1.1 THE EVOLUTION OF SUPPLY CHAIN THEORY

The field of supply chain management arose from managers’ recognition that buying, selling, manufacturing, assembling, warehousing, transporting, and delivering goods—that is, the activities of a supply chain—are expensive endeavors, and that careful attention to how these activities are carried out may reduce their cost. Supply chains used to be viewed, at least by some managers, as “necessary evils.” As a result, the mindset for supply chain managers revolved around reducing costs, by reducing inventory levels, taking advantage of economies of scale in shipping, optimizing network designs, reducing volatility in demands, and so on. By and large, these improvements were invisible to companies’ customers, provided that they did not result in longer lead times, more frequent stockouts, or other degraded service.

By the end of the last century, however, the purpose of the supply chain had begun to change as some firms discovered that supply chains could be a source of competitive advantage, rather than simply a cost driver. For example, Dell demonstrated that, through excellent supply chain management, it could deliver computers—fully customized to the buyer’s specifications—just a few days after they were ordered. In doing so, it shattered the existing paradigm for computer purchases, in which consumers could choose from only a limited number of preconfigured options. Similarly, Walmart showed that, by operating an extremely high-volume supply chain, it could land products on shelves for less money per item. As a result, Walmart offered its customers a high level of product availability and
low prices, and this combination ushered the company to its place as the world’s largest retailer. Amazon built a supply chain that is not only quick and reliable, but also feature-rich, offering users varied shipping options, convenient tracking tools, and flexible return policies. This expansive supply chain has allowed Amazon to overcome consumers’ desire for instant gratification and their preference for seeing and touching products before they buy them.

Just as the practice of supply chain management has come into its own, so, we would argue, has the study of supply chain management. In the past several decades, a huge number of papers have been published that introduce mathematical models for evaluating, analyzing, and optimizing supply chains. Supply chain management has become one of the most popular applications of operations research (OR), and one of its greatest success stories. But recently, the mathematical study of supply chains has begun to be viewed not simply as an application area for OR tools, but rather as a methodological area, capable of standing on its own two feet, with its own tools and theory. These tools are now themselves starting to be applied, not just to supply chains, but to health care, energy, humanitarian relief, the service sector, and other industries. This emerging supply chain theory is the subject of this book.

Although the models and algorithms in this book are most commonly applied to traditional, private-sector supply chains, many can be applied to new kinds of supply chains, and even to areas we might not think of as supply chains. Understanding the building blocks of traditional supply chains will prepare you to understand more recent applications of supply chain theory. The final chapter of this book is devoted to exploring how the tools of supply chain theory are used in a few of these application areas—electricity systems, health care, and public sector operations.

1.2 DEFINITIONS AND SCOPE

The term supply chain management is difficult to define, and its definition has changed over time as the purposes and components of supply chains have evolved. Perhaps the most authoritative definition comes from the Council of Supply Chain Management Professionals (CSCMP), who define supply chain management as follows:

Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. (Council of Supply Chain Management Professionals 2018b)

In the interest of keeping things a little simpler, we offer the following definitions:

A supply chain consists of the activities and infrastructure whose purpose is to move products from where they are produced to where they are consumed. Supply chain management is the set of practices required to perform the functions of a supply chain and to make them more efficient, less costly, and more profitable.

Supply chain management costs firms nearly US$1.5 trillion per year in the United States alone, representing nearly 8% of gross domestic product (GDP) (Council of Supply Chain Management Professionals 2018a). These practices include a huge range of tasks, such as forecasting, production planning, inventory management, warehouse location, supplier selection, procurement, and shipping. Mathematical models have been developed to analyze and optimize each of these practices, and these models are the primary focus of this book.
The terms “logistics” and “logistics management” are closely related to “supply chain management,” and it can be difficult to draw a clear distinction. Some companies use “logistics” to refer to the physical movement of goods; “supply chain management” includes logistics, as well as nonmovement activities such as inventory management and procurement. For other companies, “logistics” means functions carried out by the company itself, while “supply chain management” includes activities it conducts with partners, suppliers, and customers. Often, though, the two terms are used more or less interchangeably.

Supply chains are often represented graphically as a schematic network that illustrates the relationships between its elements. (See Figure 1.1.) Each vertical “level” of the supply chain (suppliers, plants, etc.) is called an echelon. A location in the network is referred to as a stage or node. The links between stages represent some type of flow—typically, the flow of goods, but sometimes the flow of information or money. The portion of the supply chain from which products originate (the left-hand portion in Figure 1.1) is referred to as upstream, while the demand end is referred to as downstream.

Actually, the phrase “supply chain” is a bit of a misnomer, since “chain” implies a linear system similar to the one pictured in Figure 1.2. In this system, sometimes referred to as a serial system, each echelon has only a single stage. But today’s supply chains more closely resemble the complex network in Figure 1.1; each echelon may have dozens, hundreds, or even thousands of nodes. (Nevertheless, we will often study serial systems of the type pictured in Figure 1.2. Even more frequently, we will study single-stage systems.)

The models we study generally try to find the least-cost or greatest-profit solution that satisfies some constraints. For example, a firm might want to choose warehouse locations to minimize transportation costs, subject to the constraint that every customer must be served. Or it might want to decide how much inventory should be stored at a given warehouse in
order to minimize the cost of holding inventory, subject to a “service level” constraint that
requires a certain percentage of customer orders to be satisfied on time. Or it might want
to design a contract with its supplier to maximize its own profit, or that of the supply chain
as a whole.

The ideal supply chain management model would globally optimize every aspect of the
supply chain, but such a model is impossible both because of the difficulties in modeling
some aspects of the supply chain mathematically and because the resulting model would
be too large and complex to solve. Instead, supply chain models typically focus on local
optimization of one element of the supply chain, or on the integration of two or more
aspects of the supply chain, generally in less detail.

1.3 LEVELS OF DECISION-MAKING IN SUPPLY CHAIN MANAGEMENT

It is convenient to think about three levels of supply chain management decisions: strategic,
tactical, and operational.

- **Strategic** aspects of the supply chain involve decisions that take effect over a long
time horizon, typically years or decades. These aspects have a major impact on all
functions of the firm. Examples include locations and sizes of warehouses, locations
and capabilities of factories, and contracts with suppliers.

- **Tactical** aspects of the supply chain involve decisions over a moderate time horizon
like months. Tactical decisions can be changed periodically but generally with some
difficulty. Examples include assignments of customers to warehouses and inventory
replenishment policies at warehouses.

- **Operational** aspects of the supply chain occur over short planning horizons such
as days or weeks, during which policies must be executed but cannot be changed.
Examples include filling customer orders and routing of delivery vehicles.

The models in this book are concerned with all three levels of decisions. For example,
the facility location models of Chapters 8 and 12 are strategic, the inventory models of
Chapters 3–6 are tactical, and the routing models of Chapters 10 and 11 are operational.