that must be understood for good integrated supply chain design. Advanced organization management concepts that facilitate better teamwork and clearer communication facilitate the "horizontal process management" needed to manage ever-changing supply chains without the disruption of continual corporate reorganization.[2]

With respect to technology, consider this sobering observation. Professor Thomas Eager, head of MIT's Department of Materials Science and Engineering, has observed and reported on what appears to be a general phenomenon: that historically innovations seem to take about 20 years from invention to commercialization of the invention.[3] He has chronicled this for materials science developments ranging from vulcanized rubber in the mid-1800s to the thin film coatings used in today's high-capacity "hard drive" data-storage devices. Eager believes this 20-year cycle can be shortened with more explicit attention to the commercial implementation. If he's right and we succeed at shortening this cycle, then we can expect an even faster impact of new technology on managing supply chains in the future!

How Siemens Integrates the Supply Chain

Siemens Medical Engineering Group is one of the world's leading producers of computed tomography (CT) equipment for use in hospitals. These large, high-tech machines, which cost from $300, 000 to nearly $1 million, provide precise X-ray cross-section images of humans for medical diagnosing. Each machine is tailored to the hospital's requirements and installed in a specially prepared space. CT equipment is manufactured in Siemens' plant in Forchheim, Germany, and shipped for installation to hospitals all around the world.

Over the past several years the company has reworked the supply chain for CT equipment from supplier to customer, reducing what was a 22-week order-to-delivery cycle to six weeks. This has been accomplished while improving the customization of the equipment for individual hospital customers. Some of the techniques Siemens uses are:

- Involving product designers to change the design for easier manufacturing, installation, and customization.
- Reducing the supplier base so that 20 key suppliers provide about 90 percent of the supplier volume (one of these suppliers is the full-service transportation provider).
- Obtaining the same performance from internal suppliers that is expected of external.
- Shifting the key suppliers to a kanban operation where parts inventory in the Forchheim plant is on consignment. Parts are delivered on a cycle that works well for the supplier, while meeting the plant production needs.
- Using simple order transactions based on standing

Information Technology (IT)
No technology has been more important to SCM's development than the twin galloping IT horses of computers and communications. The doubling of semiconductor performance every 18 months or so has been going on for decades. Over and over, a new development has overcome what seemed to be looming barriers to such rapid advancement. I expect this pace to continue. For instance, massive multi-stage supply chain analytical problems now take a long time to solve on very large and expensive computers. As a result, they are solved only occasionally and then only for planning purposes. In the future, these problems will be solvable in minutes or seconds on affordable operational computers, making such analyses an everyday part of real-time supply chain operations management.

Here are a few examples of where developments in IT may take us:

agreements with invoiceless payment made at the time of consumption by Siemens.

- Sharing all forecast and ordering information on an annual, monthly, and more frequent basis with all the key suppliers.
- Conducting monthly supplier meetings to share performance information and develop improvement ideas for implementation by Siemens or by the supplier.
- Closely tracking preparation of the hospital space so that CT equipment delivery is neither early nor late.
- Using manufacturing plant teams to do some of the installations, thereby creating two-way learning between manufacturing and field installation teams. The result is significant installation time savings.

Siemens' manager of material logistics in Forcheim, Dr. Frank Hasselberg, has a passion for integrated supply chain management. He and his team always have multiple improvement projects under way. Hasselberg's goal is to bring the order-to-delivery cycle time down below three weeks, while improving the quality and lowering cost.

- *The Internet.* The continued development of the Internet will make possible more direct selling and better service to customers. For instance, on L.L. Bean's Internet store today you can browse a wide variety of merchandise, specify exactly what you want (including size, color, and other features), and then find out if it's in stock before you order. This and more is coming from many merchandisers.
- *Low Earth Orbit Satellite (LEOS) Communications.* No fewer than four well-funded consortia will be launching hundreds of low earth orbiting communications satellites. These will provide ubiquitous worldwide communications at lower cost than today's wire/fiberoptic networks. Such economical global communications will speed the development of global supply chains.
- *Advanced Distributed Decision Support Systems.* Researchers at MIT's Media Lab have developed prototype "wearable computers" that are tied into the Internet by wireless communications. These units take input from small single-hand keyboards in one's pocket and display information on a "heads-up" display on the inside of the user's glasses. They are fairly unobtrusive now. Future miniaturization will make them an imperceptible inconvenience to the user. When joined up with high-quality speech recognition to replace the keyboard, they will be truly user-friendly. Imagine future supply chain operators and managers who are "wearing" voice-actuated computers with heads-up display glasses. They'll be able to get fast answers to their verbal questions no matter where they are or what they're doing. They can request analyses and promptly get the results from high-powered decision-support systems. And they can communicate freely with any part of the supply chain.

Manufacturing Technology
It's been an uphill battle in many companies to bring manufacturing into the supply chain team. Historically, this function has taken the position "tell us what to produce, let us produce efficiently as we know best, then you (logistics) ship it." But increasingly, advances in manufacturing technology are contributing to making the total supply chain efficient.

Here are some present and future examples:

- *Agile Manufacturing.* Agility in manufacturing allows short production runs with quick changeovers. In some cases agile manufacturing will make possible economic production runs of one item. This is a key part of how we'll achieve "mass customization."

  Another form of manufacturing agility is "place agility." For instance, in his studies of global supply chains, Donald Rosenfield of MIT's Sloan School has shown that firms that manufacture the same product in several different parts of the world can benefit from investing in a certain amount of *excess* production capacity.[4] The extra capacity enables the producer to quickly shift the manufacturing load to the optimal plants in response to fluctuations in currency exchange rates. This is a typically counter-intuitive result of good supply chain thinking: Investing in excess capacity in the right places may reduce total supply chain costs because of the compensating savings resulting from rapid response to changes in currency exchange rates.

- *Postponement.* Producing the finishing features of a product close to the customer for immediate delivery can yield some wonderful supply chain efficiencies. The primary plants can produce a more "vanilla-like" product that is shipped to facilities near to the customer where the final "flavoring" can be added in quick response to each customer order. This cuts down on the total amount in inventory, as vanillas are cheaper when produced in bulk. Furthermore, the higher-value finished goods are produced only according to customer orders and shipped immediately so they are only in inventory for the briefest time. Plus, the customer gets much faster response and is more likely to receive full orders.

For instance, Gillette is gearing up to apply postponement in its razor blade business. The basic blades will continue to be manufactured in its present two high-technology plants, but the packaging operation is being moved to regional distribution centers. Packaging (which is an assembly line-like manufacturing operation of printing the consumer package, and filling it with blades) will be done to order. This will enable labeling features to be tailored to each retailer. Furthermore, Gillette can exactly meet the retailer's blade quantity per package preference without the waste of left-over packages of the wrong quantity. The company expects to reap a 50-percent reduction in finished-goods inventory when this is full implemented.

- *Production at Consumption.* MIT researchers have developed "3-D Printing. "This technique enables a product to be produced by multiple passes of a "printer" that applies the right materials in the right pattern as directed by software.[5] This invention already has been around for nearly eight years. Think what this could mean to supply chains when the 20-year (or less) commercialization cycle brings it to widespread commercial use. You want something in your office or home-a pencil, a bar of soap, or maybe even a custom-built stereo. So you submit your electronic order and payment, and that item is immediately produced on your "3-D printer," guided by software and signals that respond to your exact, perhaps unique, specifications, ready for immediate use.

  Just think how such technology innovations could impact the product supply chain. Only raw materials are transported and stored, but at millions of points of consumption, there is no finished-goods inventory; there is no finished-goods packaging nor packaging recycling; retailers are out of the chain; raw-materials distributors are in.

Transportation Technology
Transportation technology has not been moving at the blazing pace of information technology. But it will steadily continue to advance, with occasional breakthroughs like double-stack container trains and computer-aided scheduling, routing, and load assignment.

There also will be vehicle and vehicle/logistics systems advances. One to watch is FastShip, a new containership design that is nearly twice as fast as conventional designs. Its developers have coupled ship speed with a new loading/unloading system by which strings of containers roll into and out of the ship's stern, enabling much faster loading/unloading times and fast turnaround cycles. In addition, the ship operations will be integrated with land transportation providers who will smoothly handle the containers directly to and from the landside origin/destination with almost no dock dwell time. This is a logistics *system* development, based on new transportation technology.[6]

Another intriguing possibility is the "Super Blimp." Two firms expect to have new technology blimps in prototype operation by the year 2000 for carrying cargo. These will be large and speedy (60-100 mph). They will be able to pick up huge loads (for example, groups of 40-foot containers) at their origin and deliver them directly to their destinations, without intermediate handling. New blimp technology, propulsion system advances, and advanced navigation and station-keeping systems will be used to make this possible.[7]

Are some of these advanced technologies just a fanciful dream? Maybe. Maybe not. But if the ones cited don't come to fruition, others will.

The MIT-Industry Supply Chain Program

The Integrated Supply Chain Management Program (ISCM) at the Massachusetts Institute of Technology is a joint MIT-industry effort. Its aim is to advance the state of the art in supply chain management and to accelerate implementation of supply chain improvements in the collaborating sponsor companies. The program, which began in 1995, joins progressive, non-competing, supply chain companies with faculty, research staff, and students at MIT.

The sponsor companies, most with global operations, represent a broad range of industries and supply chain experiences. The current sponsors are Caliber Logistics, Cummins Engine, Monsanto, Procter & Gamble, Quelle AG, Siemens, Solutia, Volkswagen AG, and Xerox.

MIT involvement comes from faculty, staff, and students of the Sloan School of Management, the Leaders for Manufacturing Program, the Center for Coordination Science, the Center for Information Systems Research, the Operations Research Center, the Center for Organizational Learning, and the Center for Transportation Studies, which manages the program.

The ISCM Program involves three principal activities:

- Research focused on creating practical supply chain knowledge.
- Collaboration meetings held quarterly for the exchange of supply chain knowledge and developments among the sponsors and the early dissemination of research results.
- An annual executive seminar to update senior executives and to inform non-supply chain executives on the benefits and latest techniques of integrated supply chain management.

For more information, contact James Rice, Director, MIT-Industry Integrated Supply Chain Management Program, 77 Massachusetts Ave., Room 1-235, Cambridge, MA 02139. Phone: 617-258-8584, e-mail: jrice@mit.edu

Supply Chain Future: Where Are We Going?

The supply chain management revolution is in its early stages. The logic of its development, propelled by man's steady progress in managing ever more complex systems aided by technology advances, convinces me that supply chain management has a long future-a future marked by continuous, sometimes breakthrough, progress. Some of the exciting developments include:

- *Closed-Loop Supply Chains.* Xerox and several other companies now operate their supply chain as a closed loop, feeding back used equipment, replaced parts, and used packaging for refurbishment, reuse, or sale as raw material. In fact, Xerox already generates significant revenue and profit from this recycling phase. When every function is clued into their impact on the recycle stage, we will have an even more efficient and effective supply chain.

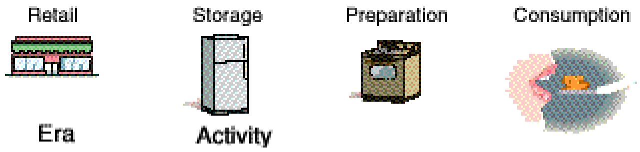
- *Supply Chains Designed for Flexibility and Responsiveness.* Today, we analyze and design supply chains for static conditions--forecast demand, current costs, and the like. The ideal supply chain for one set of conditions, however, almost surely is not ideal for another. Since conditions are certain to change, supply chain configuration will of necessity be continually revised. Thus, it's better to design for a reasonable spectrum of changes so that the chain can adapt without major upheavals, massive reinvestment, or large-scale personnel dislocations. The supply chain concept cited earlier that is configured for fast adaptation to changes in currency values exemplifies this strategy. Design for flexibility will be an important feature in the future.
- *Naturally Aligning Supply Chain Components.* Today, companies must pay explicit attention to designing the supply chain components to produce the best overall performance. In the future we may be able to equip supply chain components so that they naturally adapt to changes in other supply chain components, to changes in external conditions, and to substitution of one component operator for another (such as changing a supplier). Supply chains, like many organisms in Nature, will survive through their ability to adapt.

Explaining Supply Chain Management

I hope this picture of the supply chain as a set of interacting functions being managed in coordination to bring out the best *overall* performance explains the goal of integrated supply chain management. I hope the logical progression I've described of our growing capability to manage more complexity-leading from the two-stage physical distribution chain, to today's six- or seven-stage chains, to tomorrow's 10-plus-stage supply chains-reveals where we've come from and where we're going. I hope the rocket-science tools used in this journey do not obscure the fundamental logic of supply chain management. I hope the dynamic role of technology developments in producing continual supply chain change is now apparent. And I hope that the critical role of IT advances in making more complex supply chains manageable is clear. Finally, I hope that I've brought out the challenge and excitement of supply chain management.

EXHIBIT 7

Store-to_table Supply Chain



Era	Activity
Pre Ice-box	Home-grown
Ice-box	Daily shopping at local markets
Refrigerator	Weekly shopping at local markets
Automobile	Weekly and shopping at regional markets
Recycling	"Ultra" products and slim packages
Current IT	Telephone, fax, and Internet ordering, weekly delivery
Future IT	Daily menus, automated orders, as needed delivery

Drivers: Technology, Changing Costs, Expanding Desires

But just in case this isn't crystal clear enough to explain to your spouse and your boss, let me use this domestic supply chain example to illustrate my points. Consider the simplified domestic store-to-table supply chain **shown in Exhibit 7.** Home supplies and food flow from the retailer to home storage (refrigerator, kitchen cupboards) to food-preparation station (stove, counter top) to table, the point of consumption. Funds usually flow in the reverse direction, from consumer to retailer. But occasionally they flow in a forward direction when the retailer refunds the cost of a damaged product or spoiled food. Information flows in both directions with the retailer advertising what's available at what price, the consumer telling the cook what food to fix, the cook checking inventory and ordering food.

This really is a supply chain, for consider the following dynamics:

- If the production capacity (stove) is too small, we can't satisfy all the consumer demand (because the oven can't cook a turkey large enough to feed all the guests).
- If the storage (refrigerator) fails, some of our inventory (food) is lost.
- If the retailer is out of some SKUs (T-bone steak), we can't satisfy a key consumer (father on Fathers' Day).
- If our transportation or storage space doesn't have enough capacity (say, our car or refrigerator is too small), we incur higher transportation cost (more trips to the store).
- If good inventory records are not kept (the cook doesn't record consumption or the shopper doesn't check to see what's in low supply), we order the wrong product (fail to purchase missing food and supplies).
- And on and on.

Interestingly, this domestic supply chain illustrates the impact of past and future technology developments. For instance, with future information technology, instrumented refrigerators will record when something is consumed and automatically reorder when quantities are low. And kitchen conversations about tomorrow's dinner will be turned into automated orders.

Enjoy the Challenge

Integrated supply chain management is a straightforward concept made possible by rocket-science like hardware and software technologies. These technologies enable the integrated design and coordinated management of the multiple functions that transform raw material to finished products delivered to the customer at the right place and time. Supply chain integration is a powerful concept because it can *simultaneously* reduce costs, improve service, and increase revenues. Supply chain management has developed thanks in large measure to information technology tools that help managers deal with ever-larger degrees of complexity. The reach of supply chain management has expanded dramatically in the past decade and will continue to expand, encompassing more functions and more decision factors for decades to come.

Supply chain essentials and the basic interrelationships are eminently explainable-from the domestic food supply chain serving our homes to the worldwide manufacture, distribution, consumption, and recycling of consumer products or high-tech medical equipment.

But at the same time, supply chain management is difficult. The key elements are constantly changing because of technology developments, dynamic world economics, and marketplace shifts. Historically independent work groups must come together as teams focused on the total supply chain performance, often at the expense of their individual work group performance.

Since the pace of change never slows but only grows faster, supply chain professionals need to keep focused on some key success factors. Here is my list:

- Always keep foremost the needs and desires of the end customer.
- Measure, measure, measure to make quantitatively based decisions.
- Communicate, communicate, communicate all through the total supply chain.
- Design flexibility into the supply chain for rapid response to changing conditions.
- And most of all: Enjoy the challenge!

Footnotes

[1] Peter Senge, *The Fifth Discipline: The Art and Practice of the Learning Organization*, Doubleday, 1990.

[2]James Balyney Rice Jr., "Spanning the Functional Boundaries Through HPM," *Supply Chain Management Review*, Fall 1997, pp.60-68.

[3]Thomas W. Eagar, "bringing New Materials to Market," *Technology Review*, February/March 1995, pp.43-49.

[4]"Global and Variable Cost Manufacturing Systems," *European Journal of Operational Research*, Vol. 95, 1996, pp.325-343.

[5]Emanuel Sachs, et. al., "Injecting Molding Tooling by Three Dimensional Printing, A Desktop Manufacturing Process," Sociey of Plastic Engineers, Inc., *Technical Papers*, Vol. XLI, ANTEC '95, May 7-11, 1995, pp.997-1003.

[6]David Giles, "Faster Ships for the Future," *Scientific American*, October 1997, pp. 126-131.

[7]Steve Nadis, "The Zeppelin Also Rises," *Technology Review*, October 1997, pp.18-19.

Peter J. Metz is the deputy director of the Center for Transportation Studies at the Massachusetts Institute of Technology and the founder of the MIT-Industry Integrated Supply Chain Management Program.

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