



MICHAEL HUGOS

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Fourth Edition

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Fourth Edition

Michael Hugos

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*To my wife,
Venetia*

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Preface

My intention in this book is to speak to a wide audience of business, technical, and professional people and others looking to understand this increasingly important area of activity. I provide a clear framework for understanding supply chain theory, operations, and opportunities. I then build on that framework and show ways to create supply chains with the performance levels needed for success in this real-time global economy we live in.

I know you are busy and your time is valuable. So, I've worked hard to get to the point quickly and explain things clearly and concisely. This book provides a framework to understand the structure and operation of any supply chain. It also provides guidance and insights for how to make good use of the flood of new supply chain technologies. Ideas are provided for combining technology, people, and business processes to deliver greater levels of supply chain performance.

Chapters 1, 2, and 3 provide an introduction to the basic principles and practices that drive supply chain operations. Chapters 4, 5, and 6 discuss technologies, metrics, and techniques that are making significant impacts on the way supply chains are designed, monitored, and managed.

Chapter 7 is an exploration of how new technology can be combined with supply chain best-practices such as sales and operations planning (S&OP) to deliver a new level of supply chain performance through effective collaboration between companies working together in supply chains. The potential for using cloud computing and presently

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available software applications to build real-time supply chain collaboration platforms is presented.

Chapters 8 and 9 provide a pragmatic approach based on personal experience for defining supply chain opportunities, and designing and building systems to effectively respond to those opportunities. I present two case studies and show how companies can develop supply chain capabilities to support their evolving business goals.

The last chapter, Chapter 10, outlines opportunities for individual companies and alliances of companies to work together and employ the power of the self-adjusting feedback loop to drive real-time operations. Real-time and collaborative supply chains are the next step in the evolution of supply chain management. Self-adjusting supply chains and the economic growth and stability they make possible are central to the creation and preservation of wealth in this century.

What I say in this book is based on decades of personal experience in building and operating supply chains, plus many conversations with fellow practitioners and researchers. I am also much influenced by reading the works of other authors whom I quote and acknowledge in these chapters.

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Key Concepts of Supply Chain Management



After reading this chapter you will be able to

- Appreciate what a supply chain is and what it does.
- Understand where your company fits in the supply chains it participates in and the role it plays in those supply chains.
- Discuss ways to align your supply chain with your business strategy.
- Start an intelligent conversation about the supply chain management issues in your company.

This book is organized to give you a solid grounding in the nuts-and-bolts of supply chain management. The book explains the essential concepts and practices and then shows examples of how to put them to use. When you finish you will have a solid foundation in supply chain management to work from.

The first three chapters give you a working understanding of the key principles and business operations that drive any supply chain. The next three chapters present the techniques, technologies, and metrics to use to improve your internal operations and coordinate more effectively with your customers and suppliers in the supply chains your company is a part of.

The last four chapters show you how to find supply chain opportunities and respond effectively to best capitalize on these opportunities. Case studies are used to illustrate supply chain challenges and to present solutions for those challenges. These case studies and their solutions bring together the material presented in the rest of the book and show how it applies to real-world business situations.

Supply chains encompass the companies and the business activities needed to design, make, deliver, and use a product or service. Businesses depend on their supply chains to provide them with what they need to survive and thrive. Every business fits into one or more supply chains and has a role to play in each of them.

The pace of change and the uncertainty about how markets will evolve has made it increasingly important for companies to be aware of the supply chains they participate in and to understand the roles that they play. Those companies that learn how to build and participate in strong supply chains will have a substantial competitive advantage in their markets.

Nothing Entirely New . . . Just a Significant Evolution

The practice of supply chain management is guided by some basic underlying concepts that have not changed much over the centuries. Several hundred years ago, Napoleon made the remark, “An army marches on its stomach.” Napoleon was a master strategist and a skillful general and this remark shows that he clearly understood the importance of what we would now call an efficient supply chain. Unless the soldiers are fed, the army cannot move.

Along these same lines, there is another saying that goes, “Amateurs talk strategy and professionals talk logistics.” People can discuss all sorts of grand strategies and dashing maneuvers but none of that will be possible without first figuring out how to meet the day-to-day demands of providing an army with fuel, spare parts, food, shelter, and ammunition.

It is the seemingly mundane activities of the quartermaster and the supply sergeants that often determine an army's success. This has many analogies in business.

The term *supply chain management* arose in the late 1980s and came into widespread use in the 1990s. Prior to that time, businesses used terms such as *logistics* and *operations management* instead. Here are some definitions of a supply chain:

- “A supply chain is the alignment of firms that bring products or services to market.”—From Lambert, Stock, and Ellram (Lambert, Douglas M., James R. Stock, and Lisa M. Ellram, 1998, *Fundamentals of Logistics Management*, Boston, MA: Irwin/McGraw-Hill, Chapter 14).
- “A supply chain consists of all stages involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers themselves.”—From Chopra and Meindl (Chopra, Sunil, and Peter Meindl, 2015, *Supply Chain, 6th Edition*, Upper Saddle River, NJ: Prentice-Hall, Inc., Chapter 1).
- “A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers.”—From Ganeshan and Harrison (Ganeshan, Ram, and Terry P. Harrison, 1995, “An Introduction to Supply Chain Management,” Department of Management Sciences and Information Systems, 303 Beam Business Building, Penn State University, University Park, Pennsylvania).

If this is what a supply chain is, then we can define supply chain management as the things we do to influence the behavior of the supply

chain and get the results we want. Some definitions of supply chain management are:

- “The systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole.”—From Mentzer, DeWitt, Keebler, Min, Nix, Smith, and Zacharia (Mentzer, John T., William DeWitt, James S. Keebler, Soonhong Min, Nancy W. Nix, Carlo D. Smith, and Zach G. Zacharia, 2001, “Defining Supply Chain Management,” *Journal of Business Logistics*, Vol. 22, No. 2, p. 18).
- “Supply chain management is the coordination of production, inventory, location, and transportation among the participants in a supply chain to achieve the best mix of responsiveness and efficiency for the market being served.”—My own words.

There is a difference between the concept of supply chain management and the traditional concept of logistics. *Logistics* typically refers to activities that occur within the boundaries of a single organization and *supply chains* refers to networks of companies that work together and coordinate their actions to deliver a product to market. Also, traditional logistics focuses its attention on activities such as procurement, distribution, maintenance, and inventory management. Supply chain management acknowledges all of traditional logistics and also includes activities such as marketing, new product development, finance, and customer service.

In the wider view of supply chain thinking, these additional activities are now seen as part of the work needed to fulfill customer requests. Supply chain management views the supply chain and the organizations in it as a single entity. It brings a systems approach to understanding

and managing the different activities needed to coordinate the flow of products and services to best serve the ultimate customer. This systems approach provides the framework in which to best respond to business requirements that otherwise would seem to be in conflict with each other.

Taken individually, different supply chain requirements often have conflicting needs. For instance, the requirement of maintaining high levels of customer service calls for maintaining high levels of inventory, but then the requirement to operate efficiently calls for reducing inventory levels. It is only when these requirements are seen together as parts of a larger picture that ways can be found to effectively balance their different demands.

Effective supply chain management requires simultaneous improvements in both customer service levels and the internal operating efficiencies of the companies in the supply chain. Customer service at its most basic level means consistently high order-fill rates, high on-time delivery rates, and a very low rate of products returned by customers for whatever reason. Internal efficiency for organizations in a supply chain means that these organizations get an attractive rate of return on their investments in inventory and other assets and that they find ways to lower their operating and sales expenses.

There is a basic pattern to the practice of supply chain management. Each supply chain has its own unique set of market demands and operating challenges and yet the issues remain essentially the same in every case. Companies in any supply chain must make decisions individually and collectively regarding their actions in five areas:

- 1. *Production***—What products does the market want? How much of which products should be produced and by when? This activity includes the creation of master production schedules that take into account plant capacities, workload balancing, quality control, and equipment maintenance.

2. *Inventory*—What inventory should be stocked at each stage in a supply chain? How much inventory should be held as raw materials, semi-finished, or finished goods? The primary purpose of inventory is to act as a buffer against uncertainty in the supply chain. However, holding inventory can be expensive, so what are the optimal inventory levels and reorder points?
3. *Location*—Where should facilities for production and inventory storage be located? Where are the most cost-efficient locations for production and for storage of inventory? Should existing facilities be used or new ones built? Once these decisions are made they determine the possible paths available for product to flow through for delivery to the final consumer.
4. *Transportation*—How should inventory be moved from one supply chain location to another? Air-freight and truck delivery are generally fast and reliable but they are expensive. Shipping by sea or rail is much less expensive but usually involves longer transit times and more uncertainty. This uncertainty must be compensated for by stocking higher levels of inventory. When is it better to use which mode of transportation?
5. *Information*—How much data should be collected and how much information should be shared? Timely and accurate information holds the promise of better coordination and better decision making. With good information, people can make effective decisions about what to produce and how much, about where to locate inventory, and how best to transport it.

The sum of these decisions will define the capabilities and effectiveness of a company's supply chain. The things a company can do and the ways that it can compete in its markets are all very much dependent on the effectiveness of its supply chain. If a company's strategy is to serve a mass market and compete on the basis of price, it had better have a

supply chain that is optimized for low cost. If a company's strategy is to serve a market segment and compete on the basis of customer service and convenience, it had better have a supply chain optimized for responsiveness. Who a company is and what it can do is shaped by its supply chain and by the markets it serves.

How the Supply Chain Works

Two influential source books that define principles and practices of supply chain management are *The Goal* (Goldratt, Eliyahu M., 2014, The Goal; 30th Anniversary Edition, Great Barrington, MA: North River Press); and *Supply Chain Management, 6th Edition* by Sunil Chopra and Peter Meindl. *The Goal* explores the issues and provides answers to the problem of optimizing operations in any business system, whether it be manufacturing, mortgage loan processing, or supply chain management. *Supply Chain Management, 6th Edition* is an in-depth presentation of the concepts and techniques of the profession. Much of the material presented in this chapter and in the next two chapters can be found in greater detail in these two books.

The goal or mission of supply chain management can be defined using Eli Goldratt's words as "Increase throughput while simultaneously reducing both inventory and operating expense." In this definition, *throughput* refers to the rate at which sales to the end customer occur. Depending on the market being served, sales or throughput occur for different reasons. In some markets, customers value and will pay for high levels of service. In other markets customers seek simply the lowest price for an item.

As we saw in the previous section, there are five areas where companies can make decisions that will define their supply chain capabilities: production, inventory, location, transportation, and information. Chopra and Meindl define these areas as performance drivers that can be managed to produce the capabilities needed for a given supply chain.

**IN THE REAL WORLD**

Alexander the Great based his strategies and campaigns on his army's unique capabilities and these were made possible by effective supply chain management.

In the spirit of the saying, "Amateurs talk strategy and professionals talk logistics," let's look at the campaigns of Alexander the Great. For those who think that his greatness was only due to his ability to dream up bold moves and cut a dashing figure in the saddle, think again. Alexander was a master of supply chain management and he could not have succeeded otherwise. The authors from Greek and Roman times who recorded his deeds had little to say about something so apparently unglamorous as how he secured supplies for his army. Yet, from these same sources, many small details can be pieced together to show the overall supply chain picture and how Alexander managed it. A modern historian, Donald Engels, has investigated this topic in his book, *Alexander the Great and the Logistics of the Macedonian Army* (Engles, Donald W., 1980, *Alexander the Great and the Logistics of the Macedonian Army*, Los Angeles, CA: University of California Press).

He begins by pointing out that given the conditions and the technology that existed in Alexander's time, his strategy and tactics had to be very closely tied to his ability to get supplies and to run a lean, efficient organization. The only way to transport large amounts of material over long distances was by oceangoing ships or by barges on rivers and canals. Once away from rivers and seacoasts, an army had to be able to live off the land over which it traveled. Diminishing returns set in quickly when using pack animals and carts to haul supplies, because the animals themselves had to eat and would soon consume all the food and water they were hauling unless they could graze along the way.

Alexander's army was able to achieve its brilliant successes because it managed its supply chain so well. The army had a logistics structure that was fundamentally different from other armies of the time. In other armies the number of support people and

IN REAL WORLD (CONTINUED)

camp followers was often as large as the number of actual fighting soldiers, because armies traveled with huge numbers of carts and pack animals to carry their equipment and provisions, as well as the people needed to tend them. In the Macedonian army the use of carts was severely restricted. Soldiers were trained to carry their own equipment and provisions. Other contemporary armies did not require their soldiers to carry such heavy burdens but they paid for this because the resulting baggage trains reduced their speed and mobility. The result of the Macedonian army's logistics structure was that it became the fastest, lightest, and most mobile army of its time. It was capable of making lightning strikes against an opponent, often before they were even aware of what was happening. Because the army was able to move quickly and suddenly, Alexander could use this capability to devise strategies and employ tactics that allowed him to surprise and overwhelm enemies that were numerically much larger.

The picture that emerges of how Alexander managed his supply chain is an interesting one. For instance, time and again the historical sources mention that before he entered a new territory, he would receive the surrender of its ruler and arrange in advance with local officials for the supplies his army would need. If a region did not surrender to him in advance, Alexander would not commit his entire army to a campaign in that land. He would not risk putting his army in a situation where it could be crippled or destroyed by a lack of provisions. Instead, he would gather intelligence about the routes, the resources, and the climate of the region and then set off with a small, light force to surprise his opponent. The main army would remain behind at a well-stocked base until Alexander secured adequate supplies for it to follow.

Whenever the army set up a new base it looked for an area that provided easy access to a navigable river or a seaport. Then ships would arrive from other parts of Alexander's empire, bringing in large amounts of supplies. The army always stayed in its winter camp until the first spring harvest of the new year so that food supplies

(Continued)

IN REAL WORLD (CONTINUED)

would be available. When it marched, it avoided dry or uninhabited areas and moved through river valleys and populated regions whenever possible so the horses could graze and the army could requisition supplies along the route.

Alexander had a deep understanding of the capabilities and limitations of his supply chain. He learned well how to formulate strategies and use tactics that built upon the unique strengths that his logistics and supply chain capabilities gave him. And he wisely took measures to compensate for the limitations of his supply chain. His opponents often outnumbered him and were usually fighting on their own home territory. Yet their advantages were undermined by clumsy and inefficient supply chains that restricted their ability to act and limited their options for opposing Alexander's moves.

Effective supply chain management calls first for an understanding of each driver and how it operates. Each driver has the ability to directly affect the supply chain and enable certain capabilities. The next step is to develop an appreciation for the results that can be obtained by mixing different combinations of these drivers. Let's start by looking at the drivers individually.

Production

Production refers to the capacity of a supply chain to make and store products. The facilities of production are factories and warehouses. The fundamental decision that managers face when making production decisions is how to resolve the trade-off between responsiveness and efficiency. If factories and warehouses are built with a lot of excess capacity, they can be very flexible and respond quickly to wide swings in product demand. Facilities where all or almost all capacity is being used are not capable of responding easily to fluctuations in demand. On the other hand, capacity costs money and excess capacity is idle capacity not in use

and not generating revenue. So the more excess capacity that exists, the less efficient the operation becomes.

Factories can be built to accommodate one of two approaches to manufacturing:

1. *Product focus*—A factory that takes a product focus performs the range of different operations required to make a given product line from fabrication of different product parts to assembly of these parts.
2. *Functional focus*—A functional approach concentrates on performing just a few operations such as only making a select group of parts or only doing assembly. These functions can be applied to making many different kinds of products.

A product approach tends to result in developing expertise about a given set of products at the expense of expertise about any particular function. A functional approach results in expertise about particular functions instead of expertise in a given product. Companies need to decide which approach or what mix of these two approaches will give them the capability and expertise they need to best respond to customer demands.

As with factories, warehouses, too, can be built to accommodate different approaches. There are three main approaches to use in warehousing:

1. *Stock keeping unit (SKU) storage*—In this traditional approach, all of a given type of product is stored together. This is an efficient and easy to understand way to store products.
2. *Job lot storage*—In this approach, all the different products related to the needs of a certain type of customer or related to the needs of a particular job are stored together. This allows for an efficient picking and packing operation but usually requires more storage space than the traditional SKU storage approach.

3. *Crossdocking*—This approach was pioneered by Walmart in its drive to increase efficiencies in its supply chain. In this approach, product is not actually warehoused in the facility. Instead the facility is used to house a process where trucks from suppliers arrive and unload large quantities of different products. These large lots are then broken down into smaller lots. Smaller lots of different products are recombined according to the needs of the day and quickly loaded onto outbound trucks that deliver the products to their final destinations.

Inventory

Inventory is spread throughout the supply chain and includes everything from raw material to work in process to finished goods that are held by the manufacturers, distributors, and retailers in a supply chain. Again, managers must decide where they want to position themselves in the trade-off between responsiveness and efficiency. Holding large amounts of inventory allows a company or an entire supply chain to be very responsive to fluctuations in customer demand. However, the creation and storage of inventory is a cost and to achieve high levels of efficiency, the cost of inventory should be kept as low as possible.

There are three basic decisions to make regarding the creation and holding of inventory:

1. *Cycle inventory*—This is the amount of inventory needed to satisfy demand for the product in the period between purchases of the product. Companies tend to produce and to purchase in large lots in order to gain the advantages that economies of scale can bring. However, with large lots also come increased carrying costs. Carrying costs come from the cost to store, handle, and insure the inventory. Managers face the tradeoff between the reduced cost of ordering and better prices offered

by purchasing product in large lots and the increased carrying cost of the cycle inventory that comes with purchasing in large lots.

2. *Safety inventory*—This is inventory that is held as a buffer against uncertainty. If demand forecasting could be done with perfect accuracy, then the only inventory that would be needed would be cycle inventory. But since every forecast has some degree of uncertainty in it, we cover that uncertainty to a greater or lesser degree by holding additional inventory in case demand is suddenly greater than anticipated. The tradeoff here is to weigh the costs of carrying extra inventory against the costs of losing sales due to insufficient inventory.
3. *Seasonal inventory*—This is inventory that is built up in anticipation of predictable increases in demand that occur at certain times of the year. For example, it is predictable that demand for antifreeze will increase in the winter. If a company that makes antifreeze has a fixed production rate that is expensive to change, then it will try to manufacture product at a steady rate all year long and build up inventory during periods of low demand to cover for periods of high demand that will exceed its production rate. The alternative to building up seasonal inventory is to invest in flexible manufacturing facilities that can quickly change their rates of production of different products to respond to increases in demand. In this case, the tradeoff is between the cost of carrying seasonal inventory and the cost of having more flexible production capabilities.

Location

Location refers to the geographical site of supply chain facilities. It also includes the decisions related to which activities should be performed in each facility. The responsiveness versus efficiency tradeoff here is the

decision whether to centralize activities in fewer locations to gain economies of scale and efficiency, or to decentralize activities in many locations close to customers and suppliers in order for operations to be more responsive.

When making location decisions, managers need to consider a range of factors that relate to a given location including the cost of facilities, the cost of labor, skills available in the workforce, infrastructure conditions, taxes and tariffs, and proximity to suppliers and customers. Location decisions tend to be very strategic decisions because they commit large amounts of money to long-term plans.

Location decisions have strong impacts on the cost and performance characteristics of a supply chain. Once the size, number, and location of facilities are determined, that also defines the number of possible paths through which products can flow on the way to the final customer. Location decisions reflect a company's basic strategy for building and delivering its products to market.

Transportation

This refers to the movement of everything from raw material to finished goods between different facilities in a supply chain. In transportation the tradeoff between responsiveness and efficiency is manifested in the choice of transport mode. Fast modes of transport such as airplanes are very responsive but also more costly. Slower modes such as ship and rail are very cost efficient but not as responsive. Since transportation costs can be as much as a third of the operating cost of a supply chain, decisions made here are very important.

There are six basic modes of transport that a company can choose from:

1. *Ship*, which is very cost efficient but also the slowest mode of transport. It is limited to use between locations that are situated

next to navigable waterways and facilities such as harbors and canals.

2. *Rail*, which is also very cost efficient but can be slow. This mode is also restricted to use between locations that are served by rail lines.
3. *Pipelines*, which can be very efficient but are restricted to commodities that are liquids or gases such as water, oil, and natural gas.
4. *Trucks*, which are a relatively quick and very flexible mode of transport. Trucks can go almost anywhere. The cost of this mode is prone to fluctuations though, as the cost of fuel fluctuates and the condition of roads varies.
5. *Airplanes*, which are a very fast mode of transport and are very responsive. This is also the most expensive mode, and it is somewhat limited by the availability of appropriate airport facilities.
6. *Electronic transport*, which is the fastest mode of transport and is very flexible and cost efficient. However, it can only be used for movement of certain types of products such as electric energy, data, and products composed of data such as music, pictures, and text. Someday technology that allows us to convert matter to energy and back to matter again may completely rewrite the theory and practice of supply chain management (“Beam me up, Scotty . . .”).

Given these different modes of transportation and the location of the facilities in a supply chain, managers need to design routes and networks for moving products. A route is the path through which products move, and networks are composed of the collection of the paths and facilities connected by those paths. As a general rule, the higher the value of a product (such as electronic components or pharmaceuticals), the more its transport network should emphasize responsiveness, and the lower the value of a product (such as bulk commodities like grain or lumber), the more its network should emphasize efficiency.

Information

Information is the basis upon which to make decisions regarding the other four supply chain drivers. It is the connection between all of the activities and operations in a supply chain. To the extent that this connection is a strong one (i.e., the data is accurate, timely, and complete), the companies in a supply chain will each be able to make good decisions for their own operations. This will also tend to maximize the profitability of the supply chain as a whole. That is the way that stock markets or other free markets work, and supply chains have many of the same dynamics as markets.

Information is used for two purposes in any supply chain:

1. *Coordinating daily activities* related to the functioning of the other four supply chain drivers: production, inventory, location, and transportation. The companies in a supply chain use available data on product supply and demand to decide on weekly production schedules, inventory levels, transportation routes, and stocking locations.
2. *Forecasting and planning* to anticipate and meet future demands. Available information is used to make tactical forecasts to guide the setting of monthly and quarterly production schedules and timetables. Information is also used for strategic forecasts to guide decisions about whether to build new facilities, enter a new market, or exit an existing market.

Within an individual company the tradeoff between responsiveness and efficiency involves weighing the benefits that good information can provide against the cost of acquiring that information. Abundant, accurate information can enable very efficient operating decisions and better forecasts but the cost of building and installing systems to deliver this information can be very high.